EMFAC

EMFAC202x Updates

Mobile Source Analysis Branch
Air Quality Planning and Science Division
California Air Resources Board
July 30, 2020
Public Process So Far

User Needs Work Group

March, 2019

1st Public Workshop

Beta Release of Web Platform

Oct., 2019

March, 2020

2nd Public Workshop

July, 2020
Agenda for Today’s Workshop

**AM Session**

i. Background and Major Updates
ii. Web Platform (Demo)
iii. Activity and Forecasting

**PM Session**

v. Emission Rates
vi. Motorcycle Activity & Emission
vii. Latest Regulations
Overview

Background and Major Updates
Background of EMFAC

- California specific with USEPA approval
- More than three decades of data collection and methodology refinement
- Advanced Data Mining and Analysis
- Real World Emission Testing
- Use of Big Data (e.g., Telematics)
- Integrated modeling
A Decade of EMFAC Updates

2011

EMFAC2011
- Integrating In-Use Diesel Regulations
- Modular approach

2014

EMFAC2014
- Single Package
- Reflecting Advanced Clean Cars, 2014 Amendments to Truck and Bus Rule, and Heavy-Duty Green House Gas (GHG) Regulations

2017

EMFAC2017
- An extension of the EMFAC2014 framework
- Reflecting measures adopted before 2018

2020/2021

EMFAC202x
What's coming next?

CARB
EMFAC202x Updates

- Web Based Application
- Vehicle Population Updates
- Latest In-Use Emission Data
- New Evap Module
- Real World Vehicle Activity Profile
- New Features: Plug-in Hybrid Electric Vehicles (PHEVs), Energy
- Latest Regulatory Measures
- New Forecasting Frameworks

EMFAC202x Update
New Web Platform
Quick & Easy Access to Emissions Inventories

This tool provides emissions from onroad and offroad mobile sources in California that are estimated by EMFAC2017 v1.0.2 and OFFROAD ORION v1.0.1.
Vehicle Population Updates
Latest In-Use Emissions Data

- Light-Duty
- Heavy-Duty (Diesel and CNG)
- Motorcycle
- On-Board Diagnostic (OBD)
- PHEV
- Brake-Wear
Real World Vehicle Activity Profile

California Vehicle Inventory and Use Survey (VIUS)

Replaces the Federal VIUS (discontinued)

Data collected using a combination of surveys & instrumented vehicles

Collection of truck activity data through Telematics service providers

Information on:
- Vehicles miles traveled
- Idling/hoteling
- Drive cycles
Vocational Truck Categories

Three Level Categorization:
1. Gross Vehicle Weight Rating (GVWR)
2. In-State/International Registration Plan (IRP) Out-of-State (OOS)
3. Body Type

PHEV Module to separately categorize plug-in hybrids
- Models high power start emissions
- Accounts for electric vehicle miles travelled (VMT) and charging behavior

Energy Module
- Estimates energy consumption by plug-in electric vehicles (PEVs)
- Data from more than 50k vehicles are analyzed
New Forecasting Frameworks

Utilizing vehicle choice models from California Energy Commission (CEC) to forecast Light-Duty (LD) zero-emission vehicle (ZEV) sales

Utilizing statewide travel demand models from Caltrans to forecast Heavy-Duty (HD) Vehicle Miles Travelled (VMT)
Latest Regulatory Measures

- HD Vehicle Inspection Program (HDVIP)/Periodic Smoke Inspection Program (PSIP)
- Innovative Clean Transit (ICT)
- SAFE Part One & Final Rule
- Low NOx Omnibus
- HD Warranty
- Zero Emission (ZE) Airport Shuttle Bus
- Advanced Clean Trucks (ACT)
EMFAC202x Next Steps

- **Alpha Release and Testing**: July, 2020
- **Beta Release and Testing**: August, 2020
- **3rd Workshop**: Fall, 2020
- **Official Public Release**: Winter, 2020
- **Late 2020/Early 2021**
New Interface

EMFAC Web Platform
New EMFAC Web Platform: Quick & Easy Access to Emissions Inventories

- All the features of EMFAC on the web, including “Project Level” and “Custom Activity” modes
- Fast as it runs with preprocessed output
- Better user interface with a modern web and mobile-device friendly web design
- Provides *Fleet Database*, a database to access vehicle population at very detailed spatial resolution (e.g., census block group)
- Provides access to off-road mobile source emissions inventories

Mobile device friendly!
Demo of EMFAC Web Platform
https://arb.ca.gov/emfac
Light-Duty Vehicles (LD)

Fleet Characterization
**Latest Vehicle Registration Data**

- CARB receives a snapshot of California vehicle registration data every quarter (January, April, July, and October)
- EMFAC uses the counts of vehicle from the October snapshot
- CARB staff have made significant improvement in processing the registration data for use in EMFAC
- EMFAC202x will utilize Department of Motor Vehicle (DMV) registration data from years *2000 through 2019*
Major Data Sources

- California DMV Registration Data (2000 – 2019)
- Polk/IHS VINtelligence Web Service
- CARB Certification Executive Orders (EO)
- VIN stems to identify fuel technologies
  - Plug-in Hybrid Electric Vehicle (PHEV)
  - Battery Electric Vehicle (BEV or BEVx*)
    *essentially all electric but with a range extender (REx)
  - Fuel Cell Vehicle (FCV)
Vehicle Classes Modeled in EMFAC202x

- Heavy-Heavy Duty Trucks
- Medium Heavy Duty Trucks
- Pickups / Vans
- Motorcycles
- Passenger Vehicles
- School Buses
- Transit Buses
- Motorhomes
In the next few slides you will hear about…

<table>
<thead>
<tr>
<th>Vehicle Categories</th>
<th>Gross Vehicle Weight Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-Duty Vehicles</td>
<td></td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>N/A</td>
</tr>
<tr>
<td>Light-Duty Trucks</td>
<td>≤ 8,500 lbs.</td>
</tr>
<tr>
<td>Light-Heavy-Duty Trucks</td>
<td>8,501 – 14,000 lbs.</td>
</tr>
</tbody>
</table>
EMFAC202x vs EMFAC2017 Population Gasoline

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
EMFAC202x vs EMFAC2017 Population
Gasoline

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>EMFAC202x</th>
<th>EMFAC2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>9,500,000</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>9,700,000</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>9,900,000</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>10,100,000</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>10,300,000</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>10,500,000</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>10,700,000</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>10,900,000</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>11,100,000</td>
<td></td>
</tr>
</tbody>
</table>

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
EMFAC202x vs EMFAC2017 Population
Gasoline

Light-Heavy-Duty Trucks

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x

Calendar Year

Population

EMFAC202x  |  EMFAC2017

2011  |  520,000  |  520,000
2012  |  540,000  |  540,000
2013  |  560,000  |  560,000
2014  |  580,000  |  580,000
2015  |  590,000  |  590,000
2016  |  600,000  |  600,000
2017  |  610,000  |  610,000
2018  |  620,000  |  620,000
2019  |  640,000  |  640,000
EMFAC202x vs EMFAC2017 Population Diesel

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
EMFAC202x vs EMFAC2017 Population Diesel

Light-Duty Trucks

Calendar Year

Population

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x

*LDT: Light-Duty Trucks with GVWR ≤ 8,500 lbs.
EMFAC202x vs EMFAC2017 Population Diesel

![Graph showing population of Light-Heavy-Duty Trucks from 2011 to 2019, with data points for EMFAC202x and EMFAC2017. The graph includes a note that data after 2016 is forecasted for EMFAC2017, and DMV data for EMFAC202x.]

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x.
EMFAC202x vs EMFAC2017 Population

Electric*

Population of Electric* Passenger Cars

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x

* Electric equivalent vehicles: Vehicles with motive power of electric in DMV data and electric fraction of PHEVs
EMFAC202x vs EMFAC2017 Population Electric*

Electric equivalent vehicles: Vehicles with motive power of electric in DMV data and electric fraction of PHEVs

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
New Sales – Light-Duty Vehicles
Gasoline

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
New Sales – Light-Duty Vehicles Diesel

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
New Sales – Light-Heavy-Duty Trucks
Diesel and Gasoline

Note: data after 2016 is forecasted for EMFAC2017, DMV data for EMFAC202x
EMFAC202x Model Year Distribution
All Fuel Types

Passenger Cars
Year: 2019

Note: EMFAC202x age distributions are calculated using DMV October 2019 registration data.
EMFAC202x Model Year Distribution
All Fuel Types

Light-Duty Trucks
Year: 2019

Note: EMFAC202x age distributions are calculated using DMV October 2019 registration data.
EMFAC202x Model Year Distribution
All Fuel Types

Light-Heavy-Duty Trucks
Year: 2019

Note: EMFAC202x age distributions are calculated using DMV October 2019 registration data.
On-road Population Growth for Advanced Technology Vehicle Groups

Vehicle Technology Populations in DMV2017, DMV2018, and DMV2019

- BEV: 155,263, 209,989, 279,329
- FCV: 2,485, 4,910, 6,598
- PHEV: 136,047, 182,097, 216,193

This the population of “currently” registered in CA DMV data and is not equivalent to cumulative sales. Registration status codes that are counted include C (currently registered), E (evidence of use), and S (pending status, included if the same vehicles become C or E in the following April DMV data cut).
On-road Population Growth for Advanced Technology Vehicle Groups (all status codes)

Vehicle Technology Populations in DMV2017, DMV2018, and DMV2019 (all status codes)

DMV registration status codes include C (currently registered), E (evidence of use), N (not currently registered), P (planned non-operational), R (prior history), and S (pending status).
### Population of CA Registered On-Road Vehicles

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Cars</td>
<td>N/A</td>
<td>14.6M</td>
<td>14.5M</td>
<td>14.5M</td>
<td>14.5M</td>
</tr>
<tr>
<td>Light-Duty Trucks</td>
<td>GVWR &lt; 6000 lbs.</td>
<td>6.8M</td>
<td>6.9M</td>
<td>7.1M</td>
<td>7.3M</td>
</tr>
<tr>
<td></td>
<td>6,001 - 8,500 lbs.</td>
<td>5.2M</td>
<td>5.3M</td>
<td>5.5M</td>
<td>5.8M</td>
</tr>
<tr>
<td>Light-Heavy-Duty Trucks</td>
<td>8,501 - 10,000 lbs.</td>
<td>872,000</td>
<td>911,000</td>
<td>918,000</td>
<td>939,000</td>
</tr>
<tr>
<td></td>
<td>10,001 - 14,000 lbs.</td>
<td>185,000</td>
<td>197,000</td>
<td>201,000</td>
<td>212,000</td>
</tr>
<tr>
<td>Medium-Heavy-Duty Trucks**</td>
<td>14,001 - 16,000 lbs.</td>
<td>295,000</td>
<td>303,000</td>
<td>303,000</td>
<td>315,000</td>
</tr>
<tr>
<td></td>
<td>16,001 - 19,500 lbs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19,501 - 26,000 lbs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>26,001 - 33,000 lbs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy-Heavy-Duty Trucks**</td>
<td>GVWR &gt; 33,000 lbs.</td>
<td>222,000</td>
<td>225,000</td>
<td>227,000</td>
<td>205,000</td>
</tr>
<tr>
<td>Buses</td>
<td>ALL</td>
<td>79,000</td>
<td>86,000</td>
<td>85,000</td>
<td>86,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>27.2M</td>
<td>27.1M</td>
<td>27.3M</td>
<td>27.8M</td>
</tr>
</tbody>
</table>

* Totals were obtained from actual data and may not reflect rounding for each category
** The population is only reflective of CA registered trucks and does not account for out of state trucks driving on California roadways
Major Findings

- Gasoline passenger cars and light-duty truck populations are lower than those forecasted by EMFAC2017 for calendar years 2017-2019.
- New sales for gasoline passenger cars and diesel light-duty vehicles have declined after 2016.
- Electric passenger cars are continuing to increase but electric trucks are lower than that predicted by EMFAC2017.
- No significant change in the counts of light-duty vehicles by model year is observed (small increase after 2015).
Light-Duty Vehicles

ZEV Market Share Projection
ZEV Sales Modeling in EMFAC

Historical DMV data

Most Likely Compliance with ZEV mandate

EMFAC2017

2016

2019

2030

2050

Historical DMV data

Short-term CEC models

Long-term Flat Growth

EMFAC202x
Projections of ZEV Sales in CEC Models

• Personal vehicle choice (PVC) & Commercial vehicle choice (CVC) models
  • Long history of development since 1983
  • Important components used for policymaking in CA:
    • predicting demand for alternative fuel vehicles
    • forecasting future transportation energy consumption
    • performing analysis under a variety of scenarios

• Projections for rental and governmental sectors in 2019 Integrated Energy Policy Report (IEPR)
California Specific Data in CEC Models

- Model coefficients were estimated based on the California Vehicle Survey.
- The survey represents geographic distribution of households and businesses across CA.
- The survey collected 3,614 residential responses (including 315 PEV owner surveys) and 1,712 commercial responses (including 285 PEV owners).
CEC PVC model

Current year stock
(fuel type, vintage, vehicle class)

Next year stock
(fuel type, vintage, vehicle class)

...... 2030

Personal Vehicle Choice Model

Vehicle attributes
Socioeconomic variables
Incentives
Fuel price

Statewide vehicle stock
(sales)

Change in # of households that have 0, 1, 2, 3+ vehicles

Probability of a household replacing vehicles

Probability of purchasing/dropping vehicles of a particular class, age, and fuel type
Update ZEV Input Attributes for EMFAC Purposes

• Vehicle attributes
  • Vehicle price
  • Fuel economy
  • Range

• Incentives
  • Clean Vehicle Rebate Project (CVRP)
  • HOV lane policy
Major Data Sources

- **ZEV vehicle attributes:**
  - Vehicle price: WARDs Intelligence
  - Fuel economy and range from DOE/EPA: [https://fueleconomy.gov/](https://fueleconomy.gov/)
  - New Sales: IHS/POLK

- **Incentives:**
  - CVRP Rebate: CARB’s Annual Funding Plan
  - HOV Lane: California Vehicle Code (CVC) §§5205.5 and 21655.9
Update Projections for Vehicle Attributes for PHEV and BEV

Step 1: Calculate base-year (2018) sales-averaged attributes

Data Driven

The base year will be updated to 2019

Step 2: Make assumptions for future trend

ICCT white paper

Regulatory teams at CARB

For vehicle classes that are not available in the base year, CARB would follow CEC projections for IEPR2019 Reference scenario.
• HOV lane incentives will end in 2025
Convert CEC Models Output to EMFAC Input

CEC PVC and CVC models output new sales by fuel type & CEC vehicle classes

BEV, PHEV, FCEV sales  Vehicle sales of all fuel types

Calculate percentage of ZEV in new sales by EMFAC vehicle classes

PHEV % in new vehicle sales  BEV+FCEV % in new vehicle sales
Preliminary results

**ZEV Market Share:**
Include BEV, FCEV, and PHEV

<table>
<thead>
<tr>
<th>Model Year</th>
<th>EMFAC202x</th>
<th>EMFAC2017</th>
<th>DMV</th>
<th>AutoAlliance</th>
<th>CNCDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td></td>
<td>2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
<td>4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td>6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td></td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td></td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td></td>
<td>18%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td></td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td></td>
<td>22%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td></td>
<td>24%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td></td>
<td>26%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td></td>
<td>28%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td></td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td>32%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*AutoAlliance and CNCDA reported sales are for calendar years*
Preliminary results

ZEV Market Share: Separate BEV+FCEV and PHEV

BEV+FCEV LDV

PHEV LDV

* AutoAlliance and CNCDA reported sales are for calendar years
Next Steps

• Improve ZEV market share projections
  • Fine-tune ZEV input attributes to CEC models (price, fuel economy, and range)
  • Calibrate model results to ZEV sales of EMFAC vehicle classes in 2019 DMV data
• Spatially resolved ZEV sales projections (TBD)
  • Project GAI level sales based on statewide ZEV growth rate
  OR
  • Project ZEV sales based on regional socioeconomic factors
Light-Duty Vehicles

VMT and New Vehicle Sales Forecasting
Outline

- Introduction
- Modeling approach and data sources
- Historical and projected input data
- Modeling results
- Conclusions
Introduction

• EMFAC2017 utilized a static multivariate regression analysis

• Latest available statewide historical socioeconomic data and an improved multivariate regression analysis are used to update California-specific econometric models in EMFAC202x

• New models are used to forecast future statewide new vehicle sales and VMT of light-duty vehicles (LDV)
Statistical Modeling Approach

• Econometric approach
• Performed Ordinary Least Squares (OLS) multivariate regression analysis on numerous parameter combinations:
  • Gross domestic product (GDP), unemployment rate, housing starts, gas price, and federal Interest rate, disposable income, 1 and 2-year lagged variables
• Historical socioeconomic data included years 2001 – 2019, and projected input data used for forecasting included data for years 2019 up to 2050
Statistical Modeling Approach Cont.

• Investigated reasonableness of each combination and picked the best model for new vehicle sales and VMT
• The reasonableness test included the following criteria
  • Parameters coherency
  • Sign validity for the coefficients
  • Meaningfulness of t-statistic value
  • Overall impact on the future trends up to 2050
Data Sources

Data sources included the following:

- UCLA Anderson Forecast 2018 and 2020 reports
- California Energy Commission (CEC)
- CA Department of Finance, 2020
- CA Department of Tax and Fee Administration (CDTFA), 2019 Motor Vehicle Fuel Tax (MVF)
- Federal Reserve Economic Data, Federal Reserve Bank of St. Louis, 2019
Updated New Vehicle Sales Equation

New vehicle sales per capita =
0.05744068 – 0.004672403 \times UR + 0.00271036 \times L1\_UR

<table>
<thead>
<tr>
<th>p-value</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>89%</td>
</tr>
<tr>
<td>UR</td>
<td>4.17 \times 10^{-7}</td>
</tr>
<tr>
<td>L1 UR</td>
<td>2.29 \times 10^{-4}</td>
</tr>
</tbody>
</table>

Where:
- \textit{UR} is unemployment rate
- \textit{L1 UR} is the same as unemployment rate (UR) with one year lag
Updated VMT Equation

VMT (miles per year) =
– 381.5 – 13.75 x GAS_PRICE + 18.9 x POP + 0.0249 x L1_HS_STRT

<table>
<thead>
<tr>
<th>p-value</th>
<th>Intercept</th>
<th>GAS PRICE</th>
<th>POP</th>
<th>L1 HS STRT</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.7 × 10⁻⁸</td>
<td>1.1 × 10⁻⁵</td>
<td>5.4 × 10⁻¹²</td>
<td>9.3 × 10⁻⁷</td>
<td>98%</td>
</tr>
</tbody>
</table>

Where:

- **GAS PRICE** is gas price in dollars
- **POP** is population in millions
- **L1 HS STRT** is 1-year lagged housing starts in thousands
• Model predicts the drop in sales in 2009 resulting from the economic recession
• Slight drop starting in 2015 - econometric modeling unable to explain
• Based on UCLA Anderson Forecast reports; may differ compared to DMV October counts
VMT Trend EMFAC202x

VMT (million miles)

Calendar Year


Modeled

Historical
Calculation of Historical VMT

- **Step 1:** Statewide fuel sales data obtained from California Department of Tax and Fee Administration (CDTFA)
- **Step 2:** EMFAC2017 run estimated statewide CO$_2$ emissions and VMT for historical years
- **Step 3:** Using a value of 8,480 g CO$_2$ per gallon of gasoline, an average statewide fuel economy was developed
- **Step 4:** The average statewide fuel economy from Step 3 was used to recalculate the statewide VMT using CDTFA fuel usage from Step 1
Conclusions

• New vehicle sales and VMT equations were updated with the latest data
• Models depending on historical data such as unemployment rate and population: Designed to represent business-as-usual conditions
• COVID-19 social and economic impacts: Uncertainty for both short- and long-term forecasting
• Projections will be revised based on future data
Heavy-Duty Vehicles (HDV)

Fleet Characterization
In-state Truck & Bus New Sales
(Includes CA IRP, excludes Transit Buses)

- New sales in years 2017 and 2018 exceeded EMFAC2017 forecasts
Diesel Truck and Bus Rule  
(Engine Replacement Requirement)

• Starting in January 2020, California Department of Motor Vehicles began withholding vehicle registrations in 2020 for vehicles not meeting CARB diesel rules

• Owners of Heavy vehicles (above 26,000 lbs.) of model year 2000 and older and light vehicles (14,001 – 26,000 lbs.) of model year 2004 and older will not be able to renew their registration unless they are exempt or are using a provision under the truck and bus rule
# Fleet Categories and Weight Groups

<table>
<thead>
<tr>
<th>EMFAC Fleet Categories</th>
<th>Vehicle Weight Class Groups</th>
<th>Diesel Truck &amp; Bus Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Heavy-Duty (MHDT)</td>
<td>Class 4 (14,001-16,000 lbs. GVWR)</td>
<td>Lighter Vehicle (14,001-26,000 lbs. GVWR)</td>
</tr>
<tr>
<td></td>
<td>Class 5 (16,001-19,500 lbs. GVWR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 6 (19,501-26,000 lbs. GVWR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 7 (26,001-33,000 lbs. GVWR)</td>
<td>Heavier Vehicle (&gt;26,000 lbs. GVWR)</td>
</tr>
<tr>
<td>Heavy-Duty (HHDT)</td>
<td>Class 8 (&gt;33,000 lbs. GVWR)</td>
<td></td>
</tr>
</tbody>
</table>

GVWR = Gross Vehicle Weight Rating by Manufacturer
HHDT Interstate (IRP) Model Year (MY) Group Proportions

• In years 2017 and 2018, EMFAC2017 forecasts were close to the updated values for EMFAC202x
HHDT In-State Tractor MY Group Proportions

- In years 2017 and 2018, there were slightly lower percentages of MY2007 & Older and MY2011+ vehicles, and a higher percentage of MY2008-MY2010 than EMFAC2017 forecasted.
HHDT In-State Single MY Group Proportions

- In years 2017 and 2018, there were a higher percentage of MY2007 & Older & a lower percentage of MY2011+ vehicles than EMFAC2017 forecasted.
MHDT In-State MY Group Proportions

- In years 2017 and 2018, there were a higher percentage of MY2007 & Older & a lower percentage of MY2011+ vehicles than EMFAC2017 forecasted.
In years 2017 and 2018, EMFAC2017 forecasts were close to the updated values for EMFAC202x but with a lower percentage of MY2007 & Older and a higher percentage of MY2011+ Buses in CY2018.
CARB Enforcement Efforts

- CARB increased enforcement efforts
  - Streamlined Truck Enforcement Program (STEP)*
    - Identified longest-standing non-compliant trucks
  - Nearly 24,000 vehicle registration holds were set at CA DMV by CARB on non-compliant vehicles by the end of 2019

*Refer to page 10 of the 2019 Enforcement Report at: https://ww2.arb.ca.gov/resources/documents/enforcement-reports
Key Takeaways

• New trucks sales were higher than those estimated by EMFAC2017

• In-state fleets in 2018 were older than forecasted by EMFAC2017

• 2019 DMV registration data reflect actions taken by CARB’s Enforcement Programs (e.g., STEPS)

• CA DMV registration holds started in CY2020 for vehicles not meeting CARB in-use diesel rules
Heavy-Duty Vehicles

Activity Forecasting
Forecasting New Vehicle Sales

• In EMFAC2014 and EMFAC2017, CA’s new HD sales growth rate used Annual Energy Outlook (AEO) national new HD sales growth, adjusted by AEO national vs. CA VMT growths

• EMFAC202x uses the same method with updated data:
  • Base year HD new sales
    • Sources: DMV and IRP for CY2019 (new Base Sales)
  • National new HD sales growth trend
    • Annual Energy Outlook 2020 (AEO2020) released in January 2020
    • California’s HD VMT growth trend ratio
      • National (AEO2020) vs. California (will be discussed later)
Note: In the AEO US model, the sales of new heavy and medium trucks are affected by investment in transportation equipment (and the relative price of gas).
Forecasting VMT

New data sources for VMT growth trends in EMFAC202x

- **Drayage trucks:**
  - Forecasted cargo growth rates from Tioga (Port of Oakland) and Mercator (San Pedro Bay Ports) reports are used
  - Assuming no mode shift from truck to rail or vice versa

- **Most HD fleet categories:**
  - California Statewide Freight Forecasting Model (CSFFM)

- **Others:**
  - UCLA Anderson Annual Economic Forecasts
California Statewide Freight Forecasting Model (CSFFFM)

- Forecasts commercial vehicle and commodity flows within California
- Developed for the California Department of Transportation (Caltrans) in partnership with:
  - Other State Agencies
  - Metropolitan Planning Organizations (MPOs), and
  - Institute of Transportation Studies (ITS), UC Irvine
- Growth surrogates:
  - Import/export based on Freight Analysis Framework
  - Socioeconomic inputs consistent with Regional Transportation Plans (RTPs)
CSFFM Architecture

CSFFM Modules

1. Commodity Module
   Total Demand, Structural Direct Demand, Import / Export

2. Mode Split Module
   Truck only, Rail only
   Rail-Truck, Air-Truck
   Water only, Pipeline

3. Transshipment Module
   Split multiple modes into mode segments

4. Seasonality and Payload Factor Module

5. Network Module
   Route Choice & Traffic Assignment

Output
   Forecasted VMT by County
CSFFM VMT Growth Rates Statewide

VMT Growth Rates (Relative to CY2019)

- Medium Heavy VMT Growth Rates
- Heavy Heavy VMT Growth Rates
CSFFM VMT Growth Rates
South Coast Air Basin

Medium Heavy VMT Growth Rates
Heavy Heavy VMT Growth Rates

South Coast Air Basin CSFFM includes the counties of Los Angeles, Orange, Riverside and San Bernardino
SCAG VMT Growth Rate Comparison

Medium Heavy VMT

Heavy Heavy VMT

EMFAC202x  2020 RTP  2019 FSTIP

SCAG: Southern California Association of Governments
RTP: Regional Transportation Plan
(Adopted for federal transportation conformity purposes only)
FSTIP: Federal State Transportation Improvement Program
CSFFM VMT Growth Rates
San Joaquin Valley Air Basin

San Joaquin Valley Air Basin CSFFM includes the counties of Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare.
VMT Growth Rates by County in 2050 (Relative to CY2019)
Drayage VMT Growth Rates

- Based on port specific forecasts of cargo growth rates
  - LA/LB: Mercator report (Feb. 2016)
  - Oakland: Tioga report (May 2020)
  - Other ports: weighted average of LA/LB (87.5%) and Oakland (12.5%)
- Does not account for mode shifts between truck and rail transport
Summary and Next Steps

• HDV inventory updated for DMV registration data for years 2017 and 2018
  • 2019 update is in process

• Updated growth rates will be used to forecast future new vehicle sales and VMT in EMFAC202x
  • [NEW] CSFFM county level VMT forecasts will be used to calculate VMT growth rates for most of the Heavy-Duty truck categories
Heavy-Duty Vehicles

Transit Bus Population
Transit Bus Module

• Relatively new module (added during EMFAC 2017)
• Improve characterization of the urban transit fleets: fuel type, body type, and weight class, and the regional differences.
• Adopt new regulations: Innovative Clean Transit (ICT)
Summary of Data Sources

• Historical bus population and VMT:
  • National Transit Database (NTD)
  • Added 2016-2018 for EMFAC2020x

• Growth rates for population and VMT forecasting:
  • **MPO regions:** transit operation miles projections from Regional Transportation Plan (RTP)/Sustainable Communities Strategy (SCS)
  • **Non-MPO regions:** human population projections from Department of Finance (DOF)
  • Updated both based on the latest information for EMFAC202x

• Phase-in of Zero-Emission Buses (ZEBs):
  • Purchase requirements from Innovative Clean Transit (ICT) regulation, adopted by CARB in 2018.
**Historical Bus Population**

- EMFAC202x with updated NTD data shows 4%-8% higher bus population compared to EMFAC2017 forecasting.

There is a slight decrease in 2017 and 2018, relative to 2016.
Bus (or standard bus) is the dominant type, contributing over 65% of the total, in spite of a decrease in the recent two years.
# Bus Age Distribution

## Bus Type Age Distribution

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>Average Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016</td>
</tr>
<tr>
<td>Bus</td>
<td>7.3</td>
</tr>
<tr>
<td>Articulate Bus</td>
<td>7.6</td>
</tr>
<tr>
<td>Cutaway</td>
<td>5.3</td>
</tr>
<tr>
<td>Over-the-road Bus</td>
<td>8.5</td>
</tr>
</tbody>
</table>

## Graphical Representation

The graph illustrates the age distribution of buses from 2016 to 2018. Each line represents a different bus type, with the x-axis showing ages from 1 to 20 years.
Forecasted Bus Population

- EMFAC202x has higher bus growth rates, mainly due to the higher growth in SCAG starting in 2035

Historical data updates: NTD
Growth updates: RTP/SCS or DOF

↑ 17% in 2050
• With the ZEB purchase requirements by ICT from 2023, ZEBs gradually phase-in.
Major Findings and Next Steps

- NTD shows 4%-8% higher bus population in 2016-2018 than that forecasted by the EMFAC2017
- Faster growth for SCAG starting in 2035 explains higher annual growth rates in EMFAC202x
- ZEBs gradually phase-in with the purchase requirements of ICT
- Next steps:
  - Update battery electric and fuel cell electric ratio based on Rollout Plan
  - Implement updated emission rates for CNG buses (0.2 g/bhp-hr and 0.02 g/bhp-hr) from 200 Vehicle In-Use Emissions Testing Project
  - Combination of BEB and FCEB will be updated based on Rollout Plan data.
  - Assess the impacts of both bus activity and emission rate updates on total emission from transit buses
Heavy-Duty Vehicle

Activity Profile
Background

- HD vehicle activity profiles have significant effects on emissions
- NOx emission rates of newer trucks equipped with Selective Catalytic Reduction (SCR) technology, is highly dependent on
  - Vehicle speed
  - Number of engine start
  - Length of extended idling
- EMFAC2017 incorporated the latest findings from University of California Riverside (UCR) CE-CERT HD activity data collection study
  - 90 vehicles by 19 vocational/regional groups
  - Global Positioning System (GPS) and electronic control unit (ECU) data loggers at 1Hz resolution
Updates in EMFAC202x

• **New data collection**
  • In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Engines
    • Funded by South Coast Air Quality Management District (SCAQMD)/CEC/CARB/SoCalGas
    • Conducted by UC Riverside (UCR) and West Virginia University (WVU)
  • Portable Activity Measurement System (PAMS)
    • Telemetry loggers equipped with GPS and vehicle ECU connection
    • Tested ~200 vehicles by UCR and WVU

• **Similar data analysis method to EMFAC2017**
  • VMT distribution by speed and by hour
  • Number of starts by soak time and by hour
  • Extended idling by hours
### PAMS Data by Fuel and Vocational Type

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Fuel Type</th>
<th>Delivery</th>
<th>Goods Movement</th>
<th>Refuse</th>
<th>School Bus</th>
<th>Transit Bus</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCR</td>
<td>CNG</td>
<td>6</td>
<td>18</td>
<td>13</td>
<td>10</td>
<td>2</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>7</td>
<td>22</td>
<td>3</td>
<td>3</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>WVU</td>
<td>CNG</td>
<td>8</td>
<td>17</td>
<td>13</td>
<td>11</td>
<td>7</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>11</td>
<td>10</td>
<td>1</td>
<td>3</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td><strong>Total Used</strong></td>
<td></td>
<td><strong>32</strong></td>
<td><strong>67</strong></td>
<td><strong>27</strong></td>
<td><strong>27</strong></td>
<td><strong>9</strong></td>
<td><strong>162</strong></td>
</tr>
</tbody>
</table>

**Note:**

- UCR tested 86 vehicles in total. 81 vehicles are used for this preliminary analysis and 5 are excluded due to missing/invalid data.
- WVU tested 95 vehicles in total. 81 vehicles are used for this preliminary analysis, and 14 are excluded due to missing/invalid data.

CARB
VMT by vocation type: Goods Movement (1)

- Over 55% of VMT within speed bins of 55-65 mph

<table>
<thead>
<tr>
<th>Speed Bin</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.03</td>
<td>0.08</td>
<td>0.11</td>
<td>0.12</td>
<td>0.12</td>
<td>0.13</td>
<td>0.15</td>
<td>0.17</td>
<td>0.20</td>
<td>0.32</td>
<td>0.51</td>
<td>0.65</td>
<td>0.78</td>
<td>0.18</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.02</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.07</td>
<td>0.08</td>
<td>0.09</td>
<td>0.11</td>
<td>0.14</td>
<td>0.21</td>
<td>0.38</td>
<td>0.85</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.07</td>
<td>0.11</td>
<td>0.28</td>
<td>0.63</td>
<td>0.63</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.10</td>
<td>0.22</td>
<td>0.58</td>
<td>0.69</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
<td>0.09</td>
<td>0.18</td>
<td>0.34</td>
<td>0.51</td>
<td>0.47</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>0.01</td>
<td>0.06</td>
<td>0.08</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.17</td>
<td>0.31</td>
<td>0.59</td>
<td>0.79</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Grand Total**: 1.08 2.42 3.30 3.61 3.83 4.23 4.63 5.28 6.17 9.03 16.20 22.65 16.23 1.28 0.05 0.00 0.00

- Over 55% of VMT within speed bins of 55-65 mph

**EMFAC Category**

- **T7 Port of Los Angeles/Long Beach (T7 POLA)**: 34
- **T7 Tractor**: 25
Preliminary Results

VMT by vocation type: Goods Movement (2)

VMT distribution by speed bin

- **T7 Tractor**
  - New Data (T7 Tractor)
  - EMFAC2017 (1b-Linehaul-is)

VMT distribution by speed bin

- **T7 POLA**
  - New Data (T7 POLA)
  - EMFAC2017 (2b-Dray-SoCal)
VMT by vocation type: Delivery(1)

- Speed profile varies greatly by delivery truck type

<table>
<thead>
<tr>
<th>EMFAC Category</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>T7 Non-Neighboring Out of State (NNOOS)</td>
<td>17</td>
</tr>
<tr>
<td>T6 In-State Delivery</td>
<td>2</td>
</tr>
<tr>
<td>T6 In-State Other</td>
<td>1</td>
</tr>
<tr>
<td>T6 In-State Tractor</td>
<td>5</td>
</tr>
<tr>
<td>Others</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

Vehicle 75 (Delivery; T7 NNOOS)

Vehicle 46 (Delivery; T6 In-State Delivery)
Preliminary Results

VMT by vocation type: Delivery (2)

VMT distribution by speed bin

New Data (T7 NNOOS)  EMFAC2017 (1a-Linehaul-oos)

Cumulative % of VMT

0 20 40 60 80

Speed Bin

T7 NNOOS

T6 In-State

VMT distribution by speed bin

New Data (T6 In-State)  EMFAC2017 (5a-Food)

Cumulative % of VMT

0 20 40 60 80

Speed Bin

T7 NNOOS

T6 In-State
VMT by vocation type: Refuse

VMT distribution by speed bin

Hour of Day
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
VMT by speed bin

Cumulative % of VMT

% of VMT
0 2 4 6 8 10 12 14

New Data (Refuse) EMFAC2017 (7-Refuse)
### Preliminary Results

#### # of Starts by Soak Time (1): Examples

<table>
<thead>
<tr>
<th>Hour of Day</th>
<th>T6 In-State</th>
<th>T7 Tractor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.58</td>
<td>0.08</td>
<td>0.66</td>
</tr>
<tr>
<td>1</td>
<td>0.25</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>0.17</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td>3</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>0.08</td>
<td>0.14</td>
</tr>
<tr>
<td>5</td>
<td>0.09</td>
<td>0.25</td>
<td>0.34</td>
</tr>
<tr>
<td>6</td>
<td>0.53</td>
<td>0.66</td>
<td>1.19</td>
</tr>
<tr>
<td>7</td>
<td>0.13</td>
<td>0.18</td>
<td>0.31</td>
</tr>
<tr>
<td>8</td>
<td>0.12</td>
<td>0.12</td>
<td>0.24</td>
</tr>
<tr>
<td>9</td>
<td>0.15</td>
<td>0.08</td>
<td>0.23</td>
</tr>
<tr>
<td>10</td>
<td>0.11</td>
<td>0.08</td>
<td>0.19</td>
</tr>
<tr>
<td>11</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>12</td>
<td>0.09</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>13</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>14</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>15</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>16</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>17</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>18</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>19</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>20</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>21</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>22</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>23</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Hour of Day</th>
<th>T6 In-State</th>
<th>T7 Tractor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.58</td>
<td>0.08</td>
<td>0.66</td>
</tr>
<tr>
<td>1</td>
<td>0.25</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>0.17</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td>3</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>0.08</td>
<td>0.14</td>
</tr>
<tr>
<td>5</td>
<td>0.09</td>
<td>0.25</td>
<td>0.34</td>
</tr>
<tr>
<td>6</td>
<td>0.53</td>
<td>0.66</td>
<td>1.19</td>
</tr>
<tr>
<td>7</td>
<td>0.13</td>
<td>0.18</td>
<td>0.31</td>
</tr>
<tr>
<td>8</td>
<td>0.12</td>
<td>0.12</td>
<td>0.24</td>
</tr>
<tr>
<td>9</td>
<td>0.15</td>
<td>0.08</td>
<td>0.23</td>
</tr>
<tr>
<td>10</td>
<td>0.11</td>
<td>0.08</td>
<td>0.19</td>
</tr>
<tr>
<td>11</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>12</td>
<td>0.09</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>13</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>14</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>15</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>16</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>17</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>18</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>19</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>20</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>21</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>22</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
<tr>
<td>23</td>
<td>0.06</td>
<td>0.06</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Preliminary Results

# of Starts by Soak Time (2): Comparisons

# of starts per day

- T6 Instate
- T7 POLA
- T7 Tractor
- Refuse

# of starts with soak time >=60 minutes

- New Data
- EMFAC2017

**New Data**

- >=60 mins
- <60 mins

**EMFAC2017**
Extended Idle Hours Per Day

Extended idle hours per day

<table>
<thead>
<tr>
<th></th>
<th>Hours per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6 Instate</td>
<td>0.0</td>
</tr>
<tr>
<td>T7 POLA</td>
<td>1.5</td>
</tr>
<tr>
<td>T7 Tractor</td>
<td>2.5</td>
</tr>
<tr>
<td>Refuse</td>
<td>0.5</td>
</tr>
</tbody>
</table>

New Data
EMFAC2017
Key Takeaways

• ~200 vehicles are used for analysis
• Over 55% of VMT for goods movement trucks is within speed bins of 55-65 mph
• Compared with EMFAC2017, the new dataset shows
  • More VMT at lower speeds (except for T7 POLA)
  • Higher number of starts with soak time greater than 1-hr
  • Higher idling hours
Next Steps

• Fine-tune the data analysis with EMFAC categories
• Make similar analysis with school bus and transit bus
• Combine the data from CE-CERT 90 vehicle study for EMFAC2017
• Implement the results in EMFAC202x to assess the impact of updates on total emissions
Light-Duty Vehicles

Emission Rates
Background and Motivation

- As part of EMFAC202x
  - Light-Duty Base Emissions Rates (BER) will be updated using data from In-Use Verification Program (IUVP) and CARB Vehicle Surveillance Program (VSP) program
  - Details were presented in the October 2019 EMFAC202x workshop

- Ratio of Standards (ROS) were previously used to estimate emission rates for future technologies and certification levels, e.g., LEVIII certification levels such as ULEV50 and SULEV20
  - Update ROS based on latest information
  - Verify if the base selection is appropriate
  - Verify if applying the same ROS to different Unified Cycle (UC) bags is valid
## ROS in EMFAC2017

<table>
<thead>
<tr>
<th>Tech Group</th>
<th>Base</th>
<th>ROS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVIII ULEV70</td>
<td>LEVII ULEV</td>
<td>70/125 = 0.56</td>
</tr>
<tr>
<td>LEVIII ULEV50</td>
<td>LEVII ULEV</td>
<td>50/125 = 0.40</td>
</tr>
<tr>
<td>LEVIII SULEV20</td>
<td>LEVII SULEV</td>
<td>20/30 = 0.67</td>
</tr>
</tbody>
</table>

- ROS were derived from the ratio of emission standards between the LEVIII HC+NOx certification and its LEVII base.
- Same ROS was applied to different phases of the Unified Cycle (UC).
ROS from Recent LEV III Test Results

<table>
<thead>
<tr>
<th>Tech Group</th>
<th>Base Group</th>
<th>HC Bag 1</th>
<th>HC Bag 2</th>
<th>HC Bag 3</th>
<th>NOX Bag 1</th>
<th>NOX Bag 2</th>
<th>NOX Bag 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULEV70 (N=4)</td>
<td>SULEV30 (N=3)</td>
<td>2.25</td>
<td>2.39</td>
<td>2.49</td>
<td>1.40</td>
<td>1.84</td>
<td>1.99</td>
</tr>
</tbody>
</table>

- Most recent test results from CARB VSP
- Applying the same ROS to all test phases may not be appropriate
<table>
<thead>
<tr>
<th>Tech Group</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>SULEV30</td>
<td>Shares the same base emission regressions with LEVII SULEV</td>
</tr>
<tr>
<td>ULEV70/ULEV50</td>
<td>Based on LEVIII SULEV30 instead of LEVII ULEV</td>
</tr>
<tr>
<td>ULEV70</td>
<td>ROS are based on latest VSP data</td>
</tr>
<tr>
<td>ULEV50</td>
<td>ROS are based on available EPA Fuel Economy data and engineering judgement</td>
</tr>
<tr>
<td>SULEV20</td>
<td>ROS are based on analysis of CARB Federal Test Procedure (FTP) test data and engineering judgement (higher reduction in Bag 1 cold start)</td>
</tr>
</tbody>
</table>
## ROS in EMFAC202x

<table>
<thead>
<tr>
<th>Tech Group</th>
<th>Base</th>
<th>EMFAC 2017</th>
<th>THC</th>
<th>NOX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bag 1</td>
<td>Bag 2</td>
</tr>
<tr>
<td>LEVIII ULEV70</td>
<td>LEVIII SULEV30</td>
<td>2.33</td>
<td>2.25</td>
<td>2.39</td>
</tr>
<tr>
<td>LEVIII ULEV50</td>
<td>LEVIII SULEV30</td>
<td>1.67</td>
<td>1.63</td>
<td>1.70</td>
</tr>
<tr>
<td>LEVIII SULEV20</td>
<td>LEVIII SULEV30</td>
<td>0.67</td>
<td>0.58</td>
<td>0.90</td>
</tr>
</tbody>
</table>
THC UC Bag 1: Cold Starts Base Emission Rate

![Graph showing BER (g/mile) vs. Odometer (10k miles) for different emission levels: LEVII LEV/LEVIII LEV 160, LEVII ULEV/LEVIII ULEV125, LEVIII ULEV 70, LEVIII ULEV 50, LEVII SULEV/LEVIII SULEV 30, LEVIII SULEV 20.](image)
THC UC Bag 2: Running Exhausts Base Emission Rate

* Slope for ULEV70 was slightly adjusted so the line doesn’t exceed ULEV125
THC UC Bag 3: Warm Starts Base Emission Rate

![Graph showing emission rates across different odometer miles for various LEV categories.](image)

- LEVII LEV/LEVIII LEV 160
- LEVII ULEV/LEVIII ULEV 125
- LEVIII ULEV 70
- LEVIII ULEV 50
- LEVIII SULEV/LEVIII SULEV 30
- LEVIII SULEV 20
* Slopes for Phase 1 of ULEV70 and ULEV50 were slightly adjusted so the lines do not exceed ULEV125 and at the same time do not fall below SULEV30 emissions.
NOX UC Bag 2: Running Exhausts Base Emission Rate

![Graph showing the relationship between BER (g/mile) and Odometer (10k miles) for different emission levels.](image)

- LEVII LEV/LEVIII LEV 160
- LEVII ULEV/LEVIII ULEV125
- LEVIII ULEV 70
- LEVIII ULEV 50
- LEVII SULEV/LEVIII SULEV 30
- LEVIII SULEV 20
NOX UC Bag 3: Warm Starts Base Emission Rate

![Graph showing the relationship between BER (g/mile) and Odometer (10k miles) for different emission levels: LEVII LEV/LEVIII LEV 160, LEVII ULEV/LEVIII ULEV 125, LEVIII ULEV 70, LEVIII ULEV 50, LEVII SULEV/LEVIII SULEV 30, LEVIII SULEV 20.](image)
Impact on EMFAC Emissions

- Scenario: Start and Running, Light-Duty Vehicle, Gasoline, Annual Statewide
- EMFAC202x run includes updated LEVI and LEVII BERs (as described in October 2019 EMFAC202x workshop), as well as the updated LEVIII ROS

![Impact on Emissions Chart]

**Impact on Emissions**

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>EMFAC2017 (tpd)</th>
<th>EMFAC202x (tpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>635</td>
<td>685</td>
</tr>
<tr>
<td>2015</td>
<td>398</td>
<td>458</td>
</tr>
<tr>
<td>2020</td>
<td>217</td>
<td>258</td>
</tr>
<tr>
<td>2025</td>
<td>129</td>
<td>158</td>
</tr>
<tr>
<td>2030</td>
<td>91</td>
<td>115</td>
</tr>
<tr>
<td>2035</td>
<td>73</td>
<td>96</td>
</tr>
</tbody>
</table>

**HC + NOX Emissions (tpd)**

- CARB
Future Work

• Utilize latest data from IUVP and VSP prior to EMFAC202x release
• Target LEVIII vehicles, especially ULEV50 and SULEV20 for the Surveillance Program to fill data gaps
• Develop UC BERs for LEVIII SULEV30 based on most recent data
• Update ROS based on future emissions test data
Light-Duty Vehicles

PHEV Module
Background and Motivation

• PHEV (Plug-in Hybrid Electric Vehicle) module – new feature in EMFAC202x

• Previous EMFAC workshop (Oct 2019) – preliminary results from CARB’s real-world emission testing of eight PHEVs

• PHEV activity analysis completed via extramural contract in early 2020

• The presentation will focus on:
  • Updated PHEV emission results
  • Updated activity profiles
List of Test PHEVs Included for Analysis

1. 2017 Toyota Prius Prime (LEV III SULEV30)
2. 2017 Audi A3 E-Tron (LEV III SULEV30)
3. 2012 Chevy Volt (LEV II SULEV)
4. 2014 Ford Fusion (LEV II SULEV)

5. 2016 Ford C-Max (LEV II SULEV)
6. 2016 Hyundai Sonata (LEV III SULEV30)
9. 2016 Mercedes C350e (LEV III SULEV30)
10. 2014 Toyota Prius (LEV II SULEV)

Non blended: Vehicle 3
Blended: Vehicle 1, 2, 4, 5, 6, 9, 10

US06 capable: Vehicle 1, 2, 3
Non US06 capable: Vehicle 4, 5, 6, 9, 10
Blended vs. Non-Blended PHEVs

- **Blended**
  - Engine will start and provide propulsion power when driver demand is higher than what the electric powertrain can provide
  - Mostly non US06 capable

- **Non-Blended**
  - Electric powertrain provides all propulsion regardless of the driver demand until the car switches to charge sustaining operation when the battery reaches a low level of charge
  - US06 capable (depletes the battery first, and only when the battery is depleted, turns the ICE on to power the vehicle)
Example: Total Hydrocarbon (THC) Start Emissions with Soak Time Relationship for Blended PHEVs

- Engine was considered to be ON (start) if RPM ≥ 100
- A duration limit of 5 to 100 secs, and soak time ≥ 5 min were set for start emissions
- Blended/non-blended PHEVs showed different starts behaviors
- Start emissions binned by soak time (mins) and applied piecewise linear regressions
Comparison of PHEV Start Emissions with LEV II SULEV in EMFAC2017

- THC start emission (g/start)
- NOx start emission (g/start)

- Blended PHEVs
- Conventional vehicle
- Non-Blended PHEVs

Soak time (min)
Comparison of PHEV Running Exhaust Emissions with LEV II SULEV in EMFAC2017

- CO2 (g/mile)
- CO (g/mile)
- THC (g/mile)
- NOX (g/mile)

 graphs showing emissions across different speeds (mph) for PHEV and LEV II SULEV CV.
Almost 50% of starts have a soak time less than 60 min.

Non-blended PHEVs have higher fraction of cold starts.

Percent of Starts

Soak Time Bin Maximum (Minutes)

Conventional ICE

Blended

Non-Blended

Percent of Starts

Soak Time Bin Maximum (Minutes)
## Starts Frequency Per Day from Activity Dataset

<table>
<thead>
<tr>
<th>Category</th>
<th>Starts</th>
<th>First Starts</th>
<th>Non-First Starts &gt; 5 mins soak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional ICE</td>
<td>2.67 to 5.19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PHEV Non-blended</td>
<td>31.86</td>
<td>2.46</td>
<td>1.56</td>
</tr>
<tr>
<td>PHEV Blended</td>
<td>96.56</td>
<td>4.16</td>
<td>1.65</td>
</tr>
</tbody>
</table>
Non-Blended PHEVs have less fraction of starts in the morning and more in the afternoon.
Key Takeaways

• Cold start NOx and THC emissions from blended PHEVs can be 2 – 3x higher than the clean conventional vehicles (SULEV 30)
• In terms of running emissions, PHEVs have lower NOx and similar THC emissions as conventional vehicles
• Non-blended PHEVs have lower number of starts per day while higher fraction of cold start as compared to conventional vehicles
• PHEVs exhibit significant GHG emissions reductions
Light-Duty Vehicles

$\text{CO}_2$ Emission Rates
Introduction

• EMFAC2017 used a new approach for estimation of CO₂ emissions
  • CO₂ was calculated assuming complete combustion of fuel
  • Fuel efficiency assumptions were based on federal fuel efficiency data
  • EMFAC2017 had data for MYs 2005 through 2015
• EMFAC202x will be updated with CO₂ emission factors for new model-year vehicles (MY 2016-2020)
CO$_2$ Calculation Approach

- Identify the fuel efficiency ratings for California’s vehicle fleet:
  - Decode VIN numbers in DMV registration - identify make, model, and other vehicle attributes
  - Match make, model, and other vehicle attributes with records in fueleconomy.gov to obtain the EPA rated fuel efficiencies

Vehicle Identification Number (VIN)
- Series Name
- Make
- Model
- Model Year
- etc.
Methodology Updates

• Vehicle matching based on vehicle specifications is improved
  • Use an advanced matching algorithm to find the most similar matches between DMV and EPA’s fueleconomy.gov data
    • For details refer to SB 1014 Clean Miles Standard - 2018 Base-year Emissions Inventory Report

• Fuel economies are no longer obtained solely using VINtelligence
• \( \text{g CO}_2 \) per mile of emissions is calculated using only the 2-cycle unadjusted EPA fuel economies
Data Processing Flow Chart

VINelligence

Vehicle Specs incl. transmission type, # of cylinders, fuel type, advance vehicle type, drivetrain type

VIN

VIN and fuel economies

DMV

VIN, Make Name, Model Name, Series Name, Model Year

only if: MY 2016-2018, Vehicle class P, LDT1-3

VIN and fuel economies and vehicle specs

EPA Fuel Economy (FuelEconomy.GOV)

Advanced Matching Algorithm

All vehicle specs from DMV and VINelligence including VIN

VIN, Make Name, Serial Number, Model Year

Fuel economies and vehicle specs
Why 2-Cycle City (Unadjusted)?

- EMFAC use the Phase 2 (Bag 2) of Unified Cycle to model running emissions from light duty vehicles.
- According to emission test data, CO₂ emissions of FTP composite is almost equivalent to Phase 2 of Unified Cycle.
- Staff are looking into other methods to evaluate the appropriateness of this method to characterize real world CO₂ emission rates.

\[ y = 0.99x \]
\[ R^2 = 0.92 \]
Results
California Fleet Average CO₂ Emission Factors

Passenger Cars

\[ y = -5.0659x + 10480 \]

Model Year

Light Duty Trucks

\[ y = -10.965x + 22485 \]

Model Year
SAFE Rule

• Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule
  ❖ **Part One** (adopted September 2019): Revokes California’s authority to set its own GHG emission standards and zero-emission vehicle mandate in California
  ❖ **Final Rule** (adopted April 2020): National Highway Traffic Safety Administration (NHTSA)’s Corporate Average Fuel Economy (CAFÉ) and US EPA greenhouse gas emission standards will increase in stringency at 1.5% per year from MY2020 levels over MYs 2021-2026; relaxes current GHG emissions targets

• Staff have evaluated the impact of SAFE Vehicles Rule on GHG emissions from passenger cars and light trucks in California

• Derived from the finalized CO₂ standards rather than the finalized CAFE standards, a 1.84% and 1.75% Year-over-Year (YoY) reduction from 2020 to 2026 for the CO₂ emission factor values of gasoline passenger cars and light trucks were determined, respectively

More details on staff evaluation of SAFE Vehicle Rules impact on EMFAC model can be found at: https://ww3.arb.ca.gov/msei/emfac_off_model_co2_adjustment_factors_06262020-final.pdf
Impact of SAFE Rule on Light Duty Vehicle CO₂ Emissions

• Final Rulemaking (FRM): 1.84% YoY reduction from 2020 to 2026 for the CO₂ emission factor of gasoline passenger cars, and 1.75% YoY reduction for light trucks

Passenger Cars

\[ y = -4.9032x + 10153 \]

Light Duty Trucks

\[ y = -9.3975x + 19330 \]
Conclusions

• CO₂ emission rates are decreasing at rates equal to 5 and 11 g CO₂/mile per year for passenger cars and light duty trucks, respectively.

• While the previously established emission standards and related “augural” fuel economy standards would have achieved about 4% per year improvements through MY 2025, SAFE rule will result in much lower reduction in CO₂ emission for cars and light trucks

• Final SAFE Rule emission standards can increase tailpipe CO₂ emissions of light duty vehicles by almost 6.4 million metric tons in 2030
Light-Duty Vehicles

New Evaporative Emissions Module
Evaporative Emissions

- Major source of hydrocarbon emissions from gasoline vehicles
- New evaporative method implemented
  - Adopting USEPA’s MOVES2014b method
  - Using California-specific activity and meteorological data

- **Tank Vapor Venting:** Fuel vapor is vented out (or “breakthrough”) when carbon canister is saturated (or cannot contain all of the generated fuel vapor)

- **Permeation:** Fuel escapes through materials in the fuel system (the tank walls, hoses, and seals)

- **Liquid Leaks:** Non-vapor form of fuel escaping the fuel system (i.e. dripping fuel), ultimately evaporating
Evaporative Processes: EMFAC202x vs EMFAC2017

EMFAC202x (physical processes)
- Tank Vapor Venting
- Permeation
- Liquid Leaks

EMFAC2017 (certification processes)
- Diurnal
- Hot Soak
- Running Loss
- Resting Loss
Development of EMFAC’s new evaporative emissions module

Implementation of MOVES methods
- MOVES vehicle classes matched to comparable EMFAC vehicle classes
- Emission rates
- Porting emission algorithms from Java/MySQL to Python/MySQL

California-specific information
- Vehicle activity data from 2010-2012 California Household Travel Survey (2013)
- EMFAC’s temperature and relative humidity
- Cross-validating with existing CARB testing results

Preprocessing with MOVES
- Average tank temperature
- Cold soak tank temperature
- Cold soak initial hour fractions
- Cold/Hot soak activity fractions
EMFAC202x vs EMFAC2017: Passenger Cars, Los Angeles, July 2020

HC Emissions [tpd]

DIURN  HOTSOAK  RUNLOSS  Total

EMFAC202x  EMFAC2017
EMFAC202x vs MOVES2014b: Passenger Cars, Los Angeles, July 2020

Comparison of HC emissions for EMFAC202x vs MOVES2014b in different categories:
- Permeation
- Tank Vapor Venting
- Liquid Leaks
- Total

The graph shows the comparison of emissions in terms of tpd (tons per day) for each category.
EMFAC202x: 2020 vs 2040
Passenger Cars, Los Angeles, July 2020

- Evaporative emissions are expected to decrease
- As Tank Vapor Venting and Permeation decrease, Liquid Leak process will account for more evaporative emissions
Next Steps

- Further quality assurance
- Share the results with internal and external stakeholders
- Improve module parameters and inputs based on former California-specific test results
- Plan new tests to improve module parameters and inputs for California conditions
- Further improve the computational efficiency of the module
Light-Duty Vehicles

Brake Wear Emissions
Background

• Currently (EMFAC2017)
  • Data from 2000/2003
  • No cycle or speed effects
  • Data extrapolated to cover all technology groups/drive cycles

• New Emission Factor Development (EMFAC202x)
  • Multi-agency effort (USEPA, Caltrans, European Joint Research Committee)
  • Use modern braking materials
  • Use modern, real world driving patterns
  • Regenerative braking
Priorities for New Emission Factor Development

- Use CA relevant vehicles and brake components
- Light, medium, and Heavy-Duty vehicles
- Identify speed dependent braking cycle reflecting CA driving behavior
- Identify cycles for light, medium, and Heavy-Duty vehicles
- Use methods being adopted by European Joint Research Counsel (e.g., enclosed brake dynamometer)
- Maintain realistic temperatures
- Develop method to simulate regenerative braking
ERG/LINK Test Program

**LDVs**
- **Market Share Analysis**
- 6-7 vehicle choices
- On-road testing
- Final drive cycles, real temperatures
- Validated enclosed dyno and PM sampling systems
- ~90 tests by 3/2020

**HDVs**
- **Market Share Analysis**
- 4-5 vehicle choices
- On-road testing
- Final drive cycles, real temperatures
- Validated enclosed dyno and PM sampling systems
- ~40 tests by 1/2021

Vehicle N:
- Front brake pads
- Rear brake pads/drums
- Popular aftermarket pads
- Loaded/unloaded
- Replicates

Real world CA activity data

CARB

ERG

LINK

Caltrans

CARB
Data Collection Methods

- Survey most popular brake configurations
- Develop representative braking cycle (CBDC)
- Collect brake temperature data on test track
- Conduct braking events and controlling temperature
- Collect Brake Wear (BW) on both aluminum impactors (TSI 100S4 MOUDI) and on 47mm Teflon filters
Results

Vehicle Level Emissions (mg/mi)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>OES-NAO</th>
<th>After-NAO</th>
<th>After-LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camry</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Civic</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>F-150</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>F-150 HLW</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Prius</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Rogue</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sienna</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sienna HLW</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

PM2.5 = 0.4362 \times (PM10 100S4) + 0.3011
R^2 = 0.8985

PM2.5 = 0.3468 \times (PM10 PTFE) + 0.1665
R^2 = 0.9429

Single Wheel PM Emission Rate (mg/mi)

PM2.5
PM10

0-21
21-69
69+

Carlyle
Civic
F-150
F-150 HLW
Prius
Rogue
Sienna
Sienna HLW

Total PM2.5 100S4 / mg/mi

Total PM10 / mg/mi

R^2 = 0.8985
R^2 = 0.9429
Comparison to Other Studies

Brake-wear emission factors

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>MOVES2014a</th>
<th>Brake dynamometer</th>
<th>Emission Inventory</th>
<th>Receptor modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy Duty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light Duty</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Courtesy of Darrell Sonntag (USEPA). Study results added by ERG
Key Findings

• Front brakes emit more PM than rear brakes
• Non Asbestos Organic (NAO) friction material brakes emit less than Low Metallic (LM) brakes
• LM is more frequently used as the vehicles age
• Speed effects are not monotonic
• There appears to be a correlation to weight
• Emissions are significantly lower than EMFAC2017
## Brake Wear Basic Emission Rates

<table>
<thead>
<tr>
<th>Vehicle Categories</th>
<th>Old PM10 BER (mg/mi)</th>
<th>New PM10 BER (mg/mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>37.5</td>
<td>7.65 + 0.0492 * (ODO/10,000)</td>
</tr>
<tr>
<td>Light-duty Truck</td>
<td>37.5</td>
<td>8.38 + 0.1825 * (ODO/10,000)</td>
</tr>
<tr>
<td>Regenerative Brakes</td>
<td>37.5</td>
<td>3.30 + 0.0047 * (ODO/10,000)</td>
</tr>
</tbody>
</table>

### BW BERs

![BW BERs graph](image)

- PC
- LDT
- Regen
- EMFAC2017
Speed Correction Factors (SCF)

\[ ER(S) = BER \times SCF(S) \]

\[
\begin{align*}
y &= 0.0688x + 0.59 \\
R^2 &= 0.9984
\end{align*}
\]

\[
\begin{align*}
y &= -0.0439x + 2.8113 \\
R^2 &= 0.9995
\end{align*}
\]

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Speed Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-21 kph</td>
<td>Mean = 4.7 mph</td>
</tr>
<tr>
<td>21-69 kph</td>
<td>Mean = 19.5 mph</td>
</tr>
<tr>
<td>69+ kph</td>
<td>Mean = 54 mph</td>
</tr>
</tbody>
</table>
Future Efforts

- Heavy-Duty Vehicles (ongoing)
- Refine Speed Correction Factors
- Correlate emissions to vehicle weight
- More research into regenerative braking
- Tire Wear – Research/test program
- Final ERG Report: https://ww3.arb.ca.gov/research/single-project.php?row_id=66826
Heavy-Duty Vehicles

Emission Rates
Review of EMFAC2017 HD Emission Rate Revision

- For HHD diesel trucks:
  - Revised running exhaust emission rates of 2013+ MY using dyno data from CARB and other sources
  - Revised start and idle emission rates of 2010+ MY using PEMS data from CARB and other sources
- Estimated MHD diesel truck emission rates by scaling HHD truck emission rates
- Revised emission rates of 0.2g CNG transit buses using limited dyno data from several sources
HD Emission Rate Revision for EMFAC202x

• Running exhaust emission rates of 2013+ MY HHD and MHD based on dyno test data from CARB TBSP
• Running exhaust emission rates of natural gas HD vehicles based on PEMS data from a multi-agency 200-vehicle testing project
• Start emission rates of 2013+ MY diesel HD trucks based on PEMS data of CARB TBSP
CARB Truck & Bus Surveillance Program (TBSP)

- To date, **38** MY2013+ trucks tested on dyno over 6 test cycles
- Most trucks also tested with PEMS

![Average Cycle Speed (mph)](chart)

<table>
<thead>
<tr>
<th>PEMS Route</th>
<th>Driving Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP-WSAC-ART</td>
<td>Arterial</td>
</tr>
<tr>
<td>DP-WSAC-ART</td>
<td>Arterial / Freeway</td>
</tr>
<tr>
<td>DP-WSAC-INDEXT</td>
<td>Low Load / Low Speed</td>
</tr>
<tr>
<td>DP-PLAC</td>
<td>Uphill / Downhill</td>
</tr>
</tbody>
</table>
Most tested trucks show NOx higher than standard.
Late model years perform better in NOx but some still show in-use NOx emissions 4–5x the standard.
HHD Speed Correction Factors for NOx

![Graph showing NOx SCF vs Speed (mph) for different years: EMFAC2017 2013+, EMFAC202X 2013-15, EMFAC202X 2016+.]
2013-15 MY HHD Truck UDDS PM

- **ARB/EMA**
- **TBSP**
- **All Data Avg**
- **0.01 mg/bhp-hr**

PM of all tested trucks are below standard.

- UDDS PM (mg/mi)
- Odometer (mi)
2016+ MY HHD Truck UDDS PM

PM of late model years are well controlled
Higher PM rates at high speeds mainly due to DPF regeneration.
CARB Surveillance Program for Class 4-6 Heavy-Duty Vehicles

- To date, 6 2013+ MY vehicles were dyno tested over multiple cycles
- One vehicle was also tested with PEMS on a city-freeway route

![Bar chart showing average cycle speed (mph) for different test cycles:]

- HD High Speed Cruise: 47.9 mph
- HHDDT Cruise: 39.9 mph
- Local: 32.6 mph
- UDDS: 18.9 mph
- HHDDT Transient: 15.4 mph
- Parcel Delivery Cycle: 10.1 mph
- HHDDT Creep: 1.77 mph
- OCBC (Bus): 12.3 mph
2013+ MY MHD Truck UDDS NOx

Limited test data show lower NOx than HHD trucks

CARB
MHD Speed Correction Curves for NOx

Note: EMFAC2017 curve is from HHD
2013+ MY MHD Truck UDDS PM

PM of all tested vehicles are well controlled.
Like HHD, MHD PM rates also higher at high speeds.
Emission Factors for Natural Gas Vehicles

- Test data from the multi-agency 200-vehicle testing project
  - PEMS testing of ~100 vehicles
- To date, received PEMS data from 24 natural gas vehicles

<table>
<thead>
<tr>
<th>Technology</th>
<th>Transit Bus</th>
<th>Refuse Truck</th>
<th>Goods Movement Truck</th>
<th>Delivery Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWC (0.2 g/bhp-hr)</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>TWC (0.02 g/bhp-hr)</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
CNG Bus CO2 Rates by Speed Bin

![Bar chart showing CO2 emissions (g/mi) by speed bin (mph) for two different fuel efficiencies: 0.2 g/bhp-hr and 0.02 g/bhp-hr. The chart includes speed bins from 5 to 55 mph, with CO2 emissions ranging from 0 to 6000 g/mi.](chart.png)
CNG Bus NOx Rates by Speed Bin

Preliminary Results

-78%
-83%
-87%
-88%
-92%

Speed Bin (mph)

NOx (g/mi)

0.2g NOx Engines
0.02g NOx Engines
CNG Bus CO2 Speed Correction Curves

Preliminary Results

EMFAC202x: 0.2g Engines
EMFAC202x: 0.02g Engines
EMFAC2017: 0.2g Engines

Speed (mph)

CO2 SCF
CNG Bus NOx Speed Correction Curves

- EMFAC202x: 0.2g Engines
- EMFAC202x: 0.02g Engines
- EMFAC2017: 0.2g Engines

NOx SCF vs. Speed (mph)
CNG Refuse Truck CO2 and NOx Emission Rates and Speed Correction Curves

Low NOx refuse trucks do not show as much NOx reduction as low NOx transit buses.

Rate-speed curves are normalized to RTC speed (7.3 mph).
CNG Goods Movement (GM) Trucks CO2 and NOx Emission Rates and Speed Correction Curves

Low NOx GM trucks do not show as much NOx reduction as transit buses.

Speed correction curves are normalized to UDDS speed (18.8 mph)
HD Diesel Vehicle Start Emissions

- SCR only works above light-off temperatures
- Excessive NOx emissions are generated before light-off temperatures are reached
- Start emissions are dependent on:
  - Emission rate per start
  - Number of starts per day
HD Truck Start Emission Test Data

- Start emission rates will be based on PEMS data from CARB TBSP
  - 11 vehicles were tested on a route for start emissions testing
- Test runs were conducted after each vehicle was soaked for overnight, 8 hours, 4 hours, 2 hours, and 20 min
High emission rate indicates start emissions.
Key Takeaways

• Late model year diesel trucks are generally cleaner than but some trucks at low mileages still have very higher NOx emissions (4-5x standard)

• Low NOx CNG transit buses tested exhibit much lower NOx emissions than 0.2g CNG buses (~80-90% lower)

• Compared to 0.2g CNG engines, limited data from low NOx refuse and goods movement trucks does not show NOx reductions as high as seen in CNG transit buses (~40-70% lower)
Next Steps

• Incorporate all appropriate test data from the 200-vehicle in-use emissions project
  • Dyno data for diesel trucks
  • Additional PEMS data for natural gas vehicles
• Analyze TBSP PEMS data and revise HD diesel truck start emissions
Heavy-Duty Vehicles

Deterioration Rate
Introduction: Heavy-Duty Deterioration in EMFAC

- Current EMFAC assumptions
  - Emissions from diesel powered trucks remain stable in the absence of tampering, malfunctions, and mal-maintenance (TM&M)
  - The EIRs are based upon assumptions of the frequency (FREQ) of occurrence and the emissions increase of specific instances of TM&M
Modeling Heavy-Duty Deterioration in EMFAC

- Zero-mile emission rate (ZMR) – Fleet average UDDS emission rates while trucks are new
- In-Use Emission Deterioration (DR) – Increase of emissions over time within the in-use fleet caused by tampering, malfunction and mal-maintenance (TM&M) of engine components, and emission control systems
- Speed Correction Factors (SCF) – A method to correct emission rates at different driving speeds

\[
DR \left( \frac{g}{\text{mile} \times 10^5 \text{mi}} \right) = \frac{ZMR \times EIR}{100}
\]

\[
ER \left( \frac{g}{\text{mile}} \right) = (ZMR + DR \times \text{Odometer}) \times SCF
\]
Use On-Board Diagnostics (OBD) Data to Update Heavy-Duty Deterioration Assumptions

• On-board diagnostics (OBD) system are available for heavy-duty trucks with MY 2013+
• Heavy-duty truck OBD regulation requires that emissions control equipment be monitored for deterioration and malfunction
• Malfunction indicator lamp (MIL) status to improve our understanding of the frequency of engine component or after-treatment system failure
Use On-Board Diagnostics (OBD) Data to Update Heavy-Duty Deterioration Assumptions

- CARB completed an extramural contract to collect a large volume of OBD from model year (MY) 2013+ heavy-duty trucks to update deterioration assumptions. Current EMFAC 2017 assumptions are shown below.

<table>
<thead>
<tr>
<th>TM&amp;M Category</th>
<th>EMFAC2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010-12 MY</td>
</tr>
<tr>
<td>NOₓ Sensor</td>
<td>36%</td>
</tr>
<tr>
<td>Replacement NOₓ Sensor</td>
<td>1.8%</td>
</tr>
<tr>
<td>SCR System</td>
<td>40%</td>
</tr>
<tr>
<td>EGR Disabled / Low Flow</td>
<td>16%</td>
</tr>
<tr>
<td>DPF Leaking</td>
<td>10%</td>
</tr>
</tbody>
</table>

Data can be used to update TM&M frequencies for MY2013+ trucks.
OBD Data Collected through CARB’s Extramural Contract

Telematics data from 24,555 CA Vehicles and 180,892 US Vehicles GVWR > 14,000 lbs

457 Vehicles Collected through Truck Stops, Ports, and Repair Shops
Telematics Data: MIL On Rates

Californian trucks seem to have lower MIL ON rate than national fleets.

- US = 180,892 Vehicles
- CA = 24,555 Vehicles
MIL On Frequency Comparison with Field Data

No systematic difference between field and Telematics Data

*Repair shop data not included in “Field” Dataset
National Telematics Data: Fit to Power Function (binned by 100,000 miles)

\[ \text{MIL ON Frequency} = 0.0016 \times \text{(Odometer)}^{0.37} \]
Heavy-Duty Deterioration in EMFAC

- OBD-based MIL On rates gives us a better handle on the frequency of failure
- Need to estimate emissions % increase associated with these failures

Emission Impact Rate (EIR) = Frequency of Engine Component or After-treatment system failure \( \times \) % Emission Increase from Engine Component or After-treatment system failure
In-Use Vehicle Test Data

- Dynamometer test data through the Truck and Bus Surveillance Program (TBSP) at CARB
- CARB EMA Testing Project
- ER = Emission Rate

High emitting vehicles have 1200% NOx emissions of low mileage vehicles
Estimate the Emission Impact Rate (EIR) Using In-Use Test Data

**Method:** Use the MIL On power function to obtain the best fit ZMR and EIR

\[ \text{Emission Rate}_{\text{odometer}} = \text{Zero Mile Emission Rate (ZMR)} + \text{EIR}_{\text{odometer}} \times \text{ZMR} \]

**Final Result:** EIR (90,249 miles) = 247%
Comparison of New Deterioration Method to Linear Function

New deterioration model will result in slightly higher emission rates at mileages \( \sim 100,000 - 600,000 \) miles and lower emission rates at mileages \( > 600,000 \) miles.
Recap and Next Steps

• Summary
  ✓ A combination of OBD telematics and in-use test data were used to estimate an EIR

• Next Steps
  ✓ Corroborate emissions increase with additional data (e.g. plume capture studies)
  ✓ Repeat analysis for particulate matter (PM)
  ✓ Assess impact on heavy-duty NOx and PM emissions
Light and Heavy-Duty Vehicles

Ammonia \((\text{NH}_3)\) Emission Rates
Background

- Historically EMFAC did not estimate NH\textsubscript{3} emissions
- EMFAC202x will be the first version of the model that will have some preliminary estimates of NH\textsubscript{3} emissions using limited test data
- Will include a combination of new data and historical emission rates
- This methodology will be improved in future versions of the model
<table>
<thead>
<tr>
<th>Fuel</th>
<th>Vehicle Class</th>
<th>Model Year</th>
<th>EF (mg/mi)</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light and Medium Duty Vehicles</td>
<td>1965-1975</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1975-1979</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1980-1983</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1984-1997</td>
<td>70</td>
<td>Dynamometer studies at UC Riverside and UCLA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1998-2003</td>
<td>45</td>
<td>Caldecott tunnel study by UC Berkeley published in 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2004-2015</td>
<td>20</td>
<td>Dynamometer studies at UC Riverside and UCLA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2016+</td>
<td>42</td>
<td>CARB LDV Test Project*</td>
</tr>
<tr>
<td></td>
<td>Heavy-Duty Vehicles</td>
<td>pre-77</td>
<td>5</td>
<td>Historical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1977-1983</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1984+</td>
<td>45</td>
<td>Caldecott tunnel study by UC Berkeley published in 2009</td>
</tr>
<tr>
<td></td>
<td>Motorcycles</td>
<td>1965-1994</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1995-2007</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2008+</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light and Medium Duty Vehicles</td>
<td>All</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy-Duty Vehicles</td>
<td>2011+</td>
<td>220</td>
<td>CARB Truck and Bus Test Project*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2007-2010</td>
<td>38</td>
<td>SCAQMD Test Project*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1965-2006</td>
<td>27</td>
<td>Historical</td>
</tr>
<tr>
<td></td>
<td>Refuse</td>
<td>All</td>
<td>580</td>
<td>SCAQMD Test Project*</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>All</td>
<td>970</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>All</td>
<td>1060</td>
<td></td>
</tr>
</tbody>
</table>
HDD 2011+ NH₃ Emission Rates
CARB Truck and Bus Test Project

NH₃ (g/mi)

Odometer (miles)

All Data Mean
NH$_3$ Key Findings

- SCR equipped Heavy-Duty vehicles have substantially higher emissions than older vehicles resulting from ammonia slip.
- 2016+ gasoline light and medium duty vehicles have a moderately higher emissions than older three-way catalyst vehicles.
- 2016+ gasoline vehicles show evidence of start effects (bag 1 is higher than bag 2 on the FTP and UC cycles) - future testing is required to confirm this.
- CNG engines show much higher ammonia emissions as compared to diesel.
- Similarly, future testing should address possible speed/cycle effects.
NH₃ EMFAC202x Programming

• A “first generation” approach in modeling ammonia emissions due to lack of data
• All emissions will be treated as running exhaust
• May disaggregate by starts and running exhaust – future testing might be needed
• No speed correction factors - future testing to determine speed/cycle effects
Light-Duty Vehicles

On-Road Motorcycles
EMFAC on-road motorcycle activity and emission factors have not been updated since 2000

Mileage Accrual rates
- Provided by Motorcycle Industry Council (MIC) survey in 1990 and by MPOs in late 1990’s
- CA does not have a motorcycle Smog Check program to collect odometer data to determine annual mileage

Emission rates
- Evaporative emission factors are based on light-duty automobiles
Major Updates

- Motorcycle (MCY) population will be updated using latest DMV Registration Data (Oct 2019)
- CARB is conducting extensive emissions testing on motorcycles (using both dynamometers and PEMS) to better understand emissions from motorcycles
- CARB testing includes tampered motorcycles
  - CARB studies showed an overall 29% tamper rate
- Motorcycle accrual rates will be updated using 2017 National Household Travel Survey (NHTS) – CA data
  - Odometer schedule will also be updated using NHTS-CA data
CA registered 714,760 motorcycles and 14,429,917 Light-Duty automobiles
CA Motorcycle Population - EMFAC

CA Motorcycle Population: EMFAC2017 vs. EMFAC202x

Calendar Year

Motorcycle Population


EMFAC2017

EMFAC202x
Activity: EMFAC202x Accrual Rates

Statewide EMFAC2017 vs. 2017 NHTS CA Survey

Miles per year vs. Age (years)

EMFAC2017 vs. 2017 NHTS (CA Motorcycles)
Activity: EMFAC202x Odometer Schedule

Odometer Schedule (NHTS CA vs. EMFAC2017)

- Odom Schedule NHTS CA
- EMFAC2017
Tampered Motorcycles

• CARB staff analyzed 2,000 online CA motorcycle sales advertisements to evaluate tampered components
  • Two projects conducted Aug 2016 - Jan 2017 and Sep 2019 - Jan 2020
• Referenced CARB Executive Orders for emission controls and aftermarket parts, manuals and relevant sources to determine tampering
  • Both studies showed an overall tampering rate of 29%
  • 31% of Class 3 motorcycles were tampered, 9% of Classes 1 and 2 were tampered
Proposed Modeling of Tampering Rates by MCY Age

MCY Tamper Percentage by Age (1 to 20), Sample Size >10

\[ y = 0.0758 \ln(x) + 0.1593 \]

Percent Tamper Rate vs. Age graph
Emissions: Laboratory Testing

- 13 of 26 motorcycles tested at CARB HSL El Monte (2008 to 2020 models)
  - 7 private-owned bikes
  - 6 state-owned bikes (2 in tampered configuration)
- Exhaust tests:
  - Unified Cycle (UC) – test results used to develop proposed motorcycle emission rates for EMFAC (MY2008+, FI, Catalyst Equipped, gasoline)
  - Federal Test Procedure (FTP)
  - World Motorcycle Test Cycle (WMTC)
- Evaporative SHED tests:
  - 1-hour hot soak test
  - Multi-day diurnal test
EMFAC Emission Rates

- Analysis of motorcycle exhaust emissions test data
  - By odometer
  - For each Unified Cycle phase (Bag1, Bag 2 and Bag 3)

- Calculate the weighted emission rates
  - Non-tampered and Tampered emission rates
  - Apply Tampering rates as:
    \[
    \text{Emission rate [grams per mile]} = (\text{Tamper Bag}) \times (\text{Tamper Rate}) + (\text{Non-Tamper Bag}) \times (1 - \text{Tamper Rate})
    \]

- Compare test data weighted rates to current EMFAC2017 emission rates for each pollutant
Emission Rates - HC

UC Bag1 HC Emission Rates

UC Bag2 HC Emission Rates

UC Bag3 HC Emission Rates

EMFAC2017
New Data

grams per mile

Odom x10k miles

grams per mile

Odom x10k miles

grams per mile

Odom x10k miles

EMFAC2017
New Data
Emission Rates – CO₂

UC Bag1 CO₂ Emission Rates

UC Bag2 CO₂ Emission Rates

UC Bag3 CO₂ Emission Rates
Next Steps

- Major updates to motorcycle emissions and activity
- NHTS data will be used to update EMFAC for motorcycle accrual rates and odometer schedule
- Data collected through CARB’s motorcycle emissions testing program will be used to update exhaust emission rates
  - Evaporative emission rates and SFCs to be developed in next update
- Emissions impact of these updates will be presented in the next workshop
- The new assumptions will be used in support of potential future amendments to motorcycle emissions standards
Latest Regulatory Measures
Latest Regulatory Measures

- HDVIP/PSIP
- Innovative Clean Transit
- Advanced Clean Trucks
- HD Warranty
- ZE Airport Shuttle Bus
- Low NOx Omnibus
Heavy-Duty Vehicle Inspection (HDVIP) & Periodic Smoke Inspection Programs (PSIP)

- **Overall Strategy**
  - **HDVIP**: Roadside inspections of any heavy-duty vehicle operating in California by CARB enforcement personnel for excessive smoke, tampering, and engine certification label compliance
  - **PSIP**: Require annual self-testing for California fleets of 2 or more vehicles

- **Primary Elements**
  - Opacity limits for all MYs

- **Board Hearing**
  - May, 2018

<table>
<thead>
<tr>
<th>Engines Equipped with a Diesel Particulate Filter (DPF)</th>
<th>5% Opacity Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-2007 Model Year (MY) Engines without a DPF</td>
<td></td>
</tr>
<tr>
<td>1997–2006 MY Engines</td>
<td>20% Opacity Limit</td>
</tr>
<tr>
<td>1991–1996 MY Engines</td>
<td>30% Opacity Limit</td>
</tr>
<tr>
<td>Pre-1991 MY Engines</td>
<td>40% Opacity Limit</td>
</tr>
</tbody>
</table>

| Engines Equipped with a Level 2 Verified Diesel Emission Control Strategy (VDECS) | 20% Opacity Limit |
| Two-Engine Cranes Driven by a non-DPF Off-Road Engine                            | 40% Opacity Limit |
2018 HD Warranty

- **Overall Strategy**
  - Requires manufacturers to lengthen the mandatory emissions warranty periods of MY2022+ HD vehicles with GVWR >14,000 lbs.

- **Primary Elements**
  - Longer Warranty Periods
  - Elimination of 3,000-Hour Limit
  - Updated Maintenance Intervals

- **Board Hearing**
  - June 2018

<table>
<thead>
<tr>
<th>VEHICLE / ENGINE CATEGORY</th>
<th>GVWR</th>
<th>Current Warranty</th>
<th>Extended Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Class 8 Heavy-Heavy</td>
<td>GVWR &gt;33,000 lbs.</td>
<td>100,000 miles 5 years / 3,000 hours</td>
<td>350,000 miles 5 years</td>
</tr>
<tr>
<td>Diesel Class 6-7 Medium-Heavy</td>
<td>19,500 &lt; GVWR ≤ 33,000 lbs.</td>
<td>100,000 miles 5 years / 3,000 hours</td>
<td>150,000 miles 5 years</td>
</tr>
<tr>
<td>Diesel Class 4-5 Light-Heavy</td>
<td>14,000 lbs. &lt; GVWR ≤ 19,500 lbs.</td>
<td>100,000 miles 5 years / 3,000 hours</td>
<td>110,000 miles 5 years</td>
</tr>
</tbody>
</table>
Innovative Clean Transit (ICT)

- **Overall Strategy**
  - Requires all public transit agencies to gradually transition to a 100% zero-emission bus (ZEB) fleet

- **Primary Elements**
  - Applies to all transit agencies with buses of GVWR >14,000 lbs.
  - ZEB purchase requirements, starting from 2023
  - Low-NOx engines
  - Flexibility, exemptions, and credits

- **Board Hearings**
  - First hearing: September, 2018
  - Second hearing: December, 2018

<table>
<thead>
<tr>
<th>Year</th>
<th>ZEB % of Total New Bus Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large Transit Agency</td>
</tr>
<tr>
<td>2023</td>
<td>25%</td>
</tr>
<tr>
<td>2024</td>
<td>25%</td>
</tr>
<tr>
<td>2025</td>
<td>25%</td>
</tr>
<tr>
<td>2026</td>
<td>50%</td>
</tr>
<tr>
<td>2027</td>
<td>50%</td>
</tr>
<tr>
<td>2028</td>
<td>50%</td>
</tr>
<tr>
<td>2029 and after</td>
<td>100%</td>
</tr>
</tbody>
</table>
Zero-Emission Airport Shuttle Bus

- **Overall Strategy**
  - Requires airport shuttle operators to transition to 100 percent ZEV technologies by 2035

- **Primary Elements**
  - Applies to operators with shuttles of GVWR >8,500 lbs., which transport passengers to, from, or around a regulated airport
  - Airport shuttle operators must begin adding zero-emission shuttles to their fleets in 2027, and complete the transition to ZEVs by the end of 2035.

- **Board Hearings**
  - First hearing: February, 2019
  - Second hearing: June, 2019

<table>
<thead>
<tr>
<th>Year</th>
<th>% of Fleet That Must Be Zero-Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>2027</td>
<td>33%</td>
</tr>
<tr>
<td>2031</td>
<td>66%</td>
</tr>
<tr>
<td>2035</td>
<td>100%</td>
</tr>
</tbody>
</table>
Advanced Clean Truck (ACT)

- **Overall Strategy**
  - Requires manufacturers with >500 annual California sales to sell certain percent of zero-emission truck and bus

- **Primary Elements:**
  - Applies to manufacturers who certify Class 2B-8 chassis or complete vehicles with combustion engines
  - Requires to sell zero-emission trucks with an increasing percentage of their annual California sales from 2024 to 2035

- **Board Hearings**
  - First hearing: December 2019
  - Second hearing: June 2020

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Class 2b-3</th>
<th>Class 4-8 Vocational</th>
<th>Class 7-8 Tractors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td>5%</td>
<td>9%</td>
<td>5%</td>
</tr>
<tr>
<td>2025</td>
<td>7%</td>
<td>11%</td>
<td>7%</td>
</tr>
<tr>
<td>2026</td>
<td>10%</td>
<td>13%</td>
<td>10%</td>
</tr>
<tr>
<td>2027</td>
<td>15%</td>
<td>20%</td>
<td>15%</td>
</tr>
<tr>
<td>2028</td>
<td>20%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>2029</td>
<td>25%</td>
<td>40%</td>
<td>25%</td>
</tr>
<tr>
<td>2030</td>
<td>30%</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>2031</td>
<td>35%</td>
<td>55%</td>
<td>35%</td>
</tr>
<tr>
<td>2032</td>
<td>40%</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>2033</td>
<td>45%</td>
<td>65%</td>
<td>40%</td>
</tr>
<tr>
<td>2034</td>
<td>50%</td>
<td>70%</td>
<td>40%</td>
</tr>
<tr>
<td>2035 and after</td>
<td>55%</td>
<td>75%</td>
<td>40%</td>
</tr>
</tbody>
</table>
Low NOx Omnibus

- **Overall Strategy**
  - Requires manufacturers to meet MY2024+ California certification for heavy-duty engines with GVWR > 10,000 lbs.

- **Primary Elements**
  - A tightened standard on the Federal Test Procedure (FTP)
  - A new low-load certification cycle (LLC)
  - Improvements to the existing heavy-duty in-use testing (HDIUT) program
  - Improvements to the durability demonstration program (DDP)
  - Lengthened warranty and useful life (UL) mileages
  - Amendments to emission warranty information reporting (EWIR)

- **Board Hearings**
  - August 2020
Next Steps for EMFAC202x

- Send us your comments and feedback by August 28, 2020 on the analysis presented at the second public workshop of EMFAC202x
- Continue data collection and analysis with a cut-off date of October, 2020
- Evaluate the updated emission rates and activity using real world data (e.g., remote sensing, roadside data collection, etc.)

**Timeline:**
- **2nd Workshop:** July, 2020
- **Beta Release and Testing:** August, 2020
- **Official Public Release:** Late 2020/ Early 2021
- **3rd Workshop:** Fall, 2020
- **3rd Workshop:** Winter, 2020
Questions and Comments

For questions and comments please contact us at:
EMFAC@arb.ca.gov

You can also visit our website at:
https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory