California Environmental Protection Agency

Air Resources Board

EMFAC2017

An update to California On-road Mobile Source Emission Inventory

Mobile Source Analysis Branch
Air Quality Planning and Science Division
California Air Resources Board

emfac@arb.ca.gov

June 1, 2017

Public Process

- First public workshop – June 2017
  - ❑ Model Formulation and data analysis
- Second public workshop – October 2017
  - ❑ Emission inventory impacts
- Web database tool for emissions and emission rates
  - ❑ http://www.arb.ca.gov/emfac/
- Web-based training
  - ❑ Second Quarter of 2018
- User's Guide
- Technical documentation

Agenda for Today's Workshop
(Methodology and Data Updates)

i. **Executive Summary** – Steve Zelinka and Sam Pournazeri

ii. **Fleet Characterizations**
- Light Duty Vehicles – Ehsan Hosseini
- Heavy Duty Vehicles – Sherrie Sala-Moore

iii. **Updates to Emission Rates**
- Light Duty Emission Rates – Michael Kamboures
- Heavy Duty Emission Rates and Deteriotation – Lei Zhou and Chandan Misra

iv. **Updates to Vehicle Activity Profiles**
- Light and Heavy Duty Vehicles (LDV and HDVs) Activity Profiles – Zhen Dai

v. **GHG Module** – Guihua Wang

vi. **Forecasting** – Guihua Wang

Preliminary Agenda for October's Workshop

i. Impact of Updates on PM, NOx, HC, and CO2 Inventories

ii. Final data updates (heavy duty truck emission rates and deterioration)

iii. Development of Advanced Transit Module

iv. Natural Gas Fleet in EMFAC2017

v. Update EMFAC2017 Assumptions Based on Findings from LEV 3 Midterm Review

vi. Methodologies to Reflect Impact of Regulations

vii. Future Plan for EMFAC202x

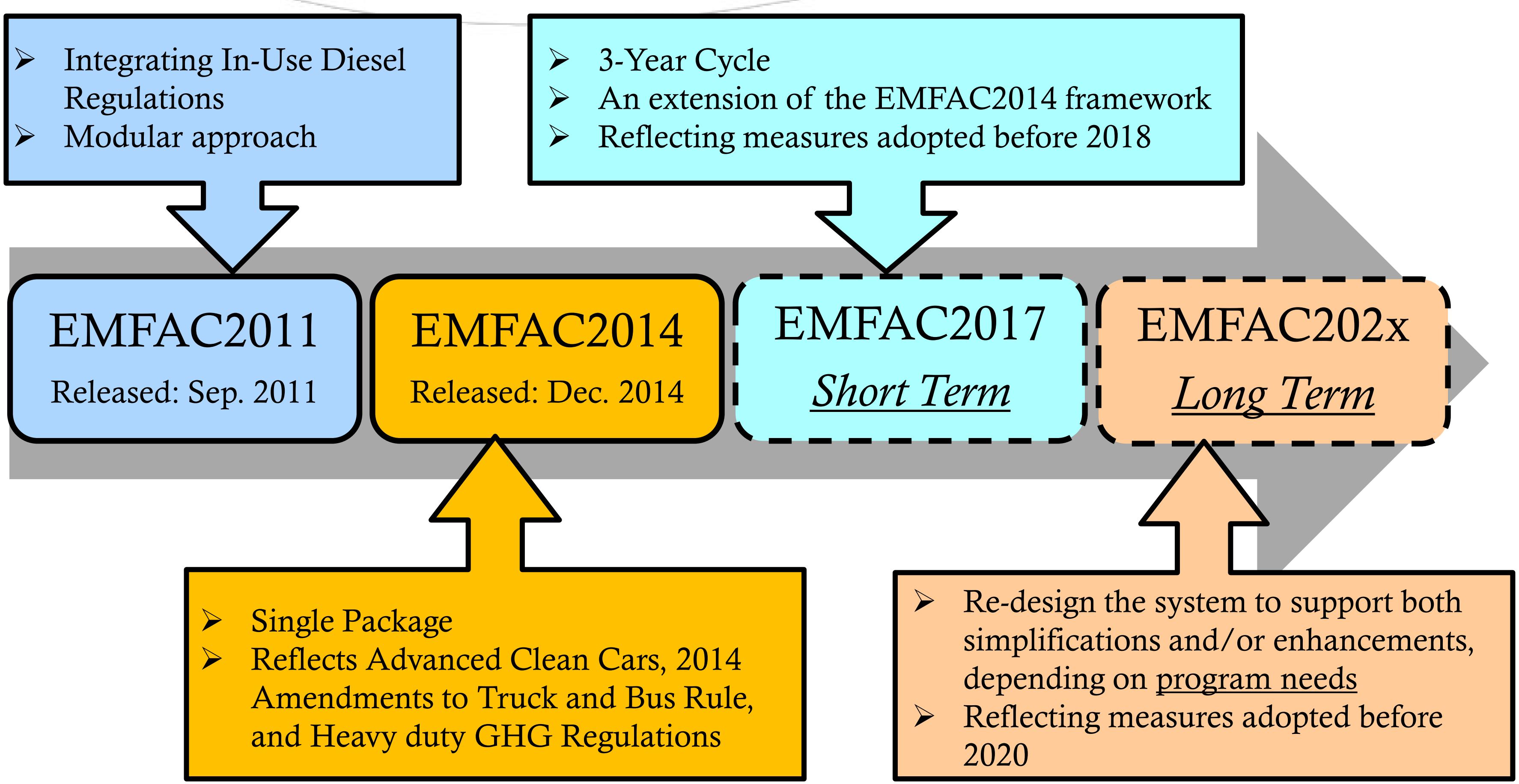
Executive Summary

- Background
- EMFAC Schedule
- Major Updates

Background

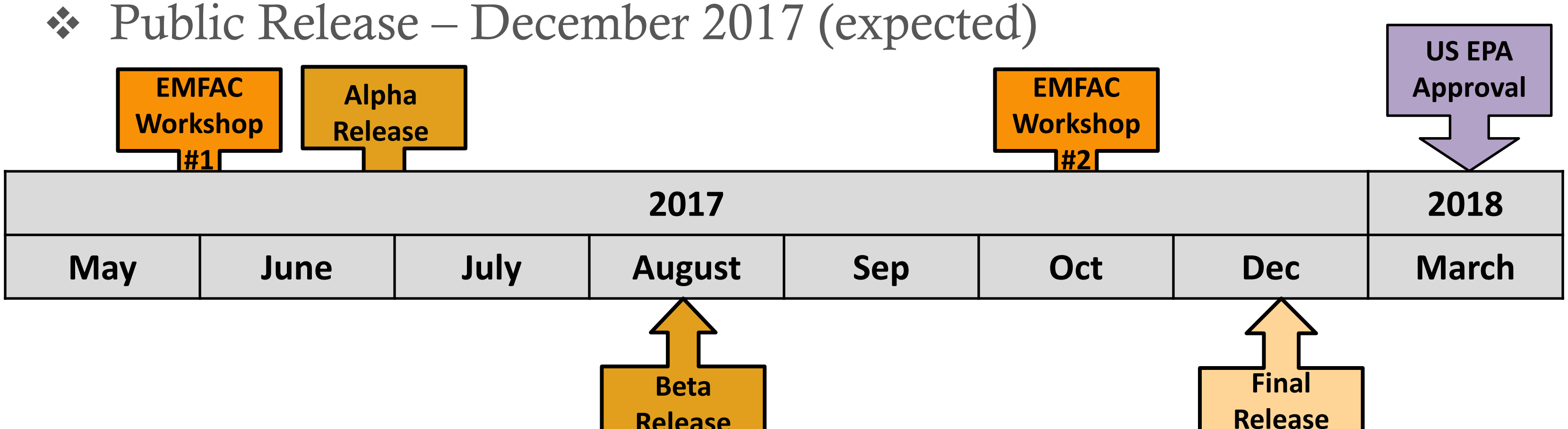
- California Air Quality Planning
  - USEPA approves EMFAC for use in California's SIPs and for Conformity Analyses
  - Can utilize California-specific MPO vehicle activity
  - Accounts for unique, California-specific regulations and emission factors
  - The 2016 Statewide SIP Strategy is based on EMFAC2014
- Rulemaking
  - Used to develop rule-specific Criteria Pollutant emission inventories
- Climate Change Planning
  - SB375
  - Scoping Plan

EMFAC Updates



EMFAC2017 Schedule – Workshops/ Model Release

- Workshops
  - 1st Workshop (Methodology) – June 1, 2017
  - 2nd Workshop (Results) – October 2017
- Releases
  - Alpha Release –Mid-June 2017
  - Beta Release – August 2017
  - Public Release – December 2017 (expected)



EMFAC2017 Major Updates

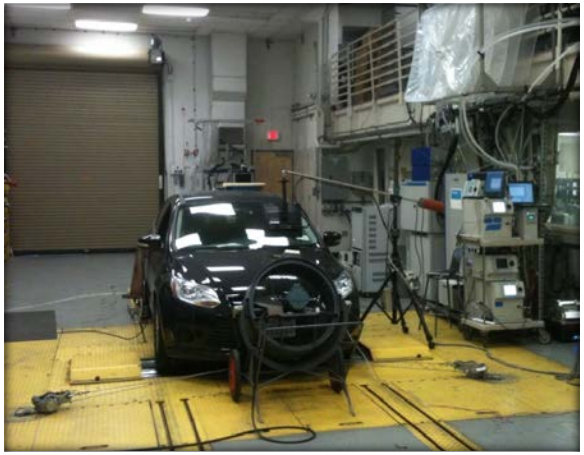
- Fleet Characterization
  - Updated vehicle population based on most recent DMV and IRP vehicle registration data
- In-Use Emissions
  - Extensive emission testing (on-road and chassis dynamometer) of both light and heavy duty vehicles
- Activity Profiles
  - California Household Travel Survey (2010 – 2012) – LDVs
  - Heavy Duty Activity Data Collection (2016) – HDVs
- GHG Module (**New feature!**)
- Regulations

EMFAC2017 – Fleet Characteristics

- Latest vehicle registration data from California Department of Motor Vehicles (DMV) and International Registration Plan (IRP)
- Higher population of light and heavy duty vehicles than projected by EMFAC2014 for calendar years 2013 – 2016
- Higher light truck (Crossovers and SUVs) sales in 2015 as compared to prior years
  - ❑ Car/truck splits has changed from 66%/34% in 2012 to 62%/38% in 2015
- Increased Penetration of 2010+MY Engine Heavy-Heavy Duty Trucks
  - ❑ More than 30% of in-state trucks (>33,000 lbs. GVWR) are 2010 or newer

EMFAC2017 – In-Use Emissions (Light Duty)

- Replaced CALIMFAC (California I/M simulation module) with an empirical data-driven model
- New light duty module based on data from
  - CARB in-house emission testing program
  - CARB/EPA light duty In-Use Verification Program (IUVP)



Differences between EMFAC2017 and EMFAC2014		
Higher Start Emission Rates for Criteria Pollutants (Start emissions as a function of soak time)	Lower Running Emission Rates	Much Less Emission Deterioration (Higher Durability and Better Smog Check Enforcement)

EMFAC2017 – In-Use Emissions (Heavy Duty)

- In-use vehicle emission testing is a key to CARB's emission inventory development
- Expanded our in-use emission testing programs to include more engine families and greater sample size
- In-use trucks are tested on a chassis dynamometer over eight different cycles
- CARB is also deploying PEMS to measure real-world emission rates

Differences between EMFAC2017 and EMFAC2014			
Compared to EMFAC2014, NOx emissions are significantly higher Higher PM emission (PM emissions significantly increase at high speeds)	Lower Start Emission Rates	Higher Idling Emission Rate	Higher PM Deterioration NOx Deterioration (under investigation)

EMFAC2017 – Activity Profiles (Light Duty)

- Updated activity profiles based on data from:
  - ❑ 2010 – 2012 California Household Travel Survey
  - ❑ 2001 – 2014 BAR Smog Check data
  - ❑ Telematics data provided by four major OEMs

CALIFORNIA Household Travel Survey

DEPARTMENT OF CONSUMER AFFAIRS BAR Bureau of Automotive Repair

Differences between EMFAC2017 and EMFAC2014		
Lower number of start per day (More than 50% of starts have a soak time of 60 min or less)	Lower mileage accrual rates for newer vehicles Higher for older ones	Updated mileage accrual rates for PEVs (based on ACC Midterm Review analysis) (eVMT ~ 11,000 miles/yr)

EMFAC2017 – Activity Profiles (Heavy Duty)

- Updated activity profiles based on data from CARB’s contract 13-301, “Collection of Activity Data From On-Road Heavy-Duty Diesel Vehicles”

- Vehicle activity and engine information data collection from 90 vehicles in California
- Enables us to characterize heavy-duty diesel vehicles (HDDV) activity profiles by vocation

Differences between EMFAC2017 and EMFAC2014		
Higher portion of low speed activities	Lower number of cold starts per day for several major categories	Lower number of idle hours per day for most categories

EMFAC2017 – GHG Module

- New approach aligns with official CARB, U.S.EPA and IPCC methodologies
- Updated fuel efficiency assumptions based on an analysis of Federal data
- New module to calculate tailpipe CO_2 emissions using a complete combustion methodology
  - ❑ Replaces previous CO_2 emission factors derived from vehicle testing.
- Updated light and heavy-duty CH_4 and N_2O emission factors using recent vehicle testing data
- N_2O estimates provided directly by the EMFAC model (previously off-model calculation)

EMFAC2017 – Emission Benefits of Regulations

- EMFAC2017 model will reflect the benefits of regulations adopted before the model release date.
- Based on the current CARB board hearing schedule, the following regulatory items are expected to be considered:
  - ❑ Amendments to Smoke Opacity (October 2017)
  - ❑ California Medium and Heavy Duty Phase 2 (October 2017)
  - ❑ Amendments to Heavy Duty Engine Warranty Requirements (December 2017)

Fleet Characterization

Light Duty Vehicles

Major Findings

- EMFAC2014 underestimated vehicle populations
  - Higher vehicle population for calendar years 2013 – 2016
- Car/truck split changed from 66%/34% in 2012 to 62%/38% in 2015
- Lower diesel light duty new vehicle sales in 2016 was observed as compared to prior years.
- LHDT new vehicle sales significantly increased in 2016 as compared to prior years.

Major Data Sources

- Historical DMV data used by EMFAC2014
- New DMV data calendar years 2013 through 2016
- Polk/IHS VINtelligence Web Service
- Ward's Database
- Certification Executive Orders

Current Status and Improvements

Completed analysis of DMV2016b (October 2016 Snapshot)

- Improvements
  - Developing a new approach for processing DMV data
  - Smog check reports no longer include vehicle weights
  - Using Ward's database to assign vehicle weights
  - Developing a new fuzzy string matching algorithm specialized for matching vehicle make and models
  - Directly using EOs to classify vehicle weight classes
  - Developing a centralized VIN decoder using Polk/IHS VINtelligence
  - Using the VIN decoder to identify fuel technology (PHEV, BEV, FCV)

- Future considerations and improvements
  - Further refining of the new string fuzzy algorithm
  - Refining data contained in the electronic EOs

DMV Processing

STEP	DESCRIPTION	PROCESS TIME
1	Identify duplicate vehicle records (10% of total records)	10%
2	Create 'Master Table‘ and obtain vehicle classifications from past datasets	8%
3	Create Geographical Area Index (GAI) and distribute the vehicle records among them	6%
4	Identify Off-Road vehicles including Off-road motorcycles, Recreational vehicles (ATV's, snowmobiles, etc.), Marine Vessels	4%
5	Indentifying and classifying new vehicles not seen in previous datasets (5 % of total records) • Processing and compiling Ward’s data • Developing a python code to classify vehicles using vehicle weights obtained from Ward’s db. • Randomly assigning against EOs • Doing research on fuzzy string matching, available methods, and customization • Developed a C++ code and modules for SQLite in order to fuzzy string matching functionality through SQL scripting	46%
6	Classify bus categories • Transit Bus • School Bus • Other Bus	13%
7	Verify & update motive power • Use POLK's VIN decoder to confirm hybrid & electrics, gas & diesel	9%
8	Update the 'pending' vehicles	4%

Major Updates
DMV Processing Improvements

- Processing time 4 to 6 months (previously 8–12 months)
- Run all unknown records through the VIN decoder
- Not all the VIN numbers can be decoded if there is miscoding in the DMV/POLK datasets
- Assign vehicle classifications directly using the EOs

Major Updates
Using VINtelligence

Before VINtelligence

MAKE_DMV	TOYT
MAKE_VINA	
MAKE_NAME	
YEAR_MODEL	2006
SERIES_CODE	
SERIES_NAME	
MODEL_CODE	
MODEL_NAME	
BODY_STYLE	UT
MOTIVE_POWER	Q
FUEL_TYPE	
GVW_CODE	
UNLADEN_WT	
INCH3_DISP	
TYPE_LIC_CODE	L0
BODY_TYPE_MODEL	4D
SOURCE	

After VINtelligence

MAKE_DMV	TOYT
MAKE_VINA	
MAKE_NAME	TOYOTA
YEAR_MODEL	2006
SERIES_CODE	
SERIES_NAME	HIGHLANDER
MODEL_CODE	
MODEL_NAME	HYBRID
BODY_STYLE	UT
MOTIVE_POWER	Q
FUEL_TYPE	B
GVW_CODE	1
UNLADEN_WT	
INCH3_DISP	201
TYPE_LIC_CODE	L0
BODY_TYPE_MODEL	4D
SOURCE	VINTEL

Major Updates
Using Electronic EOs

- Previously classifying vehicles required manually searching through the EOs.
- Now we have access to approximately 29,000 electronic EOs.
- Vehicles can now be semi-automatically classified.

Scanned EOs (PDF file)

California Environmental Protection Agency Air Resources Board	BAYERISCHE MOTOREN WERKE AG	EXECUTIVE ORDER A-008-0364-2 New Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles Page 3 of 3

BMW	428i Coupe xDrive	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	428i Gran Coupe	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	428i xDrive Convertible	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	428i xDrive Gran Coupe	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	528i	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	528i xDrive	FBMXR0130N54	1	2	PC	HCT	Partial
BMW	X1 sDrive28i	FBMXR0130N54	1	2	PC	HCT	Partial

Electronic EOs

MY	Make	Model	makeModel	EO	EngineFamily	VehType
2016	NISSAN	JUKE NISMO RS	JUKE NISMO RS	A-015-0718-1	GNSXV01.6GDB	PC
2016	NISSAN	JUKE NISMO ...	JUKE NISMO RS AWD	A-015-0718-1	GNSXV01.6GDB	PC
2016	NISSAN	JUKE NISMO ...	JUKE NISMO RS AWD	A-015-0718	GNSXV01.6GDB	PC
2016	NISSAN	JUKE	JUKE	A-015-0717	GNSXV01.6GDA	PC
2016	NISSAN	JUKE	JUKE	A-015-0717-1	GNSXV01.6GDA	PC
2016	NISSAN	JUKE AWD	JUKE AWD	A-015-0717	GNSXV01.6GDA	PC
2016	NISSAN	JUKE AWD	JUKE AWD	A-015-0717-1	GNSXV01.6GDA	PC
2016	NISSAN	VERSA	VERSA	A-015-0701	GNSXV01.6G4A	PC
2016	NISSAN	VERSA NOTE	VERSA NOTE	A-015-0701	GNSXV01.6G4A	PC
2016	NISSAN	LEAF	LEAF	A-015-0712	GNSXV0000LLB	PC
2016	NISSAN	LEAF	LEAF	A-015-0711	GNSXV0000LLA	PC
2016	INFINITI	QX80 AWD	QX80 AWD	A-015-0706	GNSXT05.6G9B	LDT4
2016	INFINITI	QX80 AWD	QX80 AWD	A-015-0706-1	GNSXT05.6G9B	LDT4
2016	INFINITI	QX80 2WD	QX80 2WD	A-015-0705-1	GNSXT05.6G9A	LDT4
2016	INFINITI	QX80 2WD	QX80 2WD	A-015-0705	GNSXT05.6G9A	LDT4

Major Updates
Fuel Technology

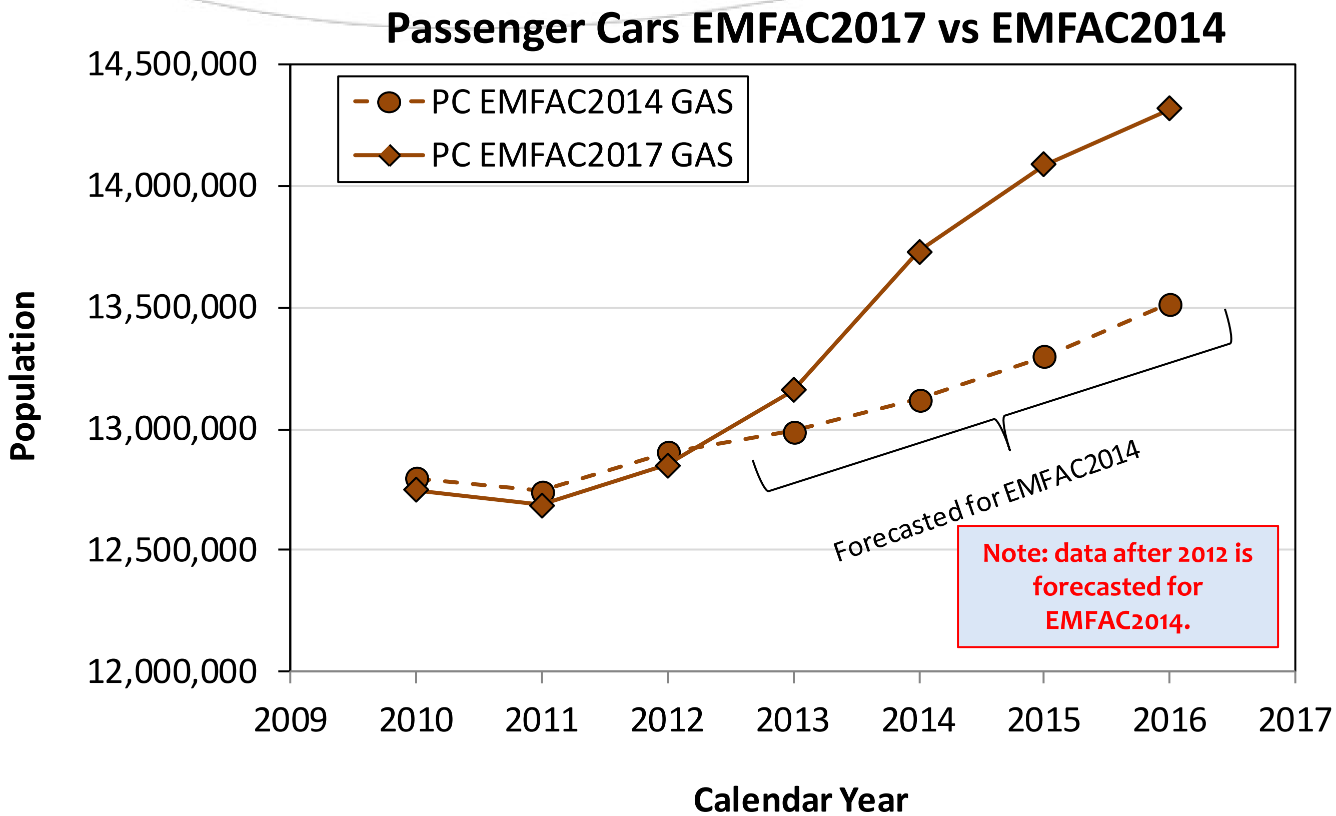
Identifying PHEV, BEV, and FCVs

- VINtelligence
  - Hybrids, fuel cell, and electric vehicles will have an "Advanced Vehicle Type Code" in VINtelligence and will be updated accordingly
- VIN patterns
  - VIN patterns will be flagged with their fuel technology and flagged in the master table

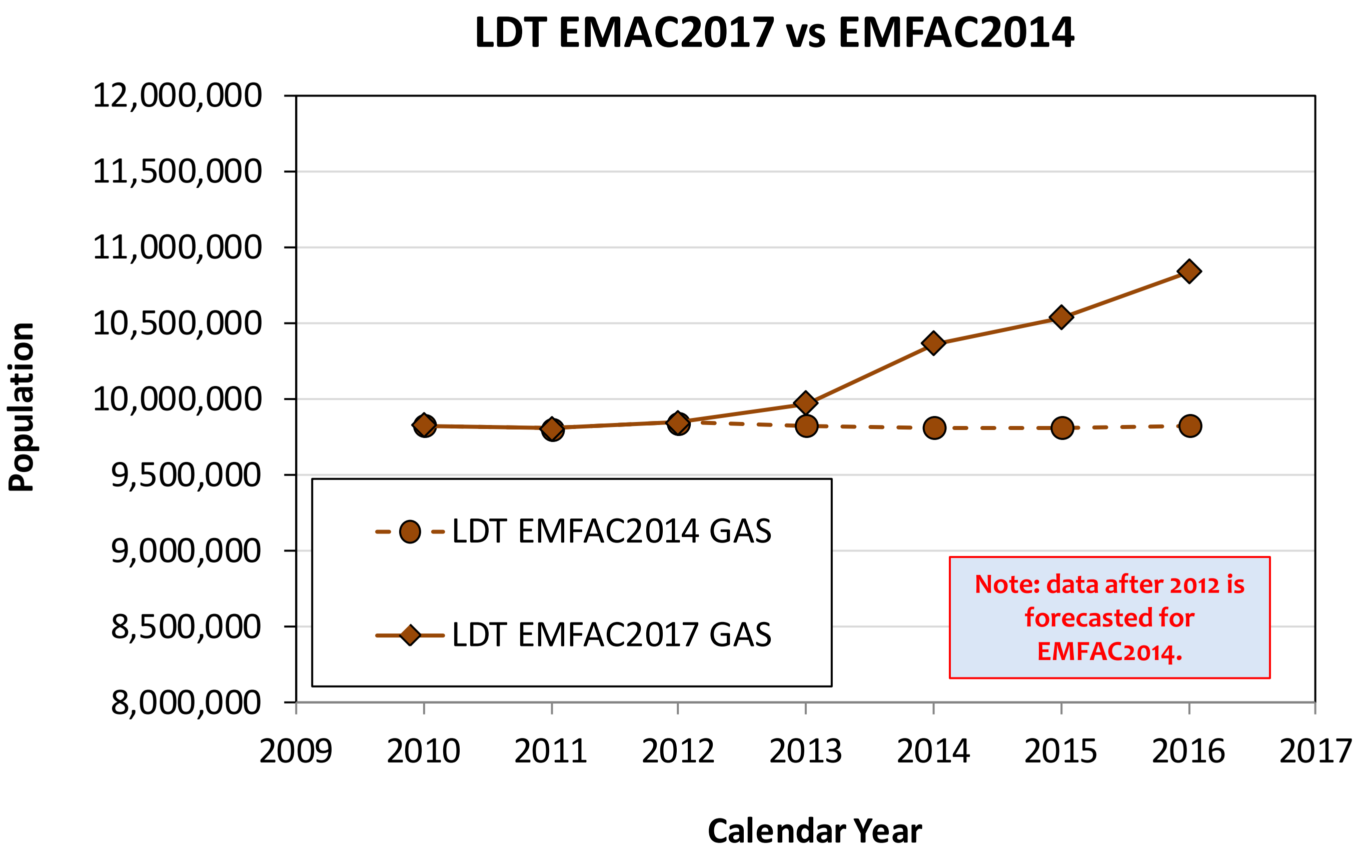
EMFAC2017 Population vs EMFAC2014 Significant Changes

- EMFAC2017 has a higher gasoline, diesel, and electric vehicle populations for years 2013 through 2016 compared to EMFAC2014.
- EMFAC2017 shows a sharp drop in the sales of new diesel PC and LDT vehicles since 2015 and a sudden increase in the sales of diesel LHDT vehicles since 2014.
- No significant change in the counts of light duty vehicles by model year is observed.

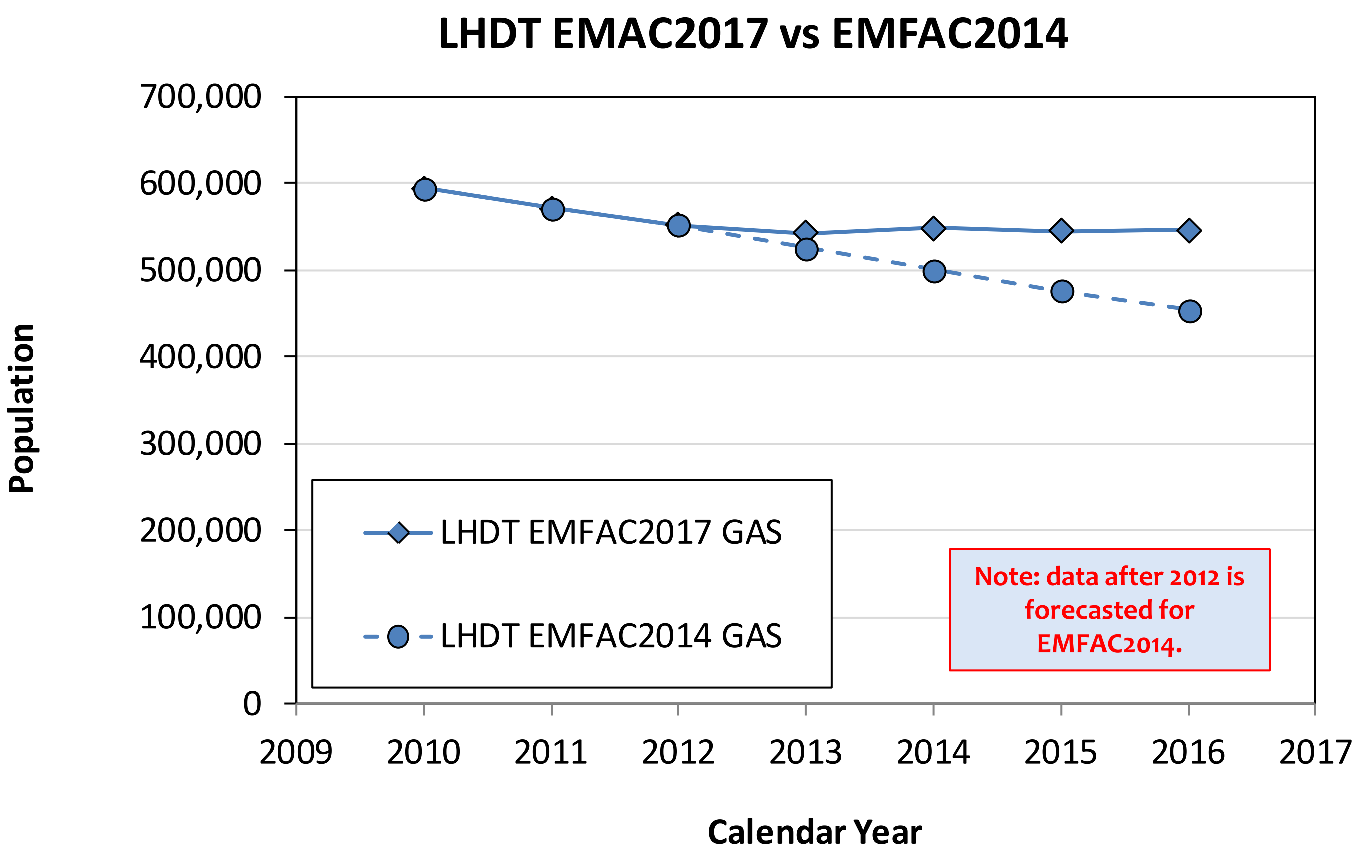
EMFAC2017 Population vs EMFAC2014 Gasoline



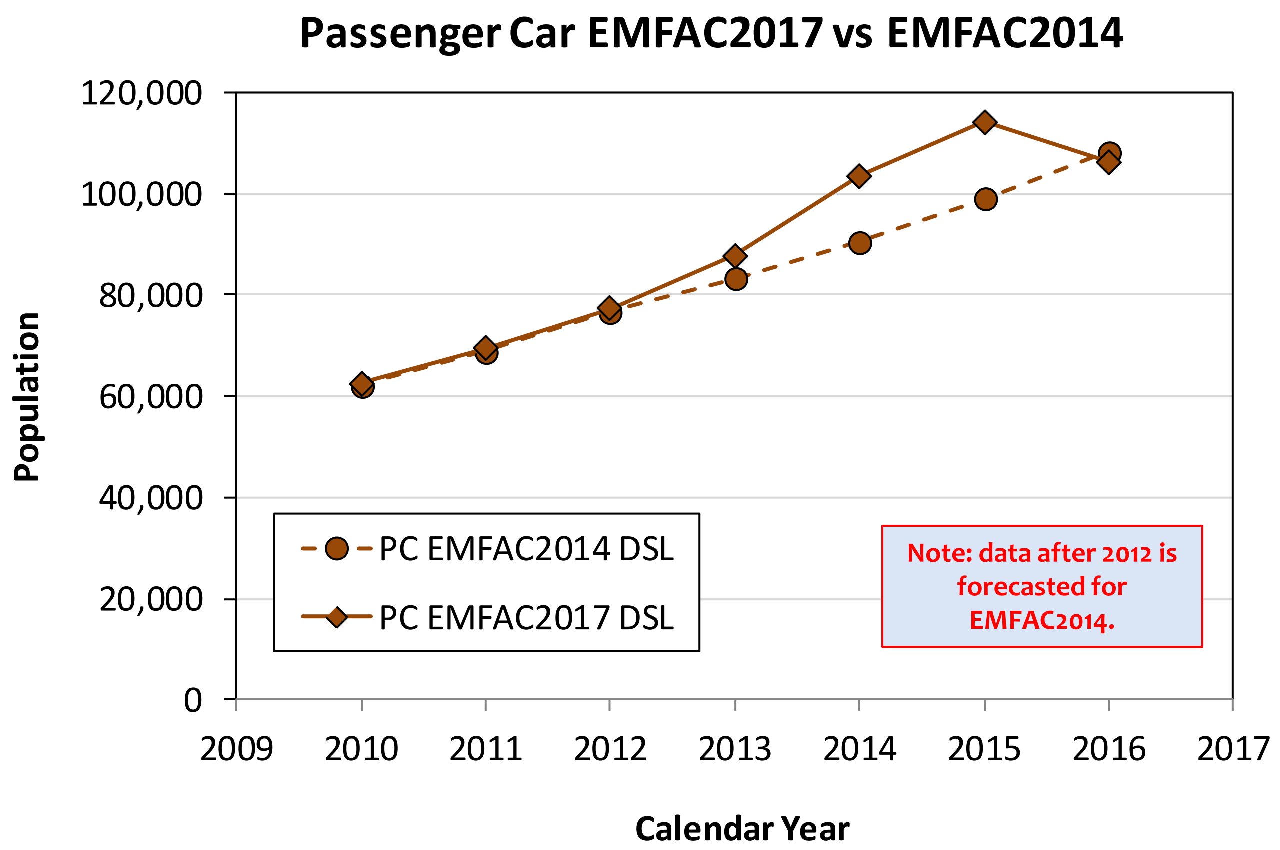
EMFAC2017 Population vs EMFAC2014 Gasoline



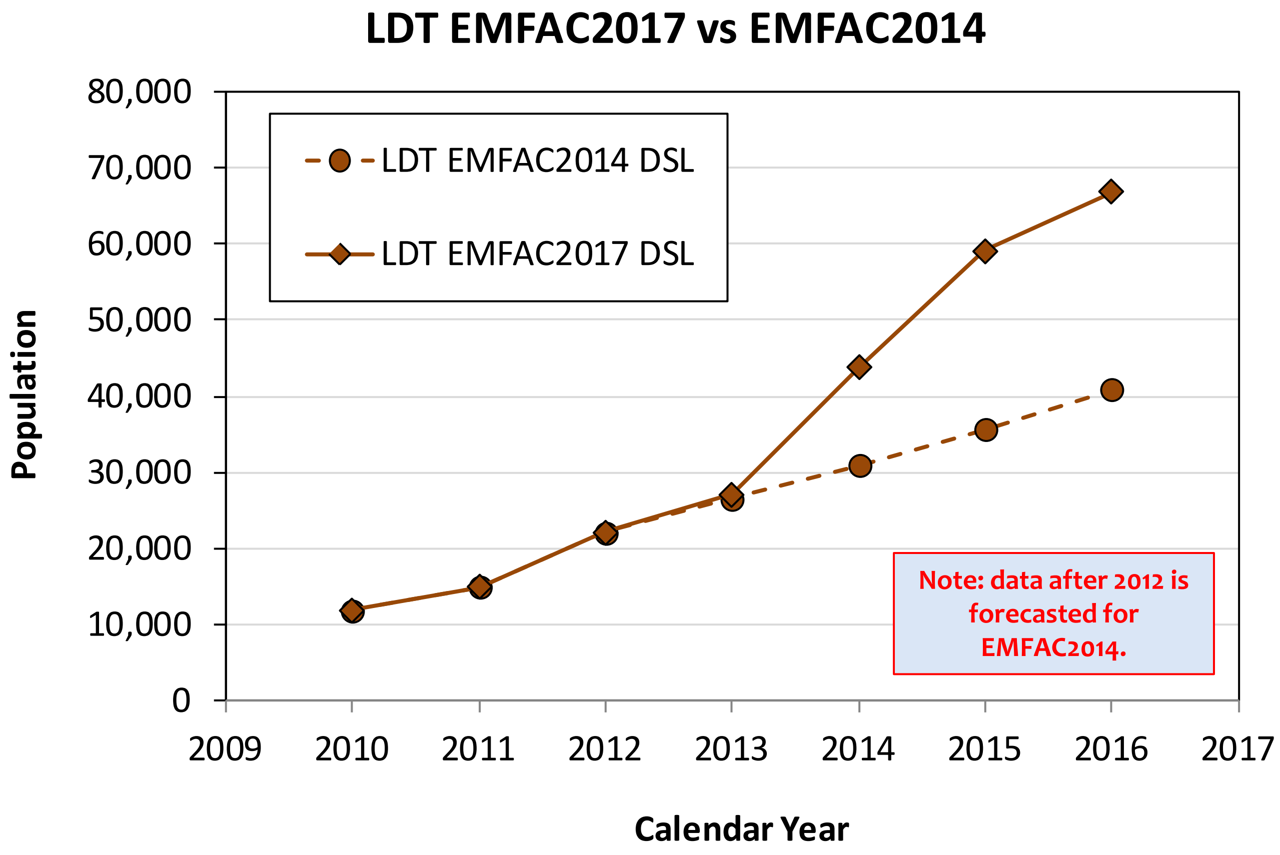
EMFAC2017 Population vs EMFAC2014 Gasoline



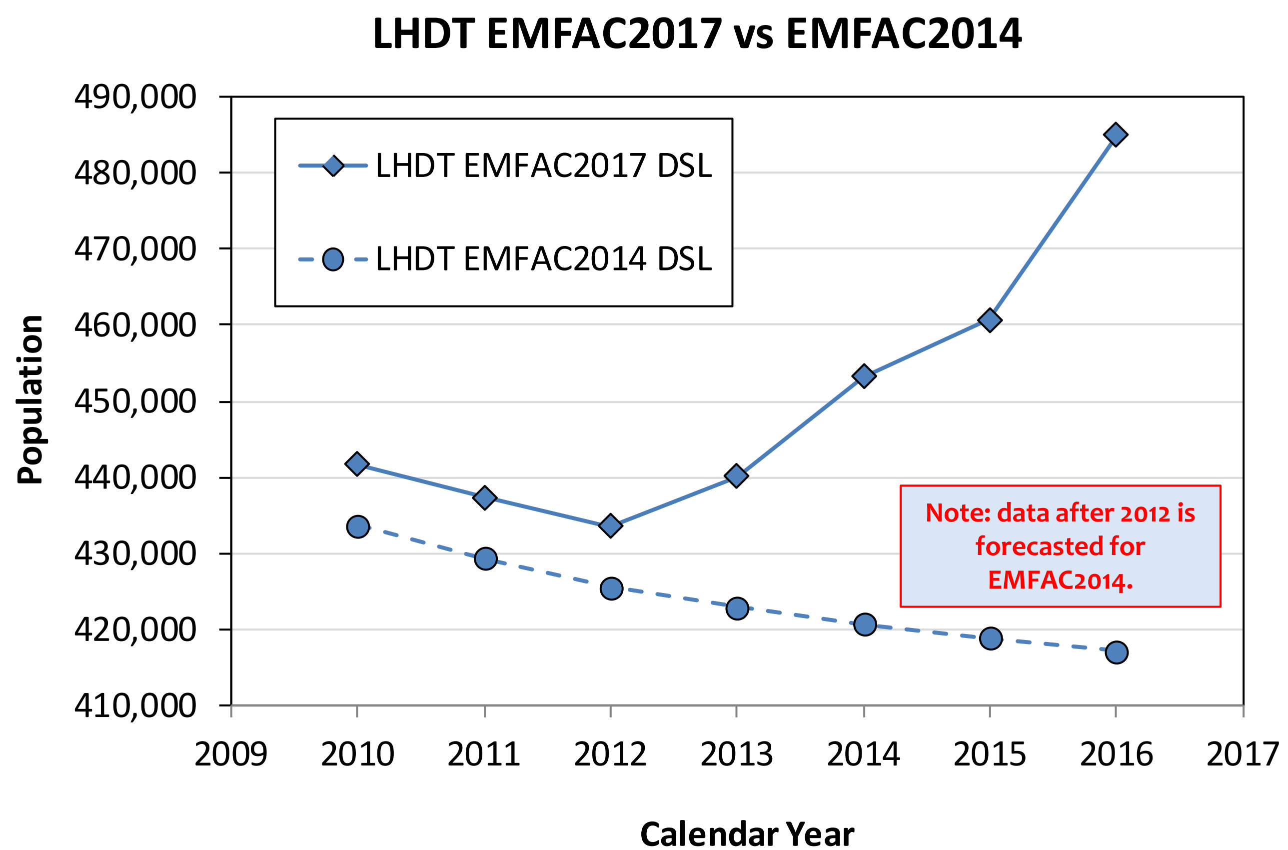
EMFAC2017 Population vs EMFAC2014 Diesel



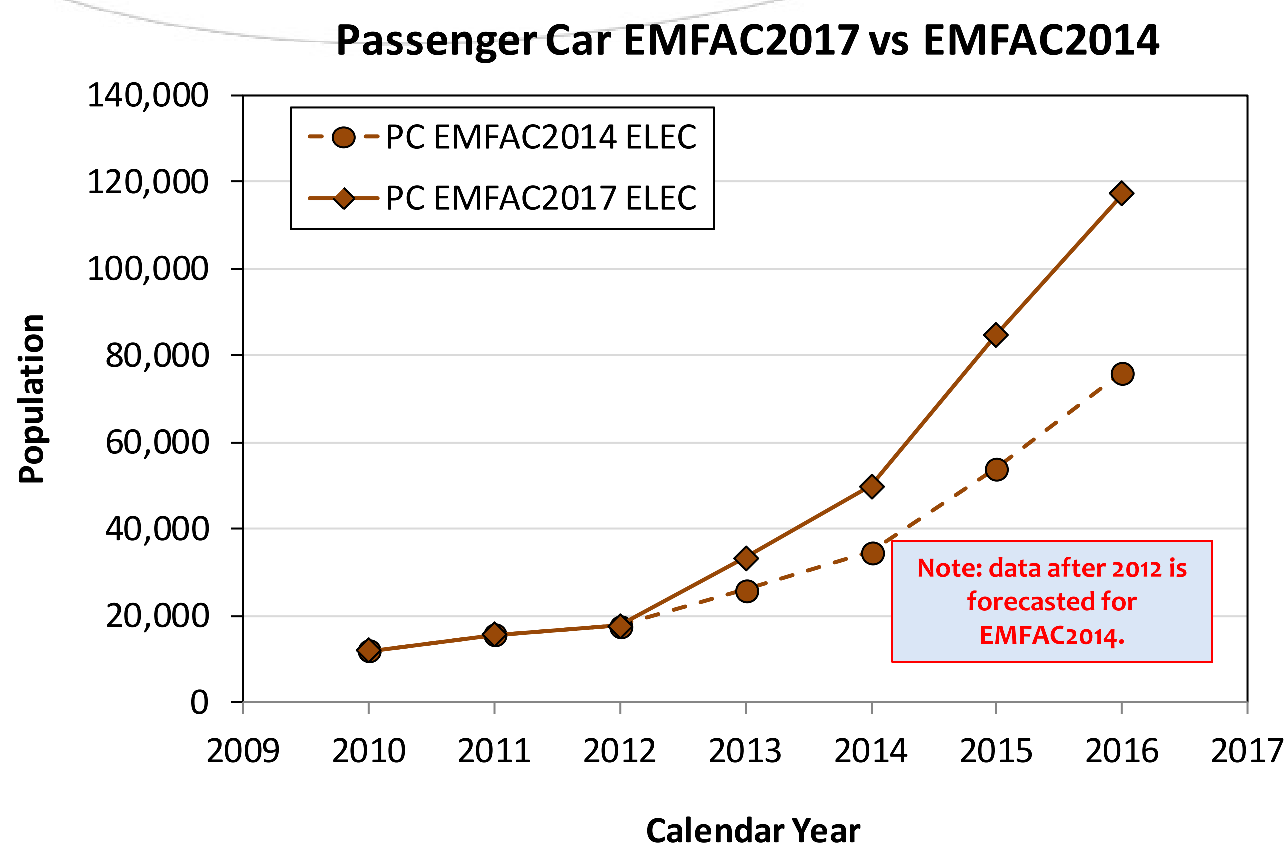
EMFAC2017 Population vs EMFAC2014 Diesel



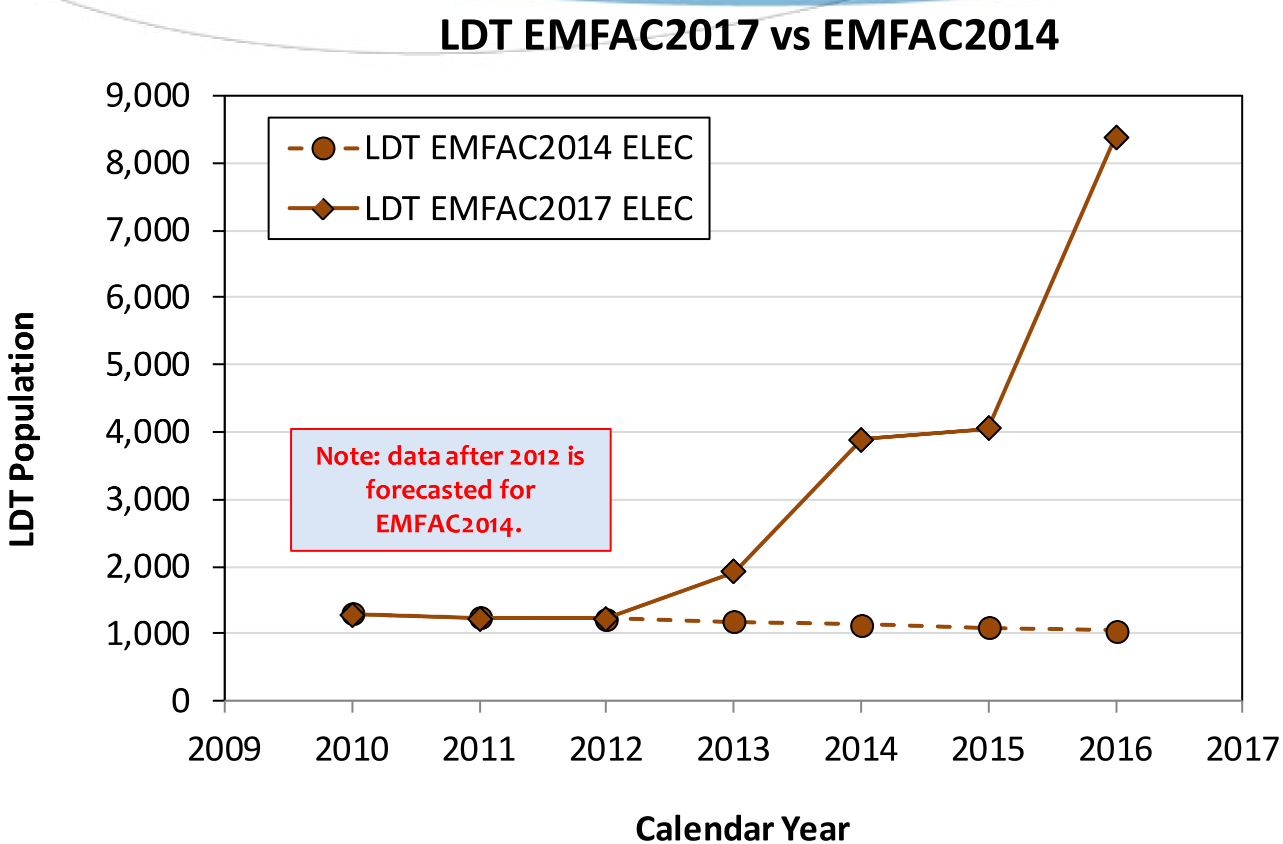
EMFAC2017 Population vs EMFAC2014 Diesel



EMFAC2017 Population vs EMFAC2014 Electric



EMFAC2017 Population vs EMFAC2014 Electric Cont'd



New Sales

- New Sales: Age≤0 in DMV and EMFAC

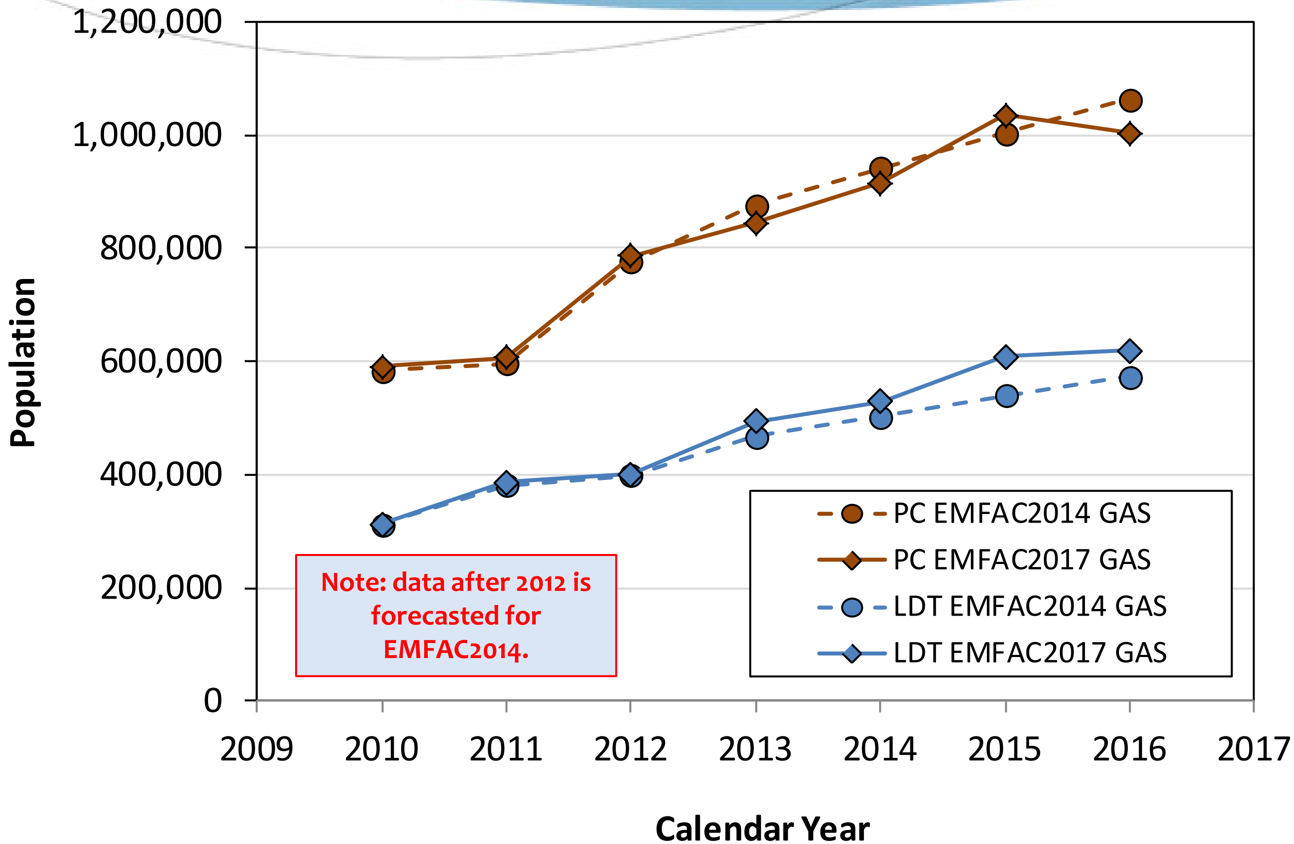
✓ Passenger Cars vs. Light Trucks
  - Light Trucks (≤ 8,500 lbs. GVWR)
  - Not the same definition as in the CAFÉ standards

✓ Light Heavy Duty Trucks (LHDT1 & LHDT2)
  - 8,501 – 14,000 GVWR

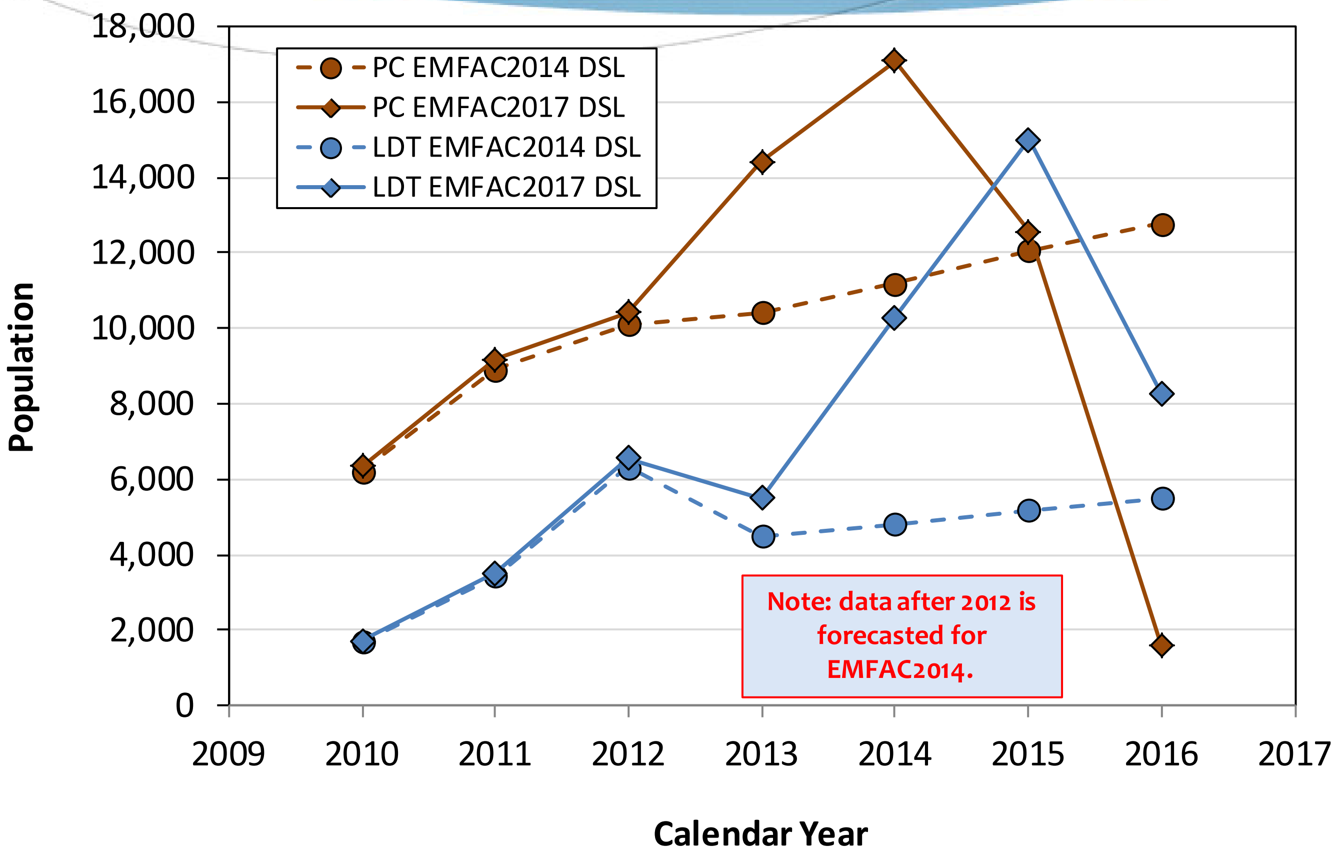
Findings

- EMFAC2014 gasoline PC and LDT new vehicle sales consistent with EMFAC2017
- Lower PC and LDT Diesel sales in 2016 as compared to prior years
- Significant increase in the LHDT sales in 2016 as compared to prior years
- No significant change in the counts of light duty vehicles by model year is observed.

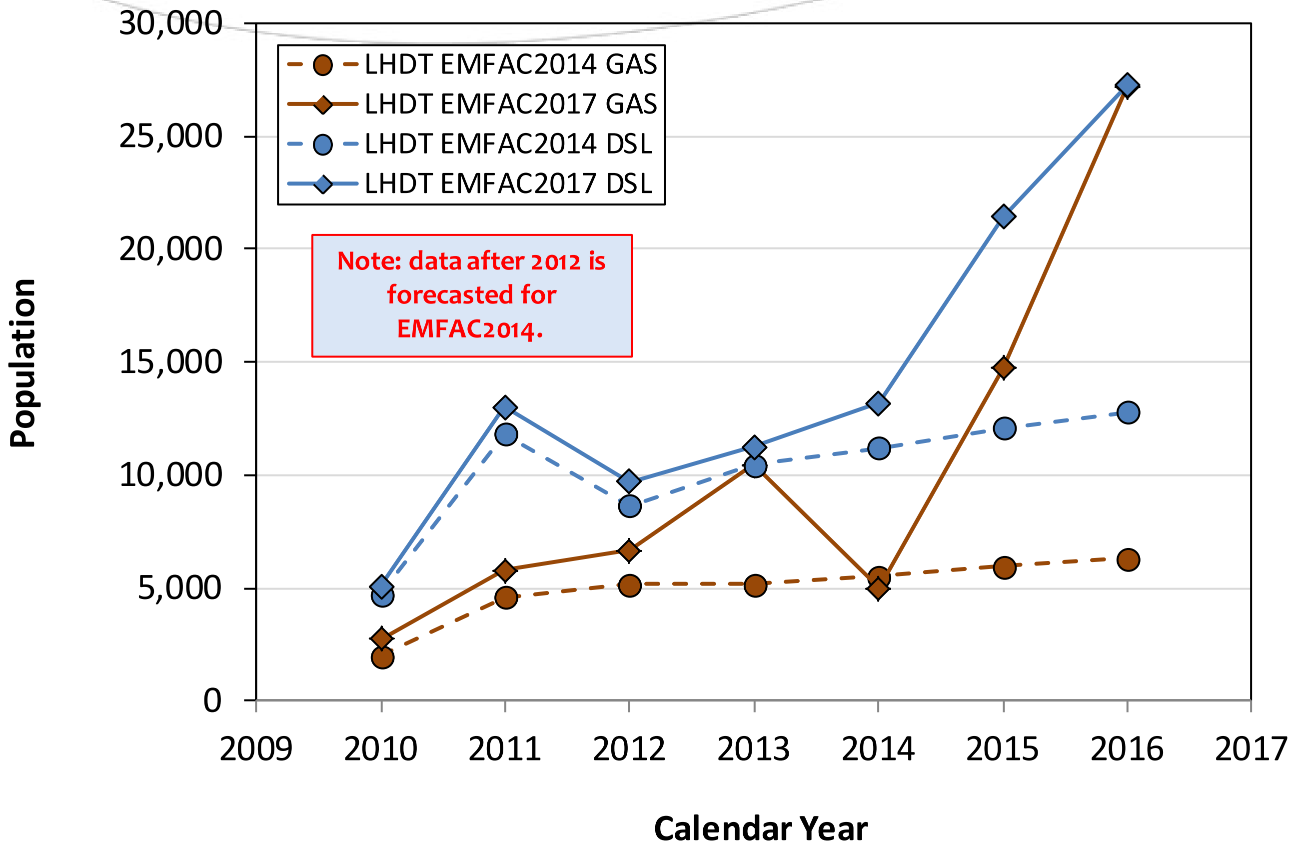
New Sales – Light Duty Vehicles Gasoline Only



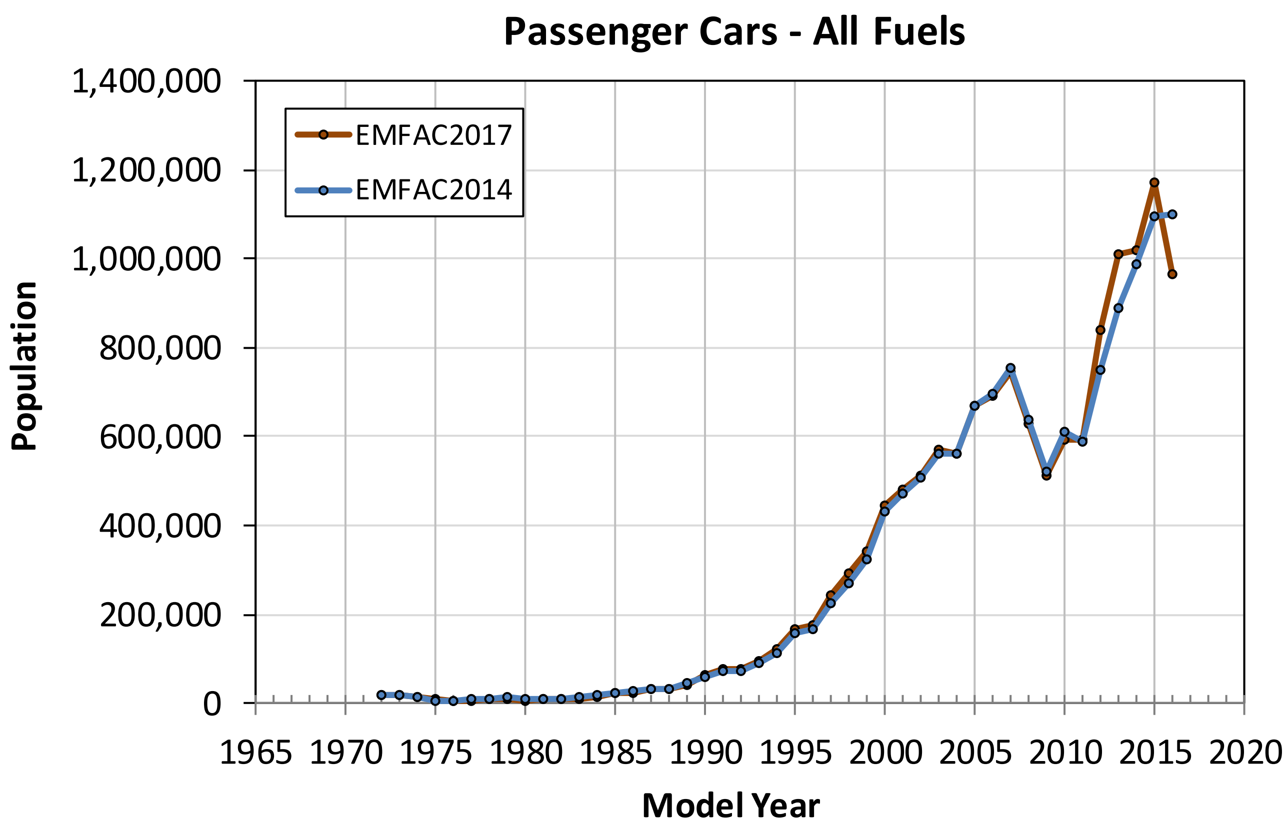
New Sales – Light Duty Vehicles Diesel Only



New Sales – Light Heavy Duty Trucks Diesel and Gasoline

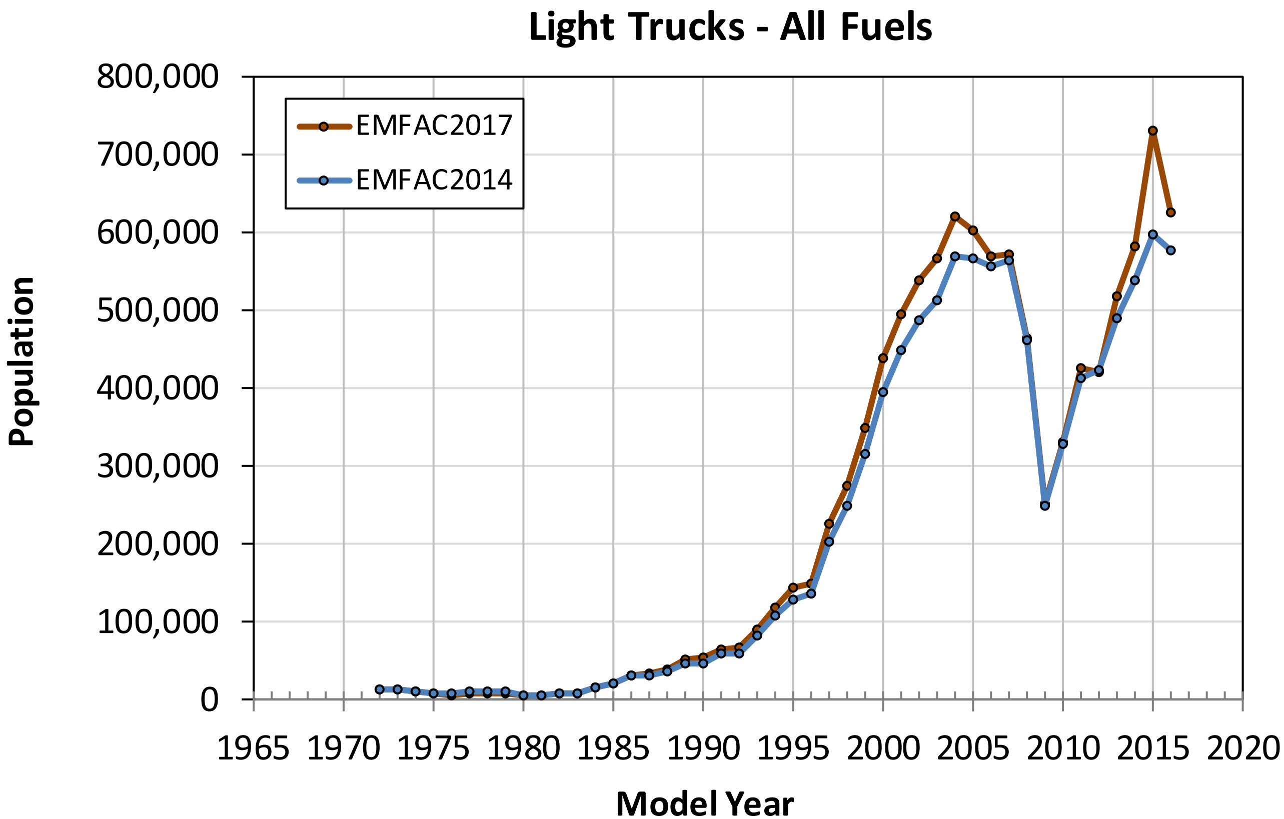


EMFAC2017 Age Distribution (All Fuel Types)



Note: EMFAC2017 age distributions are calculated using DMV2016b registration data.

EMFAC2017 Age Distribution (All Fuel Types)



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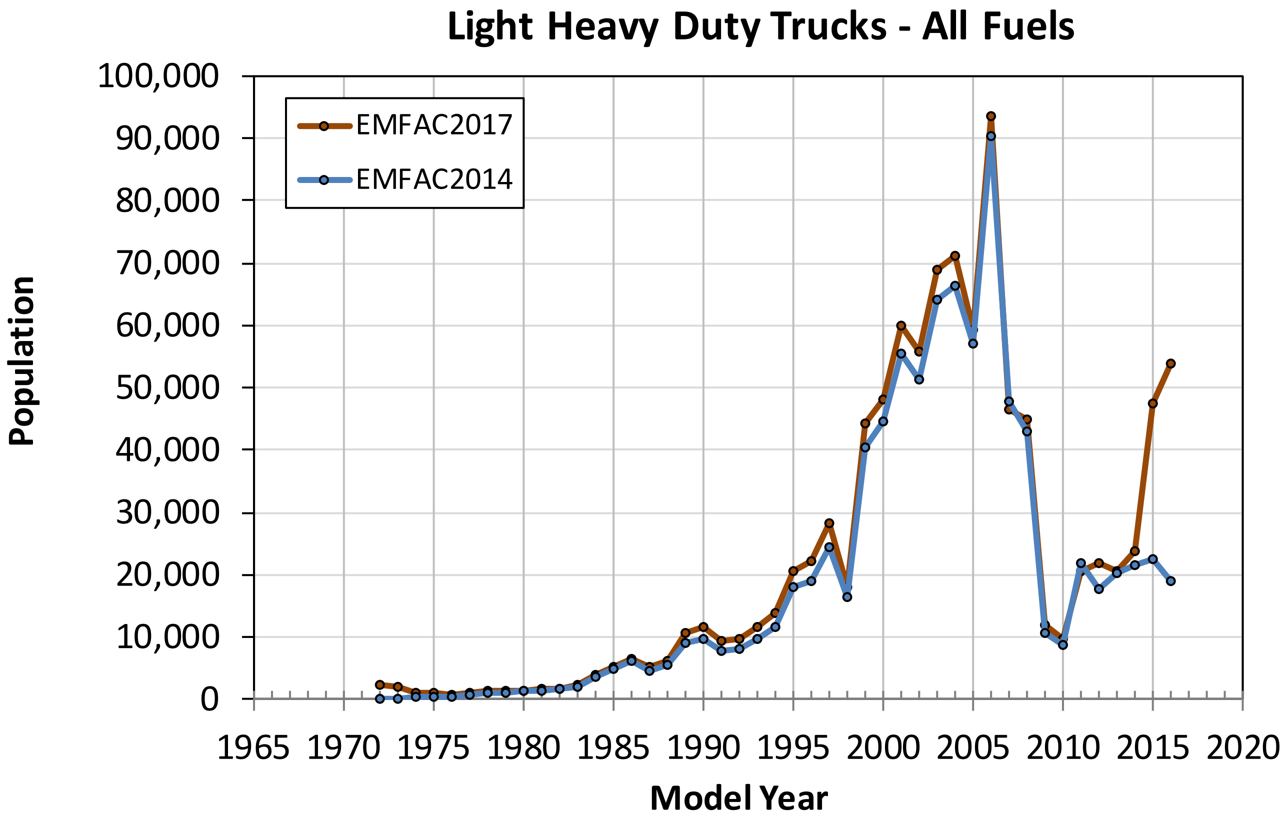
EMFAC2017 Age Distribution (All Fuel Types)



Note: EMFAC2017 age distributions are calculated using DMV2016b registration data.

Lead Staff Contact

Ehsan Hosseini, Ph.D.
Air Pollution Specialist
(626) 459-4318

Seyedehsan.Hosseini@arb.ca.gov

or

EMFAC@arb.ca.gov

Fleet Characterization

Heavy Duty Vehicles

Heavy Duty Population

- Diesel & Natural Gas Trucks and Buses
- Medium-Heavy Duty Trucks (MHD)
  - 14,001 – 33,000 lbs. GVWR
- Heavy-Heavy Duty Trucks (HHD)
  - Above 33,000 lbs. GVWR
- School Buses
- Transit Buses
- Other Buses (e.g., Motor Coach)

Major Data Sources

Data Sources include:

- Processed DMV data
- International Registration Plan (IRP)
- TRUCRS data for diesel Truck and Bus Rule
- List of VINs from Major Ports
- List of VINs from California Highway Patrol (CHP) School Bus Inspections
- National Transit Database (NTD) data

New for EMFAC2017

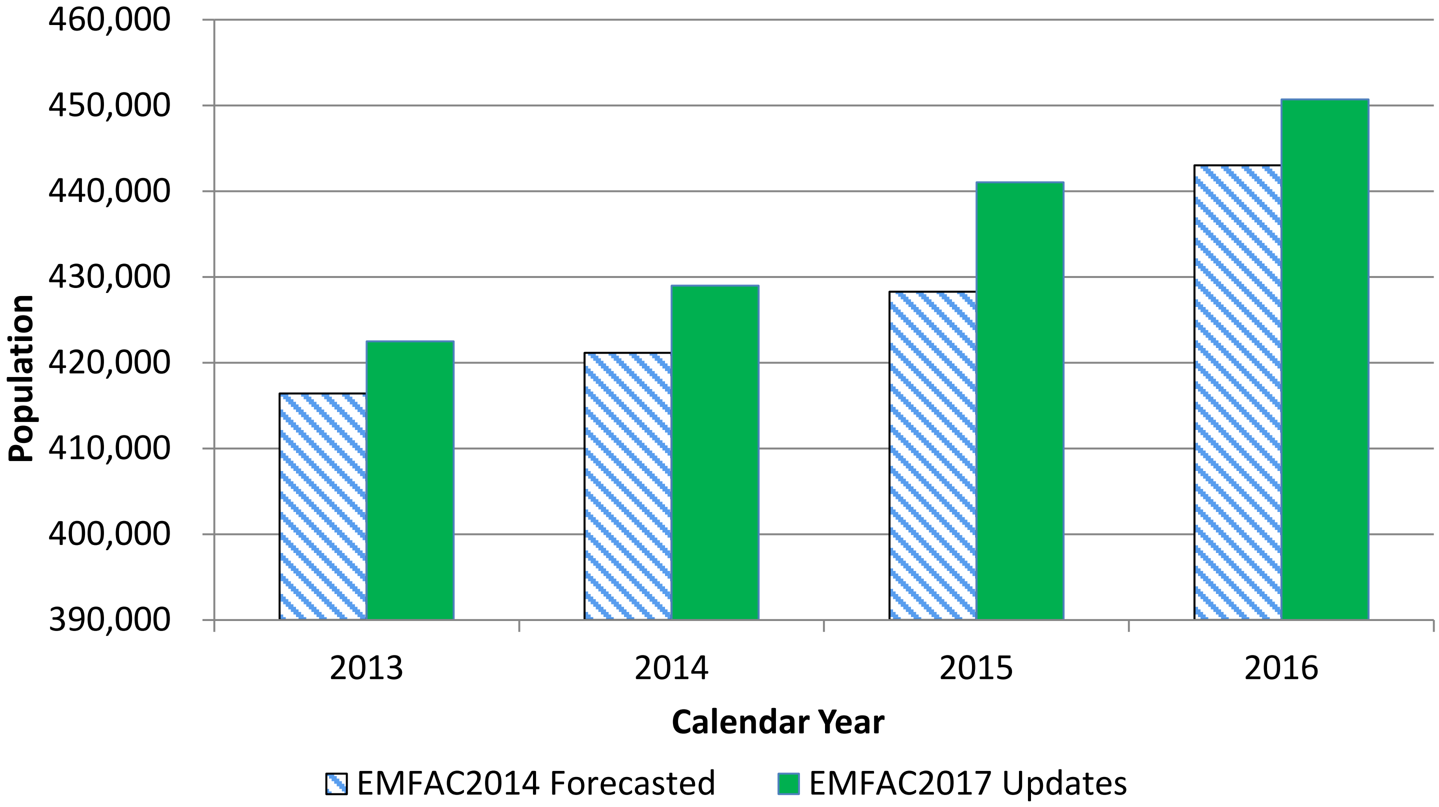
- **Port Trucks**: The major ports have provided VIN lists of vehicles actually visiting ports to flag as port trucks
- **Transit Buses**: New Transit Bus Module was developed using NTD data
- **School Buses**: School Bus counts were updated using CHP inspection lists and ARB Survey data

Major Findings

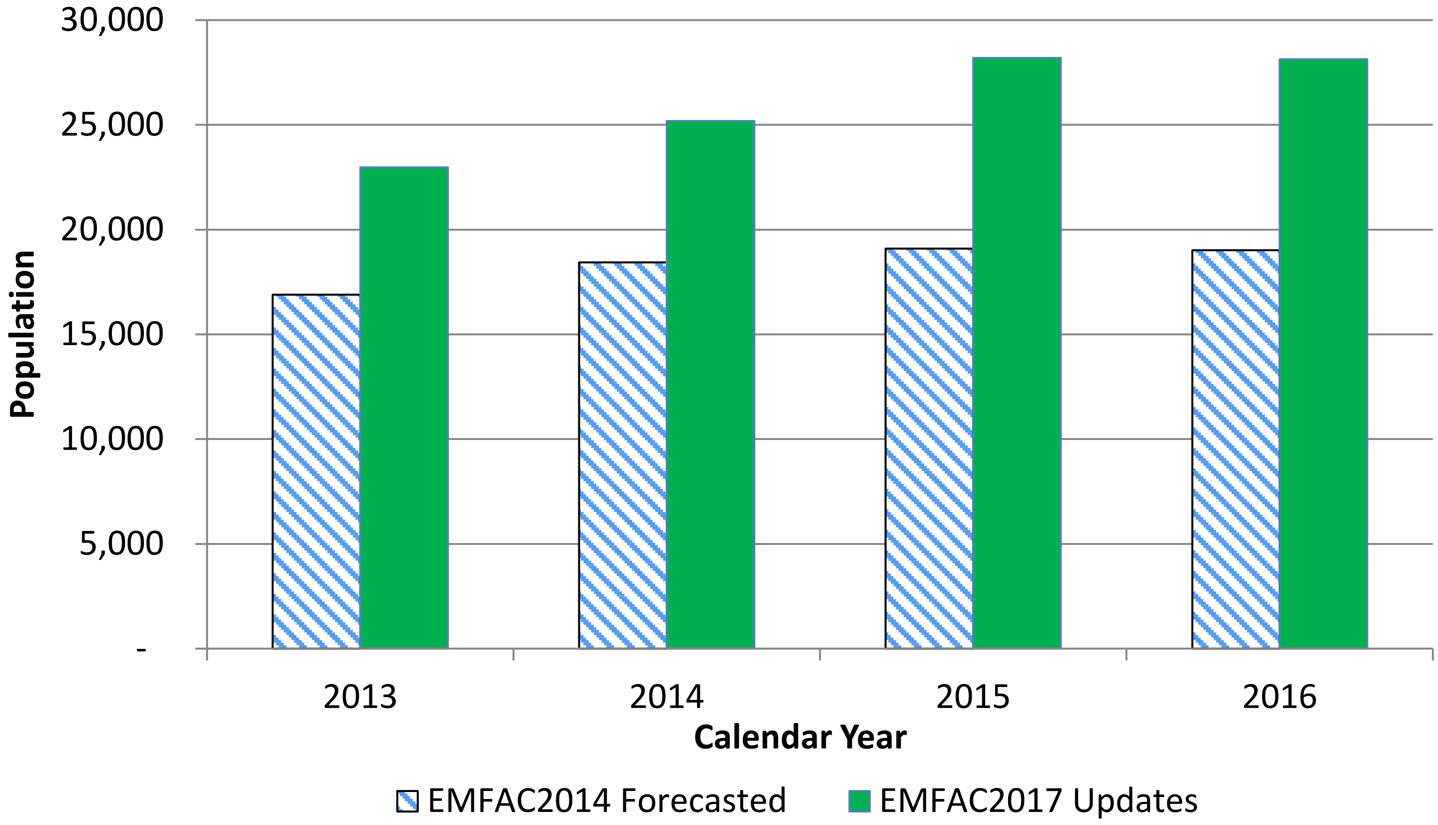
- Higher population of heavy duty vehicles than projected by EMFAC2014 for calendar years 2013 – 2016
- Increased Penetration of 2010+ MY Engine Heavy-Heavy Duty Trucks
  - ❑ More than 30% of in-state trucks (>33,000 lbs. GVWR) are 2010 or newer (engine model year)
- Higher population for school buses and lower population for transit buses as compared to EMFAC2014

In-state Trucks

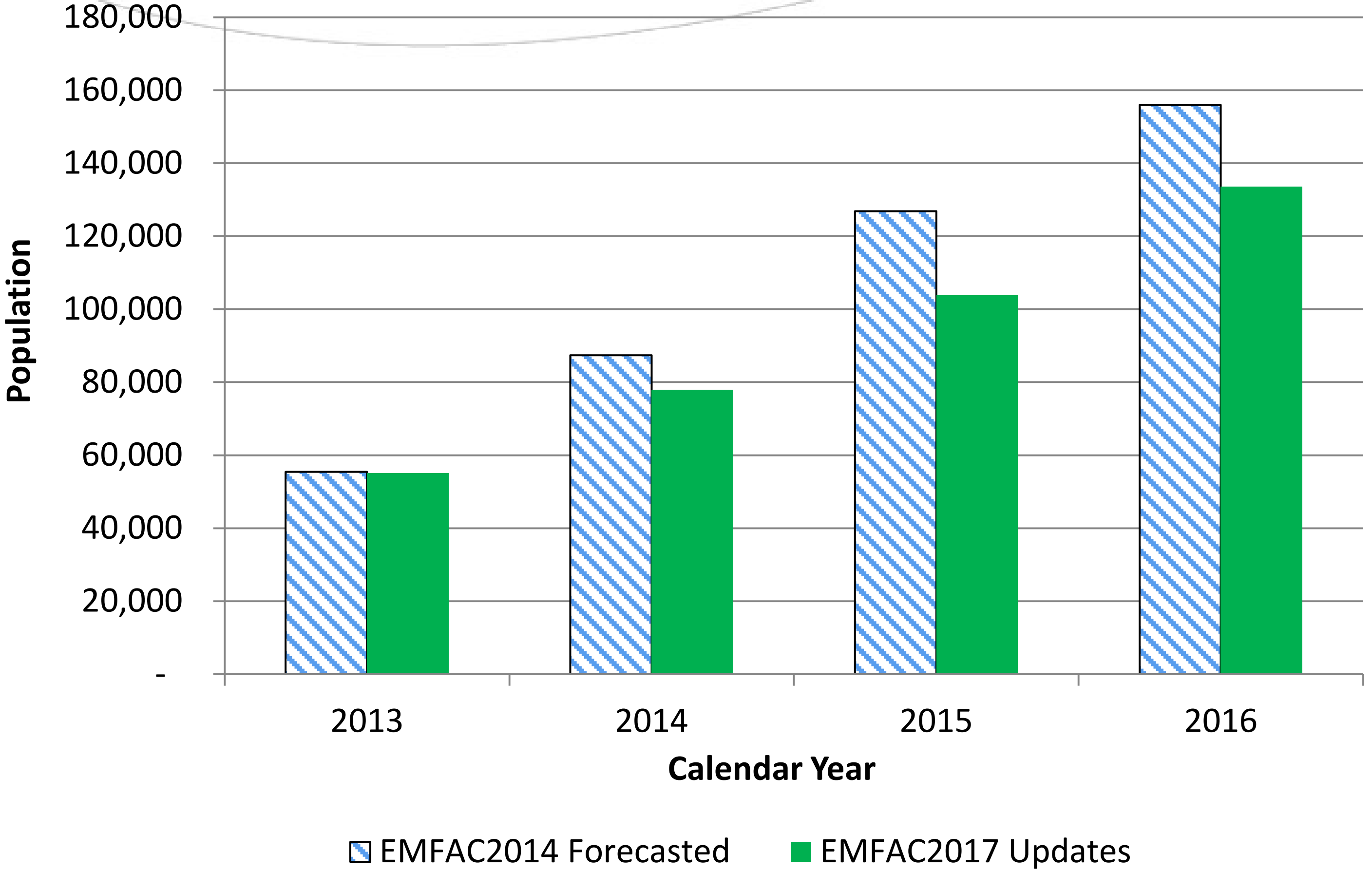
Heavy Duty In-state Trucks



New Sales for In-state Trucks



In-state Trucks MY2011 & Newer

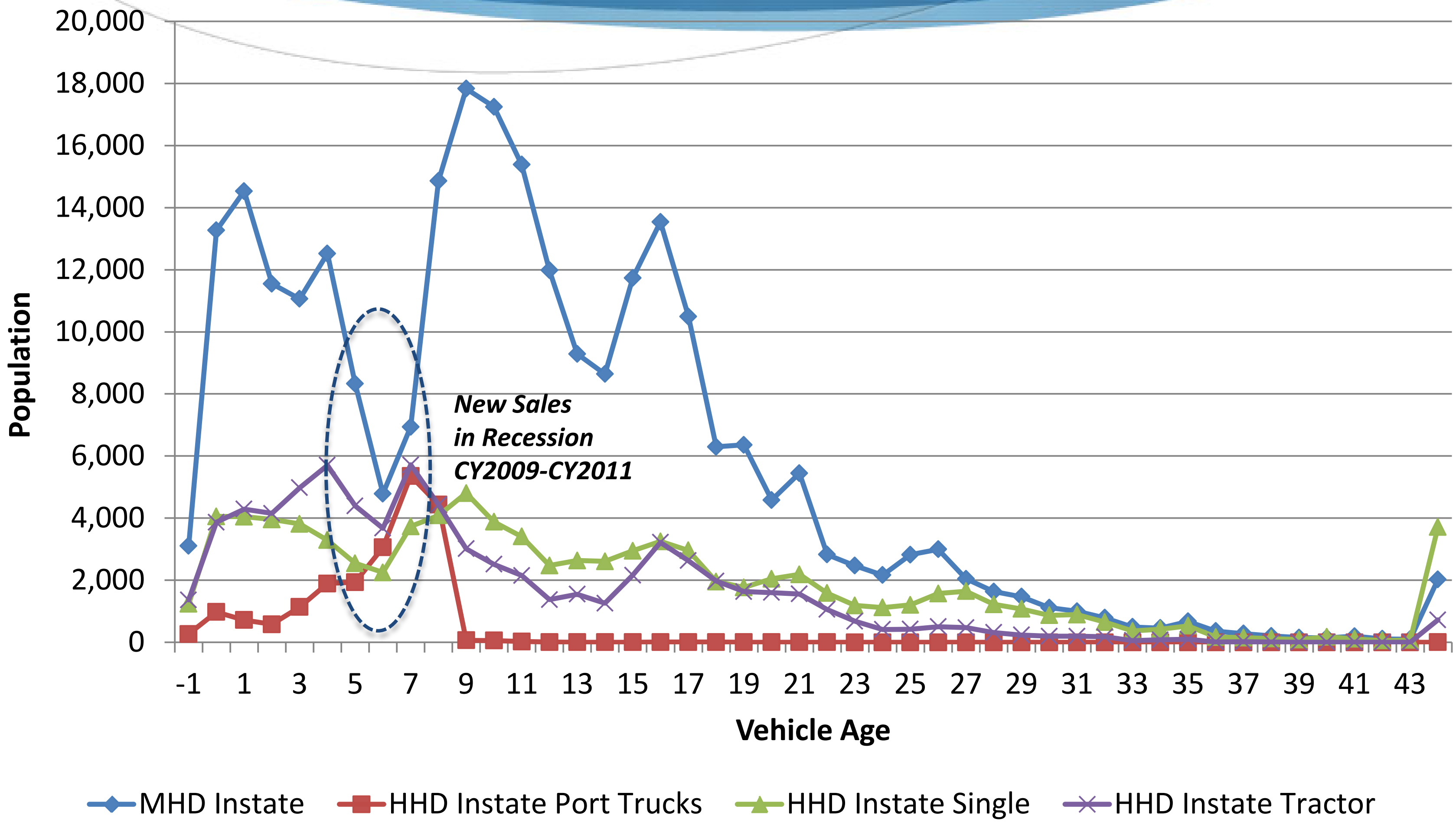


Average Ages of In-state Trucks

- Port Trucks & Instate Non-Tractors are a bit older in the new base year of 2016
  - MY2007 or newer engines by 1/1/2014 to meet drayage rule requirements
  - New vehicle sales decreased during recessionary years
- HHD Tractors are newer in New Base Year=2016
  - Truck and Bus rule requires PM filters and MY2010 engine replacement vehicles from CY2012 to CY2023
- All MHD & HHD trucks have to meet MY2010 engine requirement by January 1, 2023

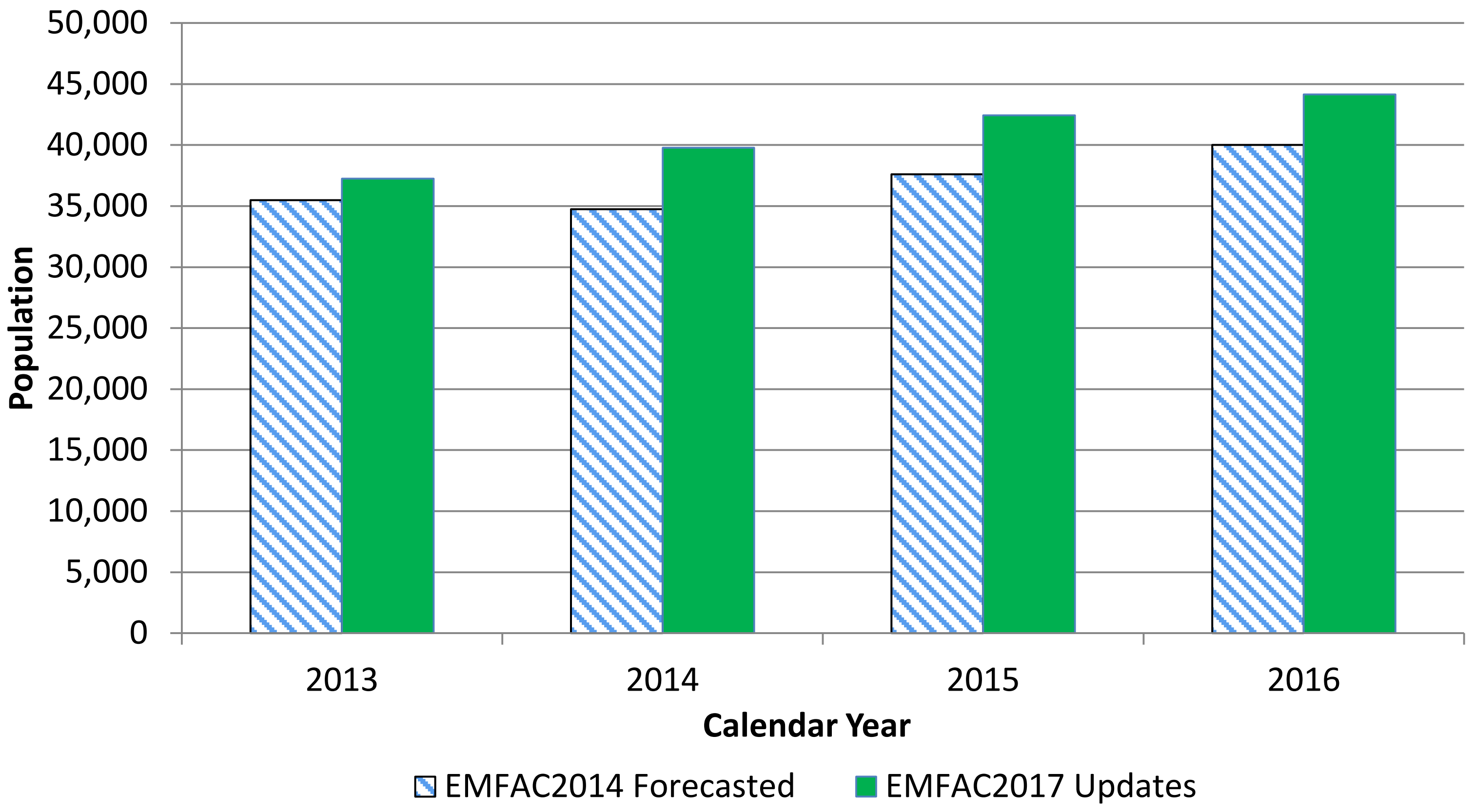
Fleet Group	CY2012* Average Age	CY2016** Average Age
HHD Instate Port Trucks	4.8	5.6
HHD Instate Tractor	12.1	9.6
MHD Instate	10.8	11.3
HHD Instate Single	13.6	13.9
* Base Year for EMFAC2014		
** Base Year for EMFAC2017		

CY2016 Age Distribution for Instate Trucks



Inter-state Trucks

Heavy Duty CA IRP Trucks

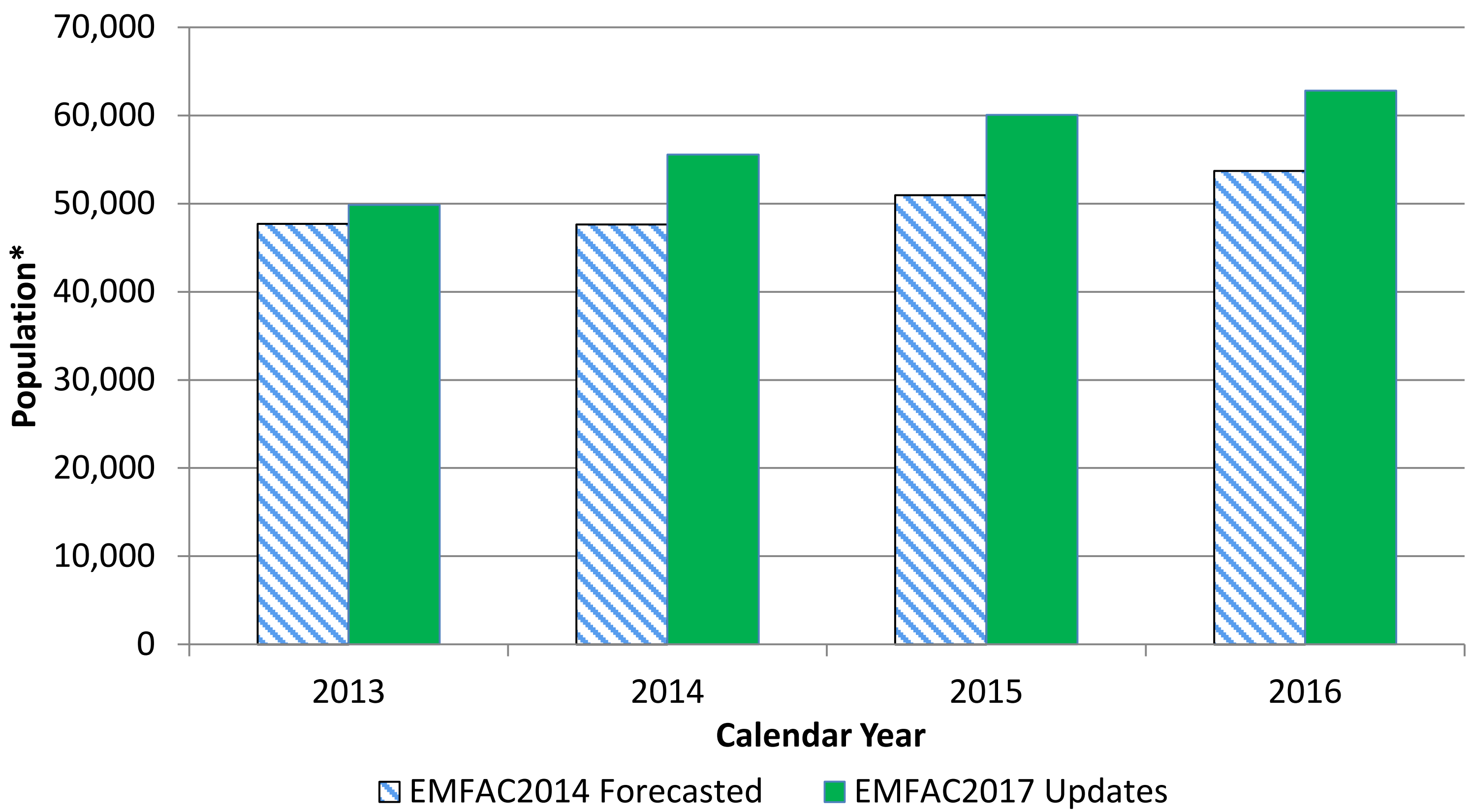


Average Ages of CA IRP Trucks

- MHD & HHD Tractors are newer in New Base Year=2016

Fleet Group	CY2012* Average Age	CY2016** Average Age
MHD CA IRP	7.1	6.8
HHD CA IRP	7.5	5.7
* Base Year for EMFAC2014		
** Base Year for EMFAC2017		

Heavy Duty Out-of-State Trucks



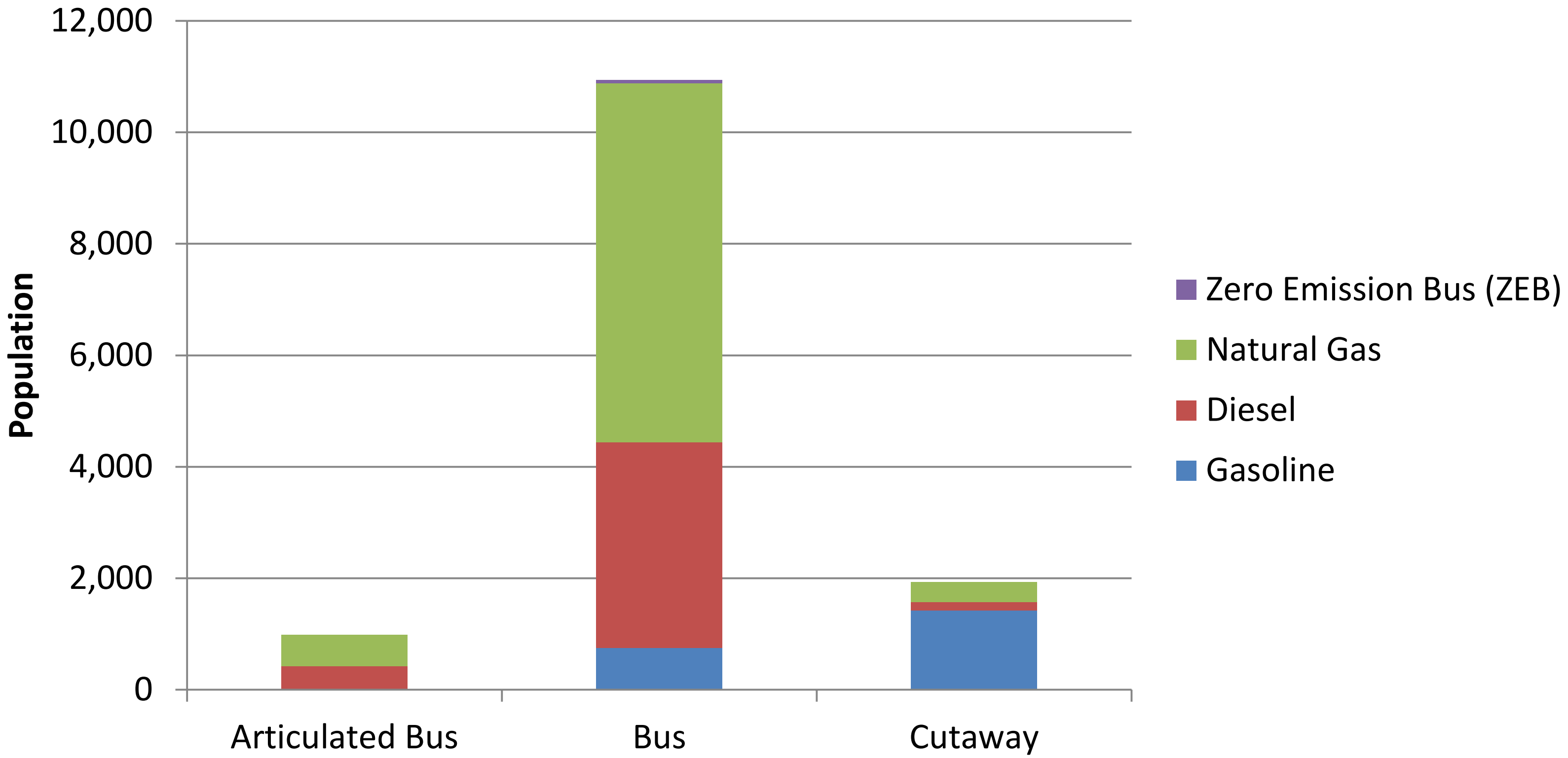
*Population of out-of-state trucks operating in California on a typical weekday

Buses

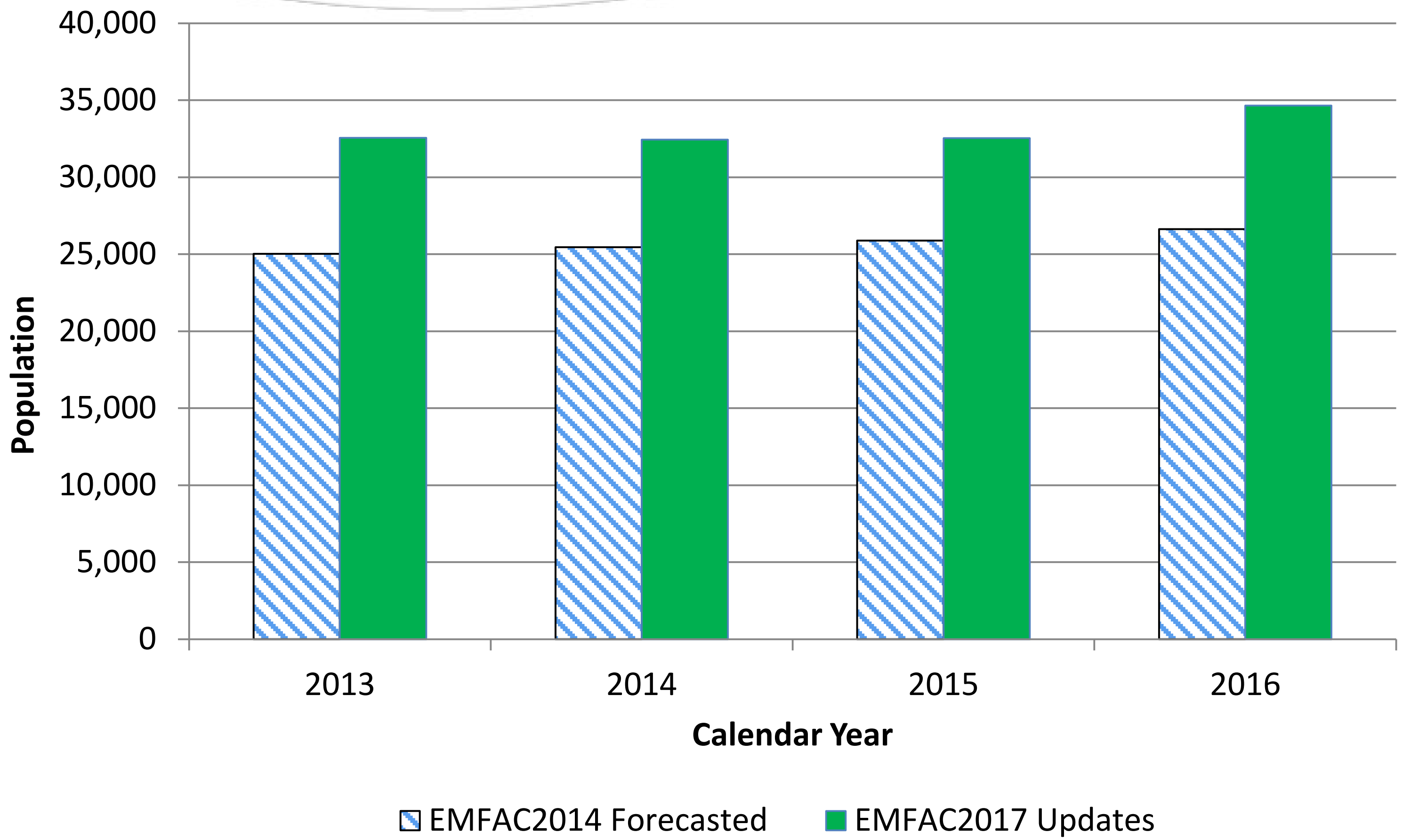
New Transit Bus Module

- Data Source = National Transit Database (NTD) https://www.transit.dot.gov/ntd
  - Provides California Transit Data for CY2000 – CY2015
    - All transit agencies receiving or benefit from federal §5307 or §5311 grants are required to report data to NTD
    - Provides fleet inventory data delineated by vehicle type, service mode, manufacturer, model, seating capacity, etc.
    - Consistent with EMFAC classification: school bus, motor coach and all other buses categories are excluded
    - CY2015 used as base year for forecasting future population

CY2015 Base Year Transit Bus Inventory



Update CHP School Bus Lists



Truck and Bus Rule

- Enforcement analysis indicated 25 to 30% of diesel trucks in California may not be in compliance with Truck and Bus Rule
- SB1 will tie DMV registration to Truck and Bus Rule Compliance by CY2020
- Staff are working to update Truck and Bus Compliance Assumptions in EMFAC2017

(In Progress)

Lead Staff Contact

Sherrie Sala-Moore
Air Resources Engineer
(916) 322 0343
sherrie.sala-moore@arb.ca.gov

or

EMFAC@arb.ca.gov

Emission Rates

Light Duty Vehicles

EMFAC LD Exhaust Emissions

EMFAC assumes two operational modes: stabilized running mode and starts mode

- Stabilized running mode
  - Engine and catalyst at normal operating temperatures
  - Varies by speed, temperature, humidity, AC on/off
- Starts mode
  - Occurs in the time period immediately after ignition
  - Varies by the "soak" length (the time in which the vehicle has been sitting) and by temperature

Running Emissions = RUNEX (g/mi) * VMT(mi)

Starts Emissions = STREX (g/start) * Trips (starts/day)

Major Update to EMFAC

EMFAC no longer estimates Inspection and Maintenance (I/M) benefits

- Previously, the CALIMFAC module calculated with-I/M emission rates by simulating I/M on top of no-I/M emission rates
- No-I/M emission rates are no longer available.

All Vehicles subject to smog check program, so I/M benefits implicit

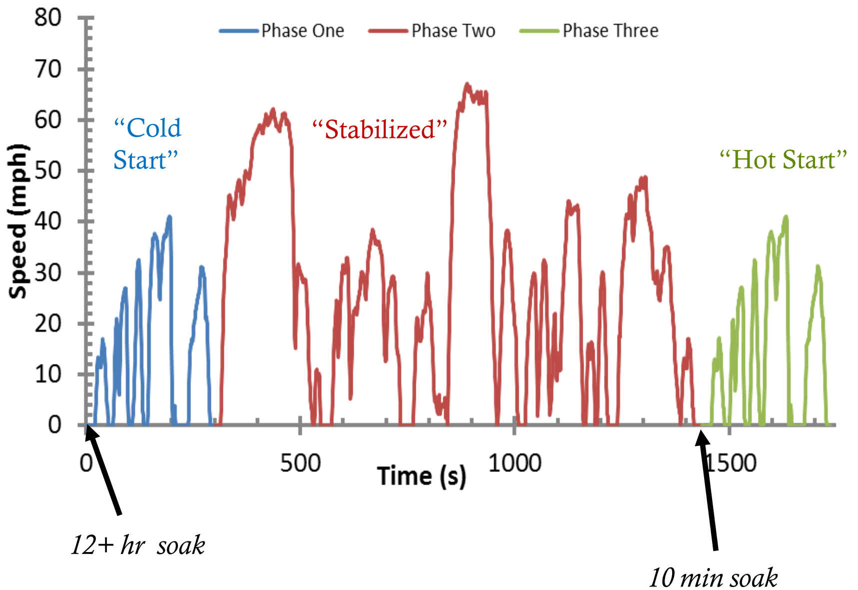
EMFAC LD emission rates now empirical

- Developed from chassis dynamometer testing of LD vehicles

Light-Duty Emission Rates in EMFAC

Light-duty vehicle exhaust emissions computed using base emission rates (BERs) from the California Unified Cycle (UC)

- HC, NOx, PM, CO, GHGs, and other pollutants



EMFAC2014	UC Phase 1 (UC_{P1}): "starts emissions" UC Phase 2 (UC_{P2}): "running emissions" UC Phase 3 (UC_{P3}): not used

UC_{P1} Duration: 1.2 mi, 300 s
UC_{P2} Duration: 8.6 mi, 1135 s
UC_{P3} Duration: 1.2 mi, 300 s

EMFAC2014 ⇒ EMFAC2017

New odometer dependent UC_{P1}, UC_{P2}, and UC_{P3} BERs have been developed

- For Low Emission Vehicle I (LEV1), **LEVII**, and LEVIII vehicles
- For **HCs**, **NOx**, CO
- New Data Sources
  - Manufacturer In-Use Verification Program (IUVP)
  - CARB's Vehicle Surveillance Program (VSP)
- Deterioration Modeling: 3-tier emission regime approach replaces EMFAC2014's 5-tier approach

A new method for computing cold start emission rates

- $UC_{P1\text{-}300s}$ – $UC_{P3\text{-}300s}$ replaces $UC_{P1\text{-}100s}$

Revised soak correction factor curves developed to model warm starts

3-Takeaways

(1) HC and NOx running exhaust emission rates are well below EMFAC2014 estimates

*Deterioration almost negligible for LEVII LEVs and LEVII ULEVs

(2) HC and NOx starts exhaust emission rates are well above EMFAC2014 estimates for LEVII ULEVs and SULEVs

*HCs: LEVII ULEVs: 3.6x, LEVII SULEVs: 5.5x

*NOx: LEVII ULEVs: 3.1x, LEVII SULEVs: 10.6x

(3) NOx Starts emissions are more dependent on soak time than assumed in prior EMFAC versions

*Higher when preceded by soaks > 30 min

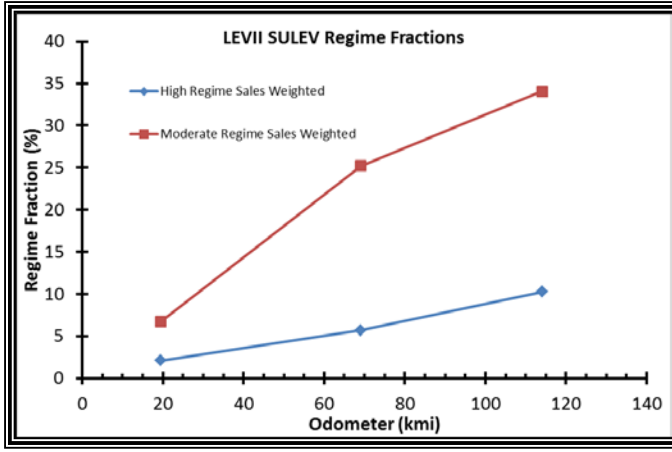
*Lower when preceded by soaks < 30 min

Development of New UC BERs

IUVP

- Data collected from 1000s of **FTP-75** tested in-use vehicles
- Test results sorted by vehicle certification standard (LEV1 ULEV, etc.) and odometer
- Composite **FTP-75** ERs used to further segregate vehicles into **3 Emission Regimes bins**
- Bin counts weighted using California vehicle sales data
  - Weighted counts used to develop **Regime Fraction (RF) equations**

Emission Regime	Range	MIL Status
Normal	0 to 1.0 x Std.	No MIL
Moderate	1.0 to 2.0 x Std.	No MIL
High	> 2.0x Std.	



VSP

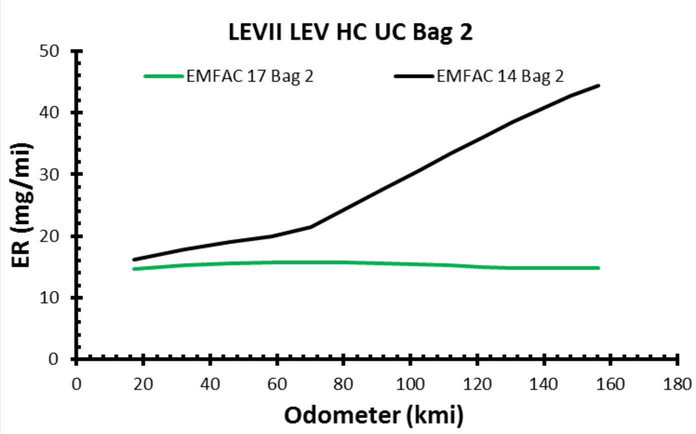
- Data collected from hundreds of FTP and UC tested in-use vehicles
- Staff sorted test results by vehicle certification standard
- Composite **FTP-75** ERs used to further split vehicles into 3 Emission Regimes bins
- Average $\mathbf{UC_{P1}}$, $\mathbf{UC_{P2}}$, $\mathbf{UC_{P3}}$ ERs computed for each regime
- RFs, versus odometer, coupled with regime emission rates to derive odometer dependent BERs

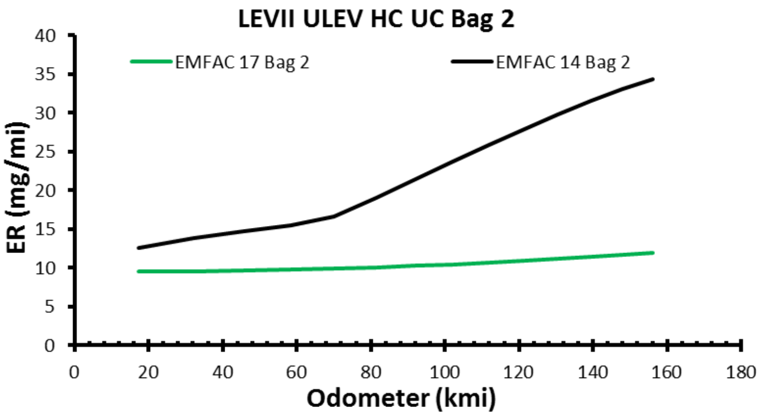
$$BER(odo) = RF_{Normal}(odo)*ER_{Normal} + RF_{Moderate}(odo)*ER_{Moderate} + RF_{High}(odo)*ER_{High}$$

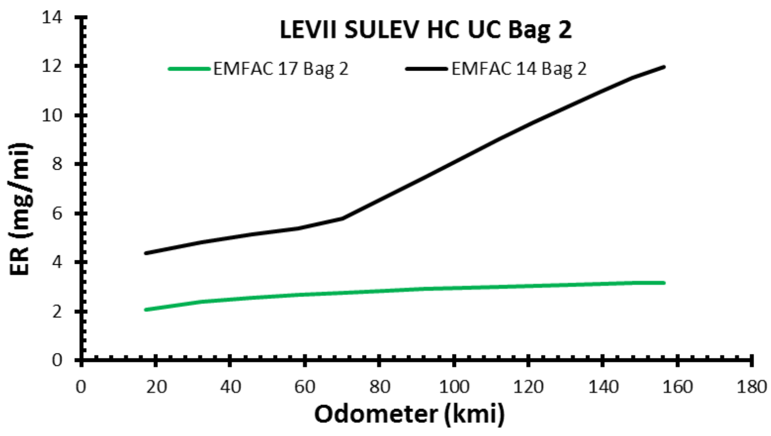
Running Exhaust Emission Rates

HC Running Exhaust ERs

HC Running Exhaust ER = HC UC$_{P2}$ BER (odo)





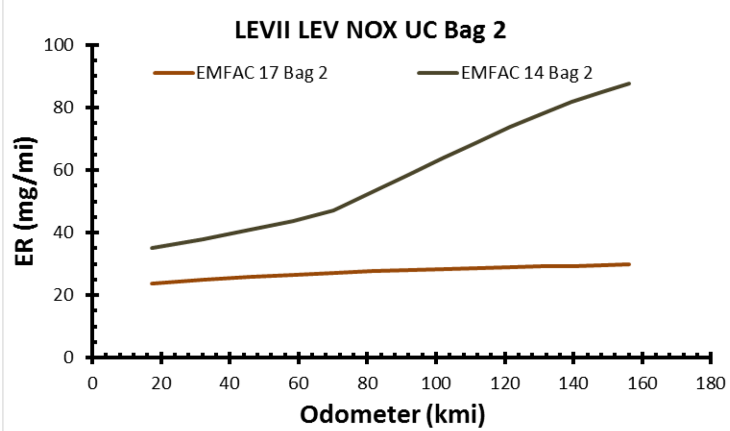


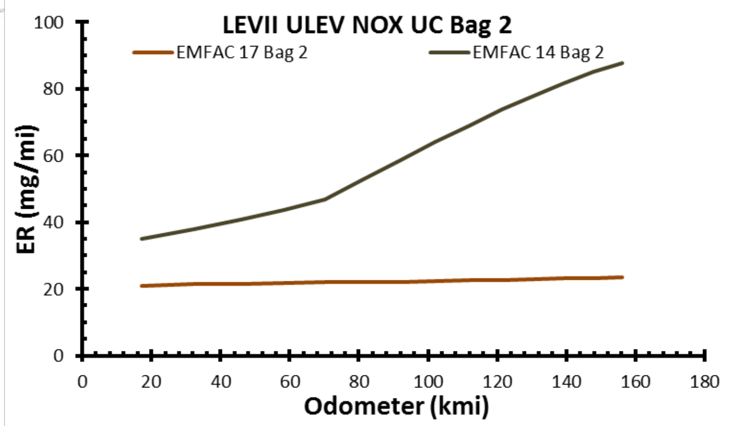
HC UC$_{P2}$ emission levels below previous assumptions

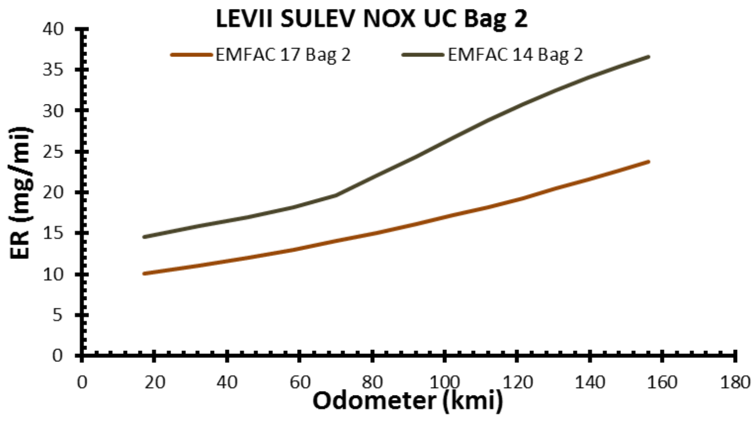
HC UC$_{P2}$ emissions independent of odometer

NOx Running Exhaust BERs

NOx Running Exhaust ER = NOx UC_{P2} BER (odo)







NOx UC_{P2} emissions depend on odometer for SULEVs only

NOx RE emission levels are substantially below previous assumptions

Starts Exhaust Emission Rates

EMFAC2017 LD Starts Exhaust ERs: Three Main Updates

1. EMFAC2017 start emission rates (StERs) updated using new UC BERs from IUVP and VSP data

2. CARB adopted new approach to computing StERs

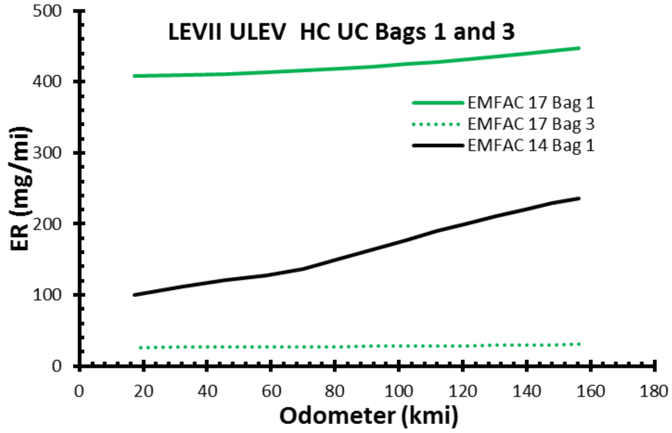
   $\text{Cold StER} = UC_{P1\text{-}100s}$ *replaced by* $\text{Cold StER} = UC_{P1} - UC_{P3}$

3. New warm starts data, from the VSP, used to update EMFAC's Soak Correction Factor Curve equations (SoFs)

   $\text{Warm StER} = \text{Cold StER} * \text{SoF}(t = \text{soak time})$

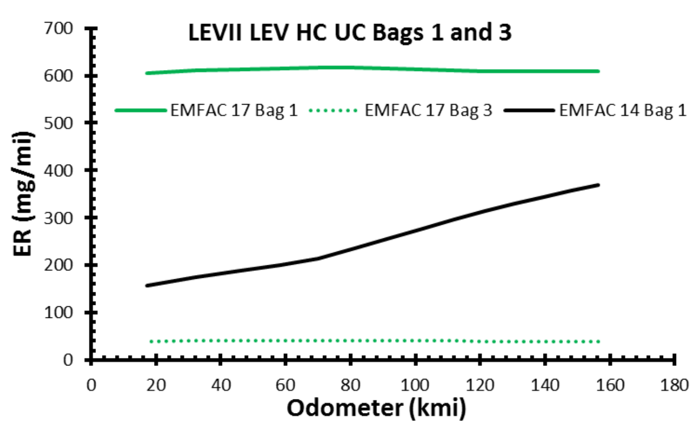
HC: Starts Exhaust BERs

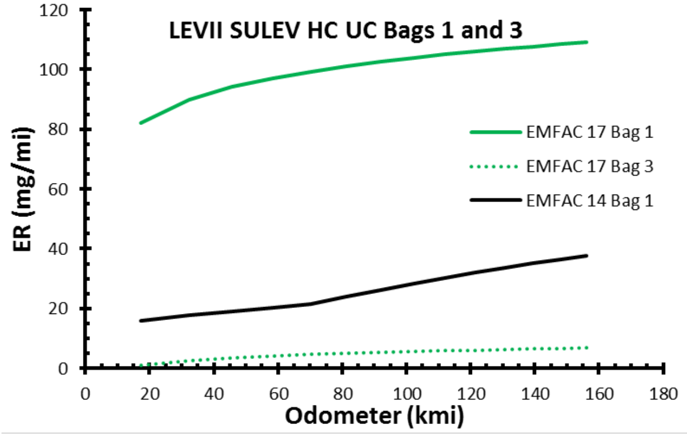
HC emissions in UC_{P1} much higher than anticipated



UC_{P1} HC dominates UC_{P3} HC

HC odometer dependence was not observed in LEVs and ULEVs

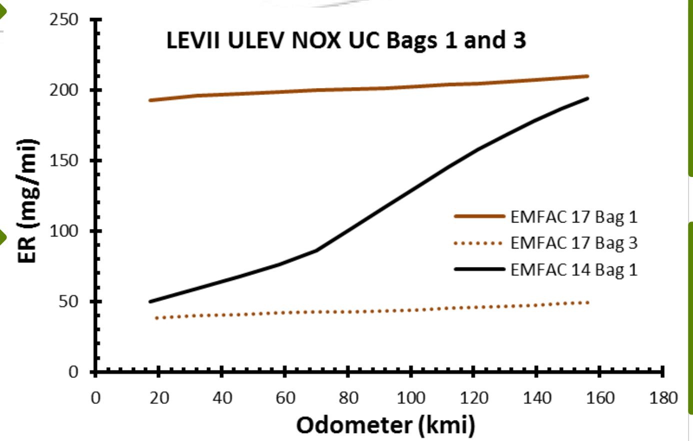




NOx: Starts Exhaust BERs

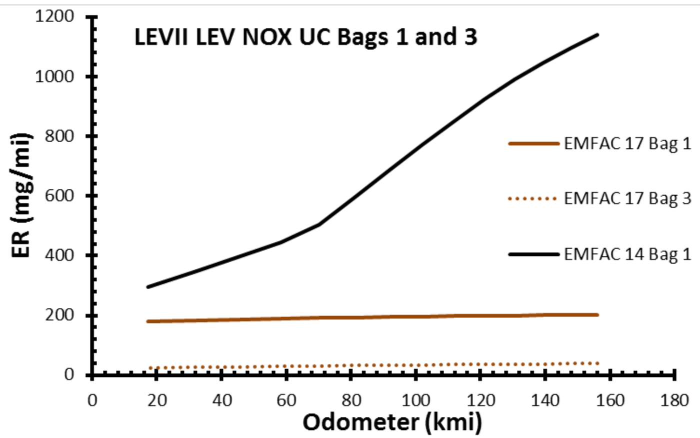
UC_{P1} NOx emissions >> than UC_{P3}

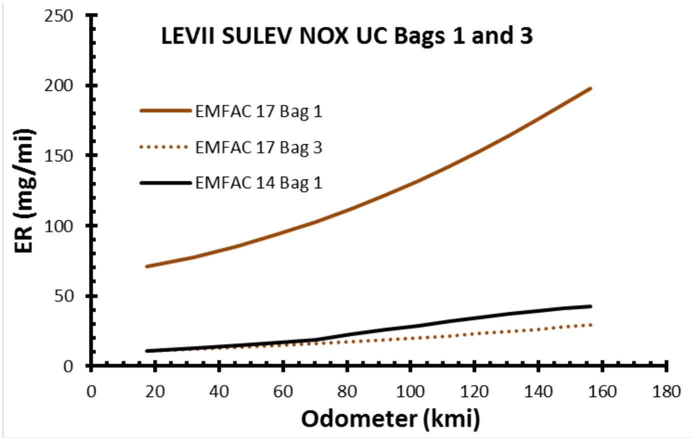
LEVII LEVs emit less NOx in UC_{P1} than assumed in EMFAC2014



LEVII ULEVs emit NOx at the same level as LEVII LEVs (same FTP standard)

LEVII ULEVs and SULEVs emit much more NOx during UC_{P1} than previously assumed.





Starts Method Update

EMFAC2014: 100s Method

$StER = StCF \times UC_{P1} BER(odo)$

(mg/start) (mi/start) (mg/mi)

where

$StCF = CE_{P1\text{-}100} / UC_{P1\text{-}300}$

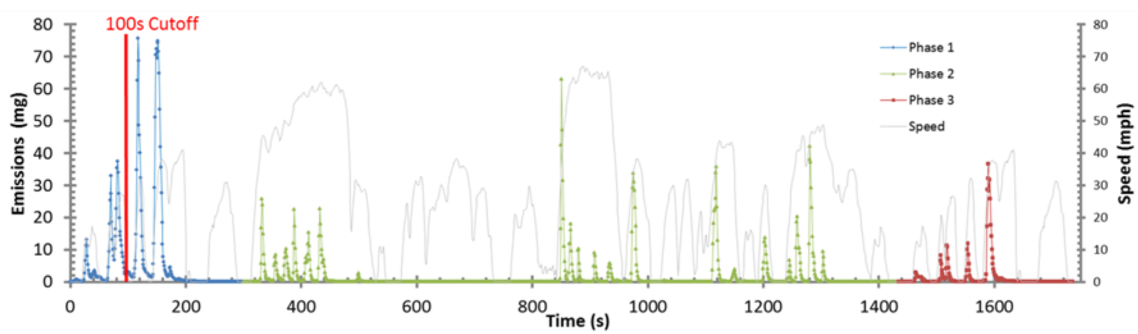
(mi/start) (mg/start) (mg/mi)

(**HCs: 0.79 mi/start**, **NOx: 0.49 mi/start**)*

***for veh w/ 3-way catalysts and MPFI**

Issues

1. Does not exclude running emissions
2. Does not include starts emissions past 100s
3. Cannot be used to model non-modal pollutants
4. Requires substantial post-processing



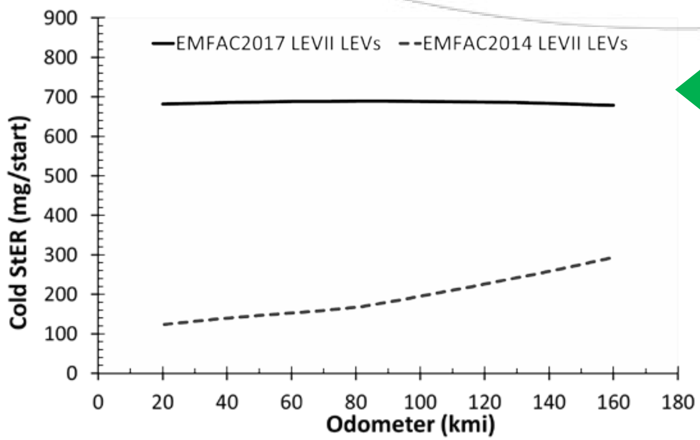
EMFAC2017: Phase-Integrated Method

$StER = 1.2 \times [UC_{P1}BER(odo) - UC_{P3}BER(odo)]$

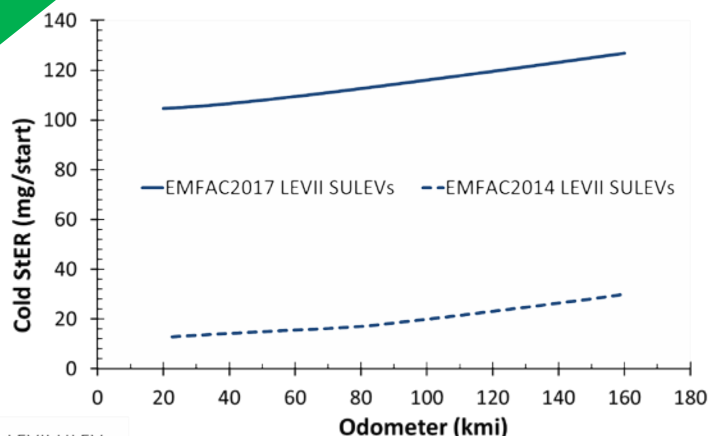
(mg/start) (mi/start) (mg/mi) (mg/mi)

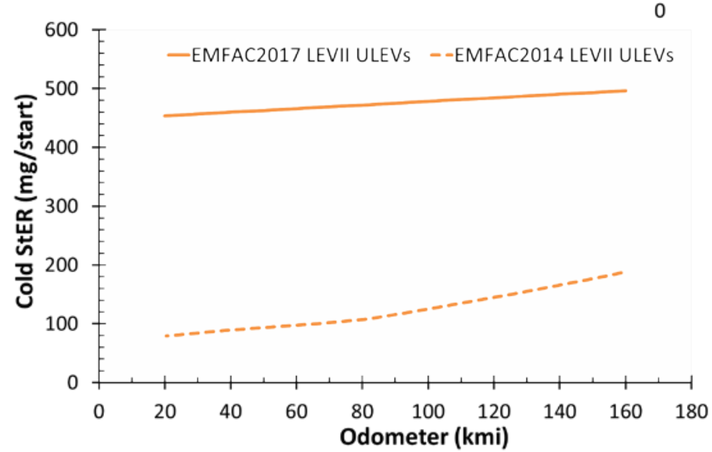
analogous to USEPA's FTP-Based Method

Cold StER EMFAC2017 vs. EMFAC2014: HCs

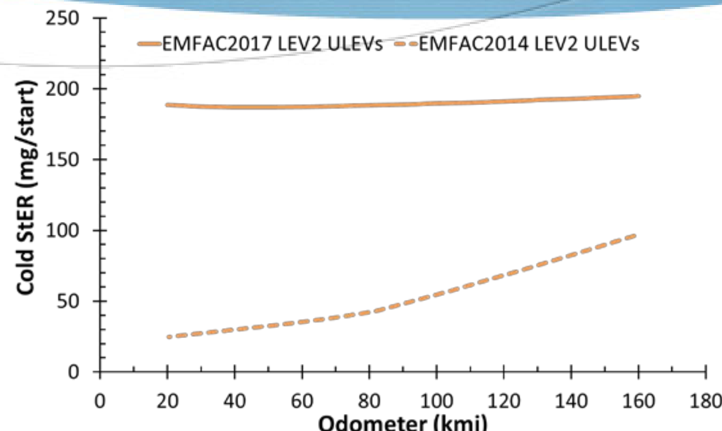


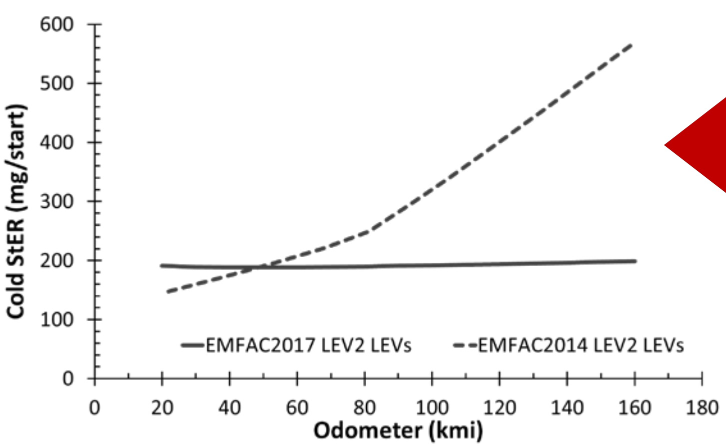
Starts HC ERs much larger than previously modeled
LEVII LEVs: 3.3 x
LEVII ULEVs: 3.6 x
LEVII SULEVs: 5.5 x





Cold StER EMFAC2017 vs. EMFAC2014: NOx



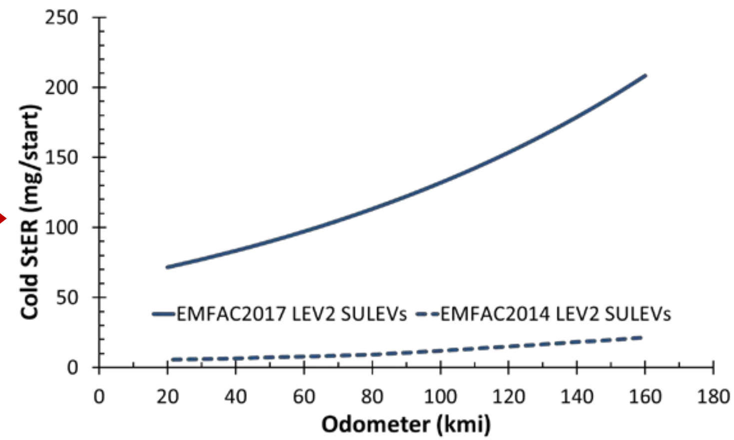


Starts NOx emissions higher for LEVII ULEVs and SULEVs and lower for LEVII LEVs

LEVII LEVs: 0.54 x

LEVII ULEVs: 3.1 x

LEVII SULEVs: 10.6 x



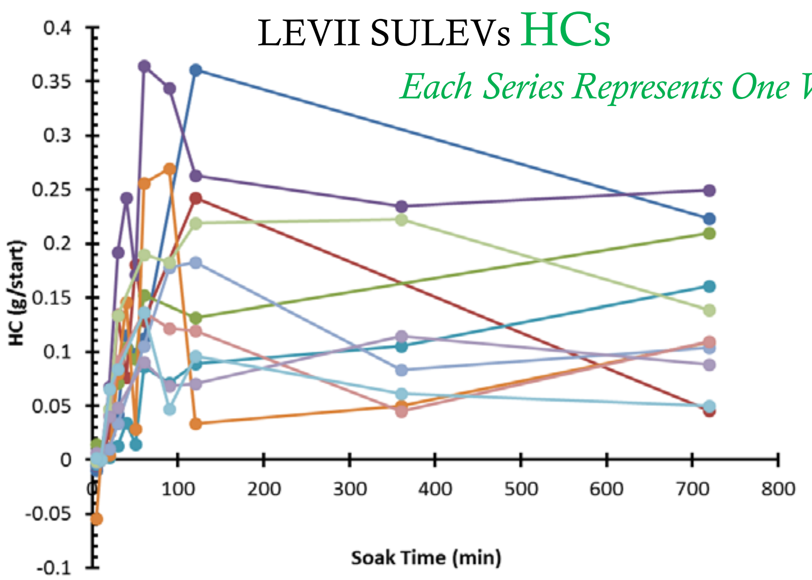
Warm Starts: HCs

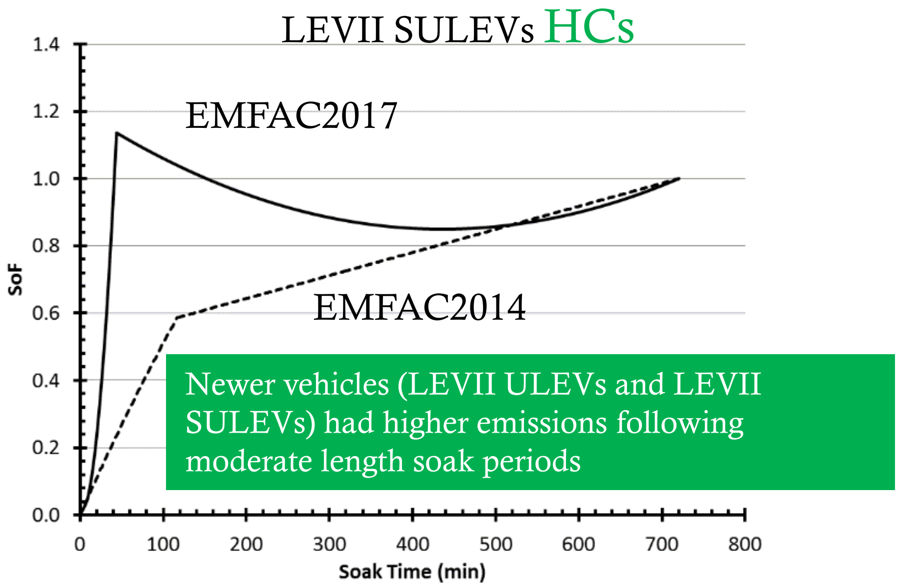
EMFAC uses SoFs to compute warm start ERs

Warm StER(odo) = StER(odo)*SoF(t), t = soak time

VSP included UC Phase 1 testing following various soak periods

- These data were used to derive new SoFs





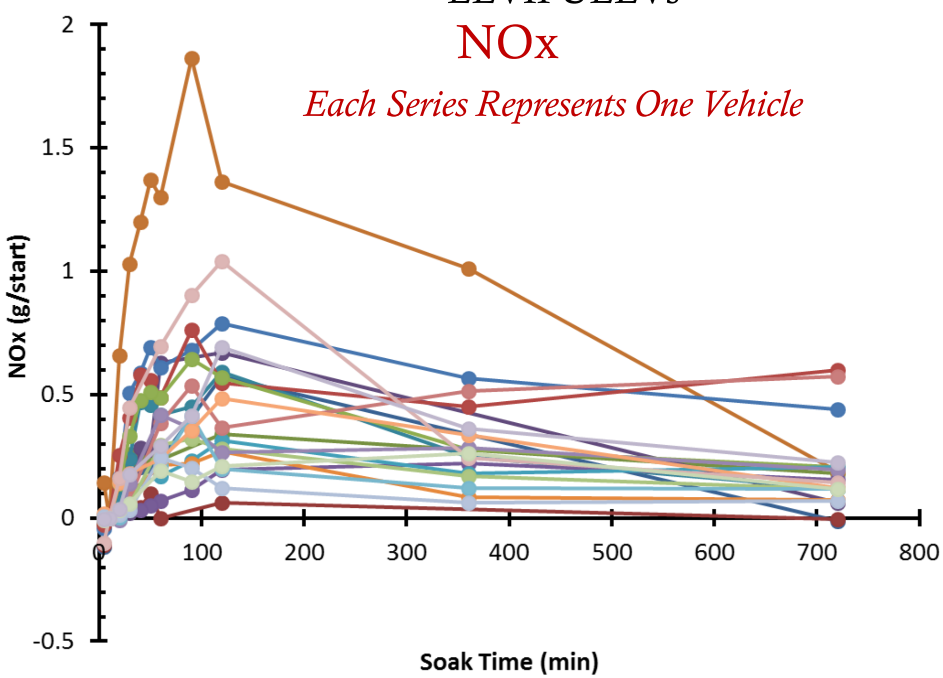
Warm Starts: NOx

Newer vehicles (LEVII ULEVs and LEVII SULEVs) had higher emissions following moderate length soak periods AND lower emissions following very short soak periods

LEVII ULEVs

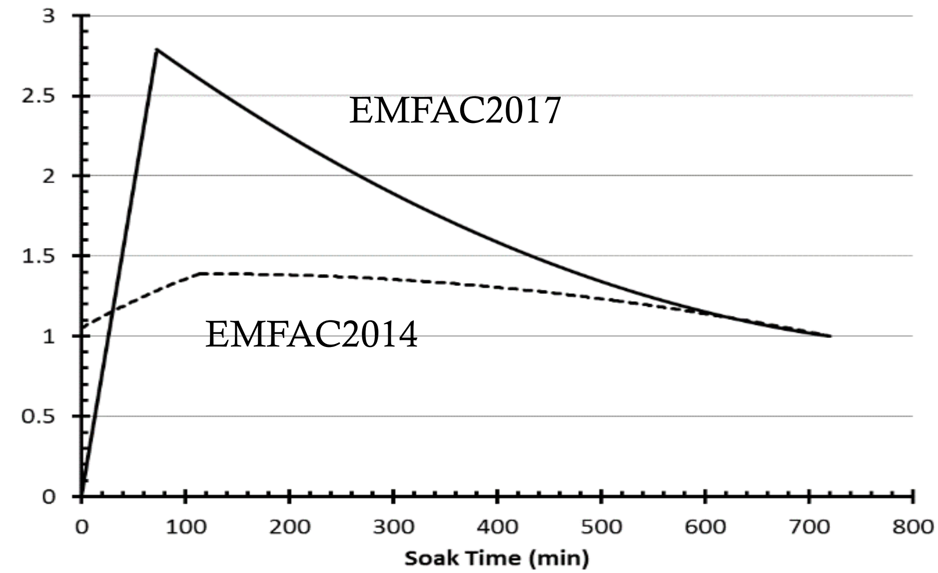
NOx

Each Series Represents One Vehicle



LEVII ULEVs

NOx



Lead Staff Contact

Michael Kamboures
Air Pollution Specialist
(916) 322 0343
michael.kamboures@arb.ca.gov

or

EMFAC@arb.ca.gov

Emission Rates

Heavy Duty Vehicles

Outline

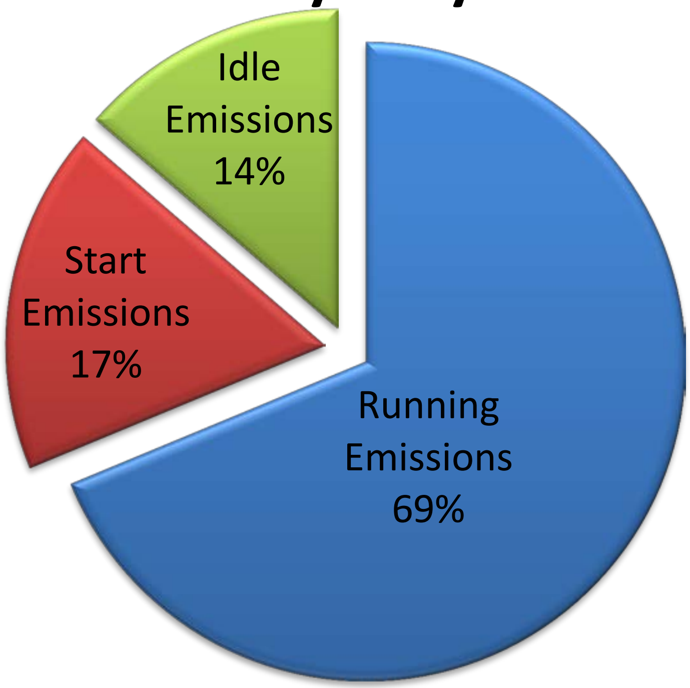
- Introduction to HD emission factors
- Updates to:
  - HD truck running exhaust emission rates and speed correction factors
  - Start emission rates
  - Idle emission rates
  - Transit bus emission rates

Introduction to HD Vehicle Emission Factors

- EMFAC2007/2011
  - Test data from CRC E55/59 project
  - Emission rate projections for 2007/2010 standard trucks
- EMFAC2014
  - Test data from 2007/2010 standard trucks
  - Focus on DPF and SCR equipped trucks
- EMFAC2017
  - Test data from late model vehicles with emphasis on 2013+ MY trucks with OBD

EMFAC2014 Modeled NOx Emissions

2010+ MY Heavy Duty Diesel Trucks



Calendar Year 2031

Running Exhaust Emission Rates

Dynamometer Test Cycles

Test Cycle/Mode	Average Speed (mph)	Duration (sec)	Length (mi)
UDDS	18.8	1060	5.54
Creep	1.8	253	0.12
Near Dock Drayage	6.6	3,046	5.59
Local Drayage	9.3	3,362	8.70
Transient	15.4	668	2.85
40-mph Cruise	39.9	2,083	23.1
50-mph Cruise	50.2	757	10.5
62-mph Cruise	62.0	1,385	23.2
OCBC	12.1	1,950	6.54

Test Data for Running Exhaust Emissions

- EMA/UCR HD diesel truck testing
  - Five 2012+ engine model year trucks
    - ARB confirmatory testing of three of five trucks
  - UDDS, Creep, Transient, 40-mph Cruise, 50-mph Cruise
- ARB Truck and Bus Surveillance Program
  - Seventeen HD diesel trucks (to date)
  - UDDS, Near Dock Drayage, Local Drayage, 40-mph Cruise, 62-mph Cruise
- Test vehicles selected randomly to cover major engine families of different manufacturers

Emissions Deterioration

- Emissions deterioration of HD engine is caused by
  - Tampering , mal-maintenance, and control component malfunction (TM&M)
- Deterioration is expressed as emissions impact rate (EIR) and determined by:
  - Frequency of TM&M
  - Emissions increase (%) of TM&M

Major TM&M Frequency and Emissions Increase (2013+ Engine MY)

After-treatment System TM&M	TM&M Freq (%)	Emissions Increase (%)			
		EMFAC2014		EMFAC2017	
		NOx	PM	NOx	PM
DPF Leaking	26.3	0	600	0	5200
DPF Disabled	2	0	1,000	0	10,000
SCR Malfunction	33.3	300	15	300	15
NOx Sensor #1	30	200	0	200	0
NOx Sensor #2	1.5	200	0	200	0

***Frequency and emission increase at 1,000,000 miles**

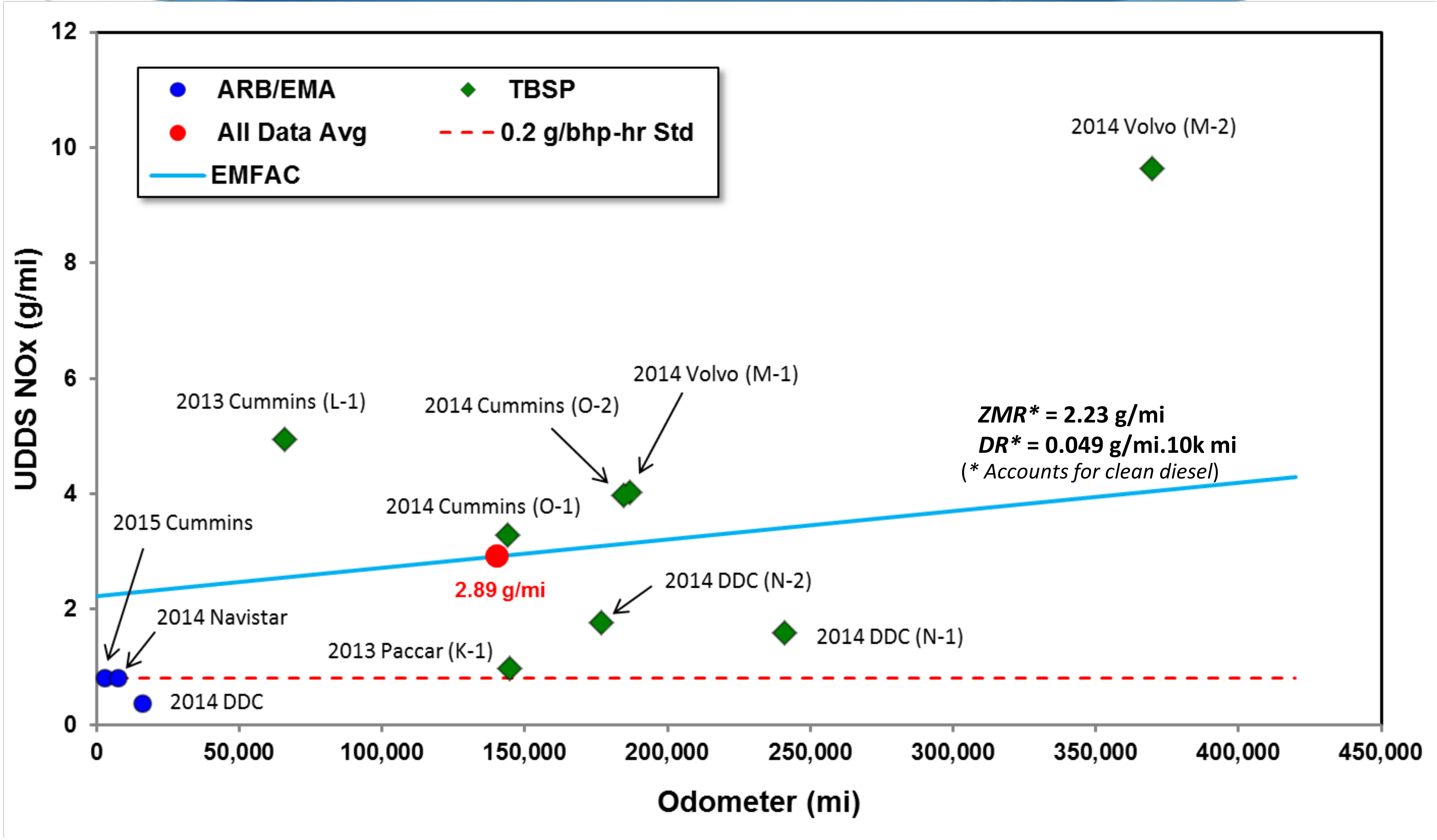
Running Exhaust Emission Rate

- Average emission rate (ER_{avg}) is average of dynamometer test results over UDDS cycle
- ER_{avg} is then back-projected to "zero-mile rates (ZMR)" using emission impact rate (EIR)
- Deterioration rate (DR) is rate of emissions increase

– ***Zero Mile Rate:*** $$\text{ZMR (g/mi)} = \frac{ER_{avg}}{\left(1+\boldsymbol{EIR}\times\frac{Odo_{avg}}{1{,}000{,}000}\right)}$$

– ***Deterioration Rate***: $$\text{DR (g/mi/10k mi)} = \frac{ZMR\times \boldsymbol{EIR}}{100}$$

UDDS NOx Emission Rate for 2013+ MY HHD Trucks

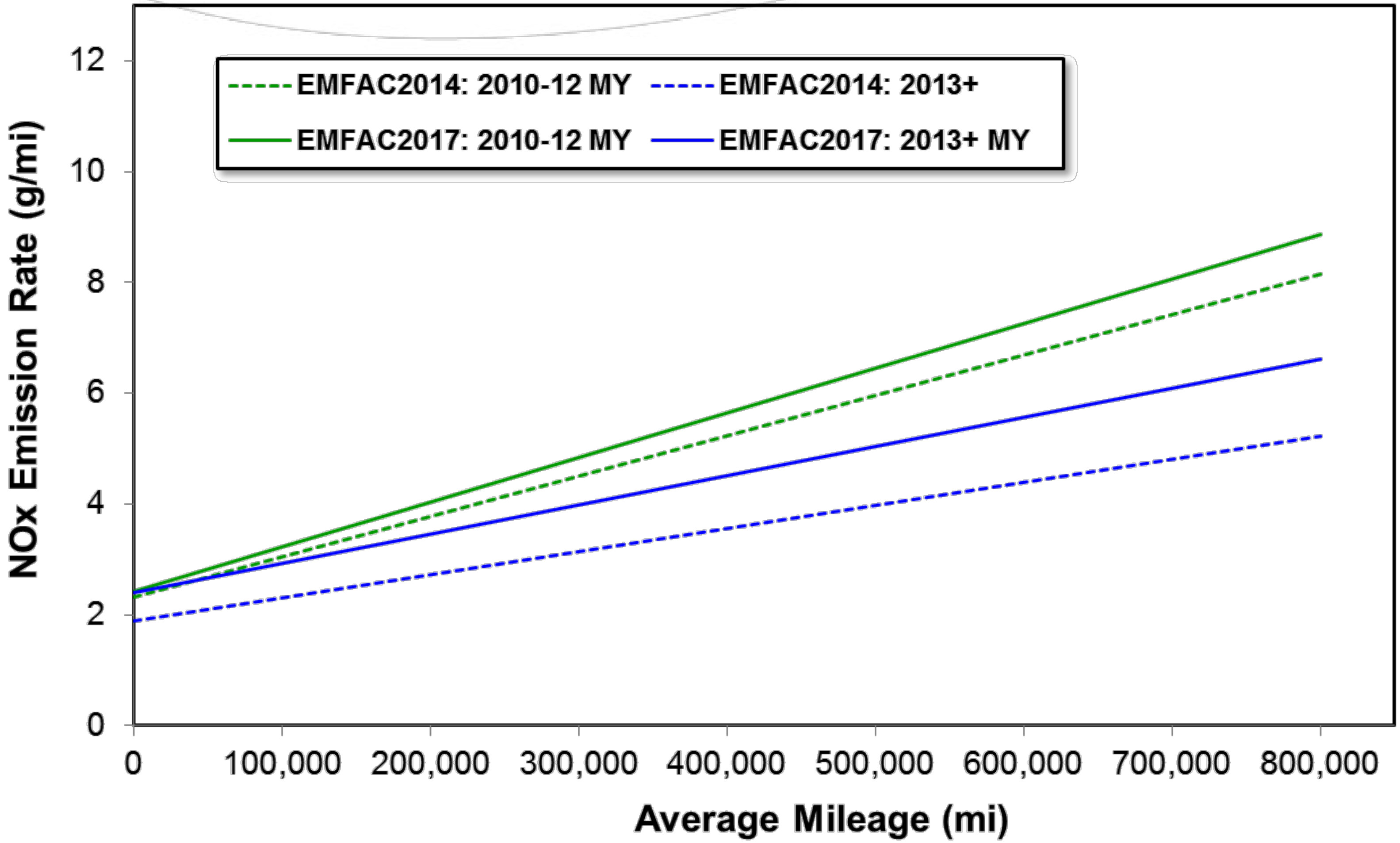


Comparison of Zero-Mile Rates

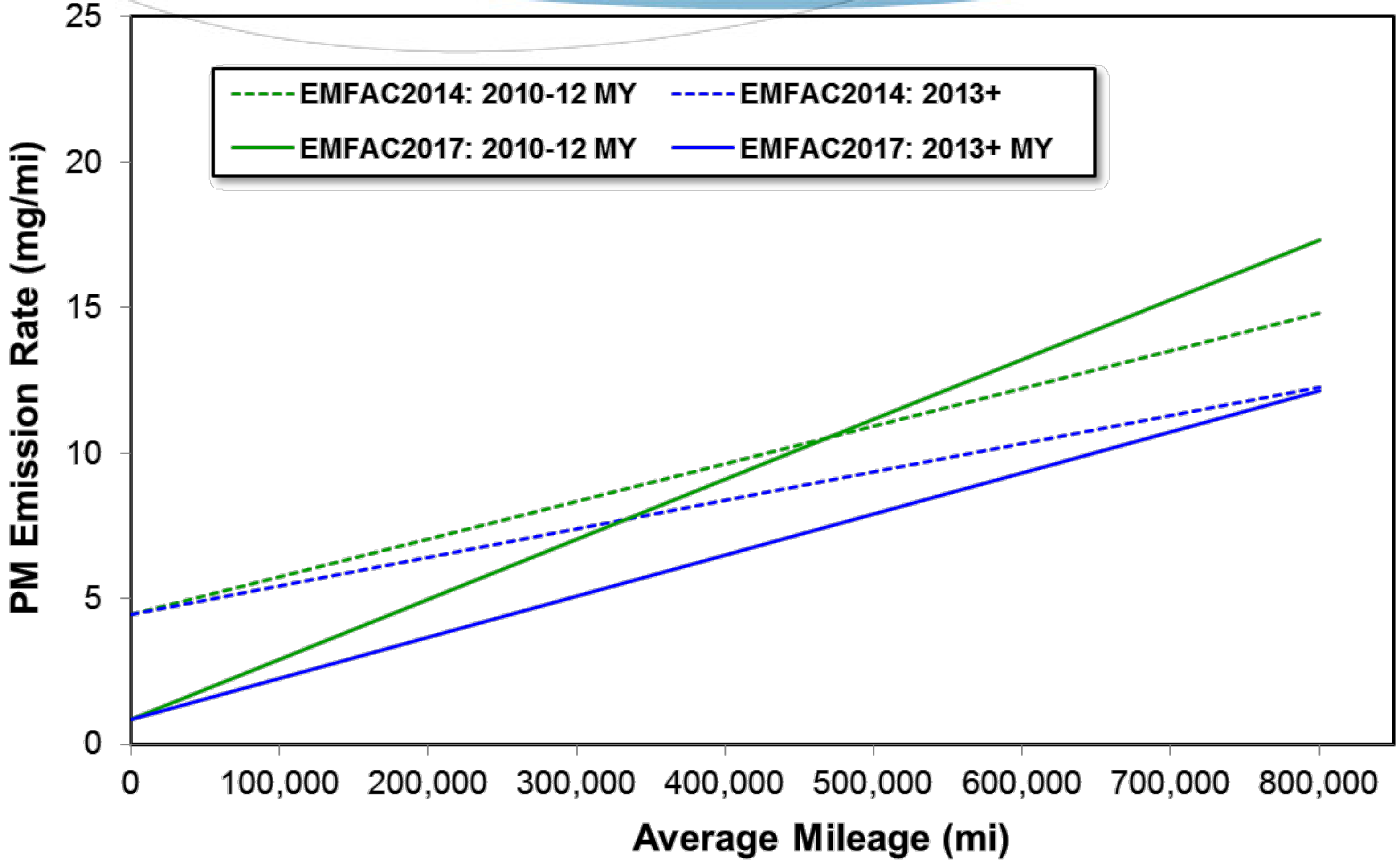
Engine Model Year	EMFAC2014			EMFAC2017		
	NOx* (g/mi)	PM* (mg/mi)	CO2 (g/mi)	NOx* (g/mi)	PM* (mg/mi)	CO2 (g/mi)
2010-12	2.33	4.4	2,056	2.45	0.9	2,220
2013+	1.89	4.4	2,056	2.40	0.9	2,088

*** NOx and PM rates have been normalized to pre-Clean Diesel fuel for EMFAC model**

NOx Emissions Deterioration



PM Emissions Deterioration



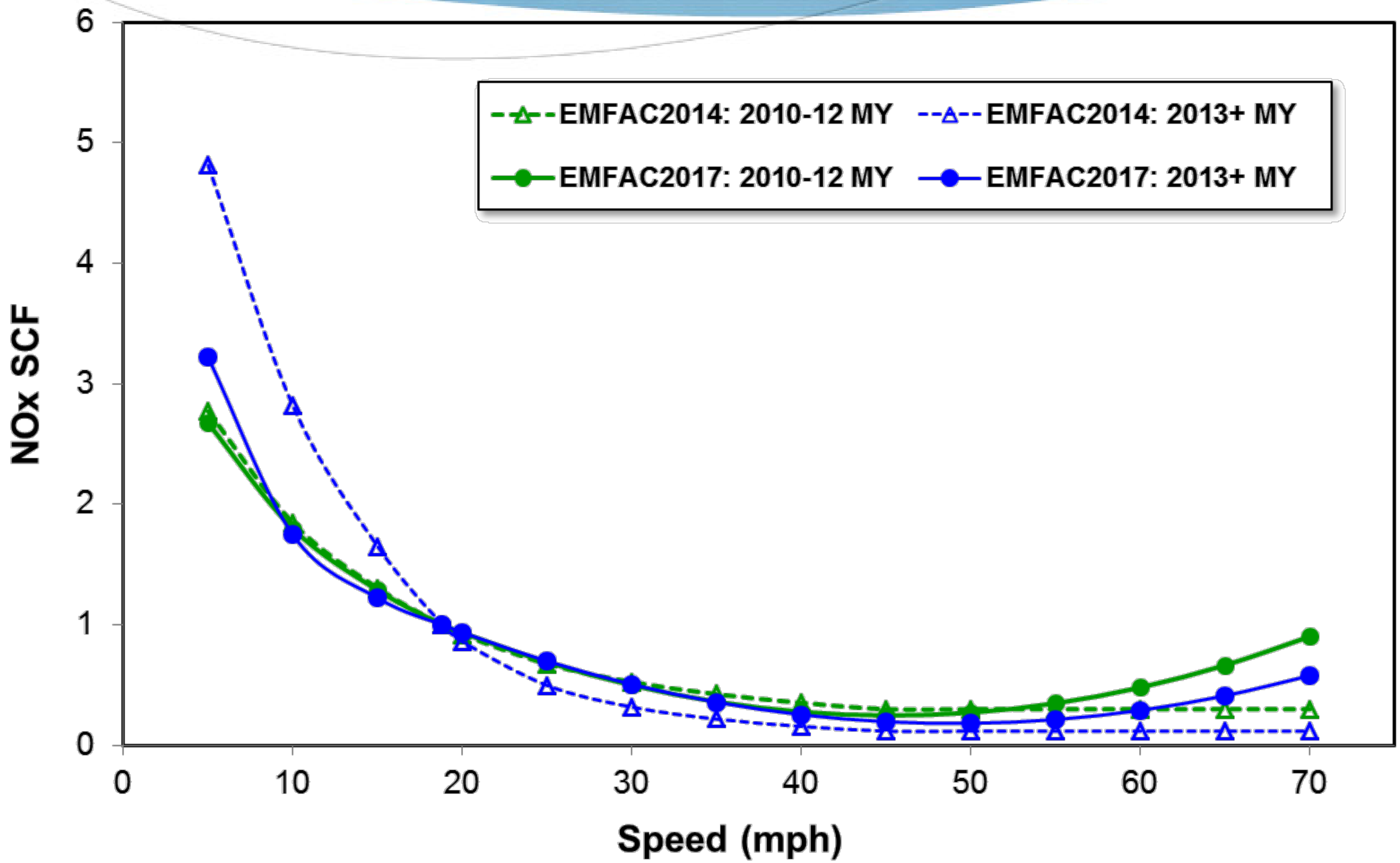
Speed Correction Factors

- Running exhaust emission rates vary by speed

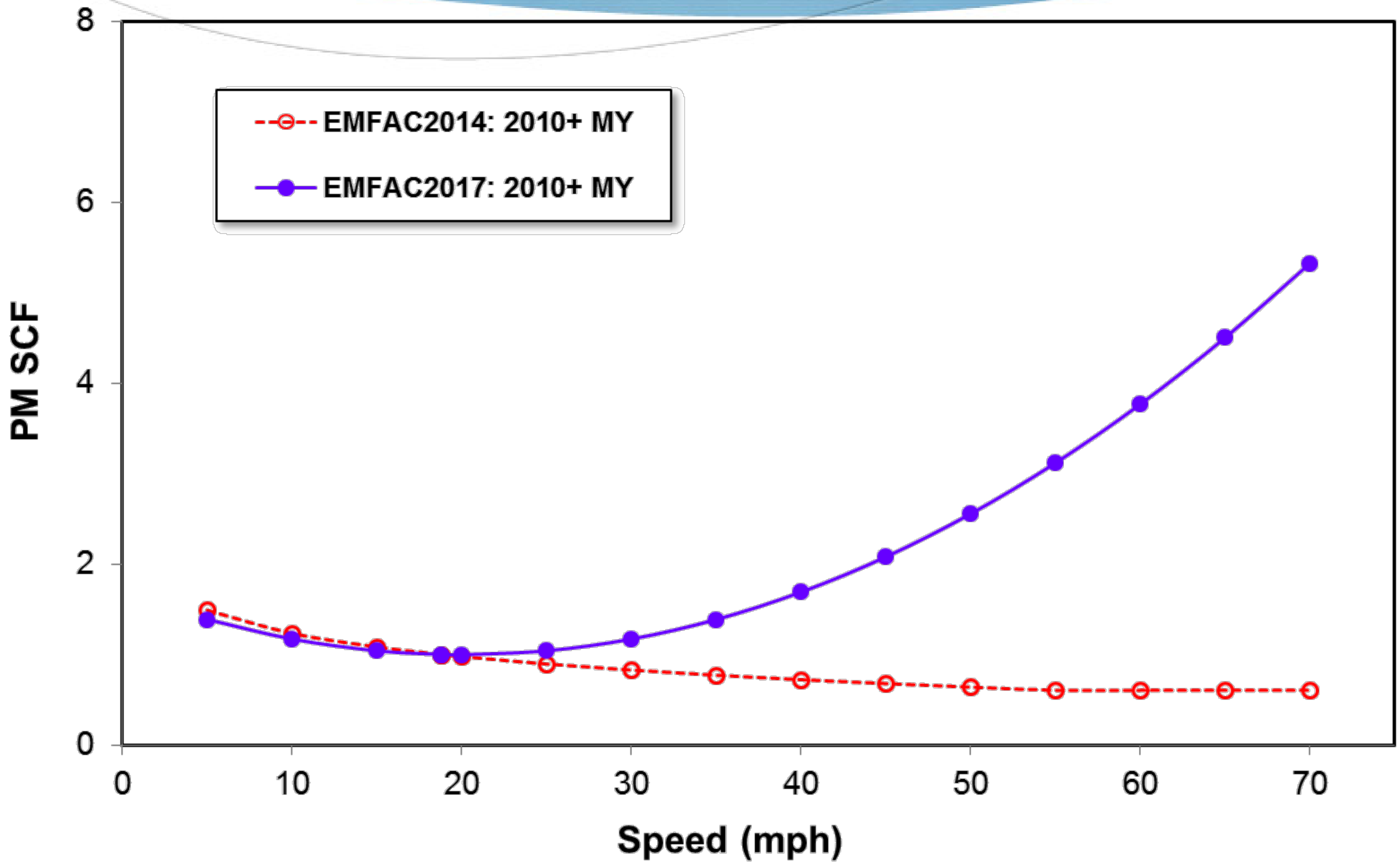
$$ER_{MY} = (ZMR_{MY} + DR_{MY} \times Odometer_{Age}) \times SCF_{MY}$$

- Dynamometer test data provide emission rates at different test cycle speeds
- Speed correction factors developed based on emission rates of six test cycles

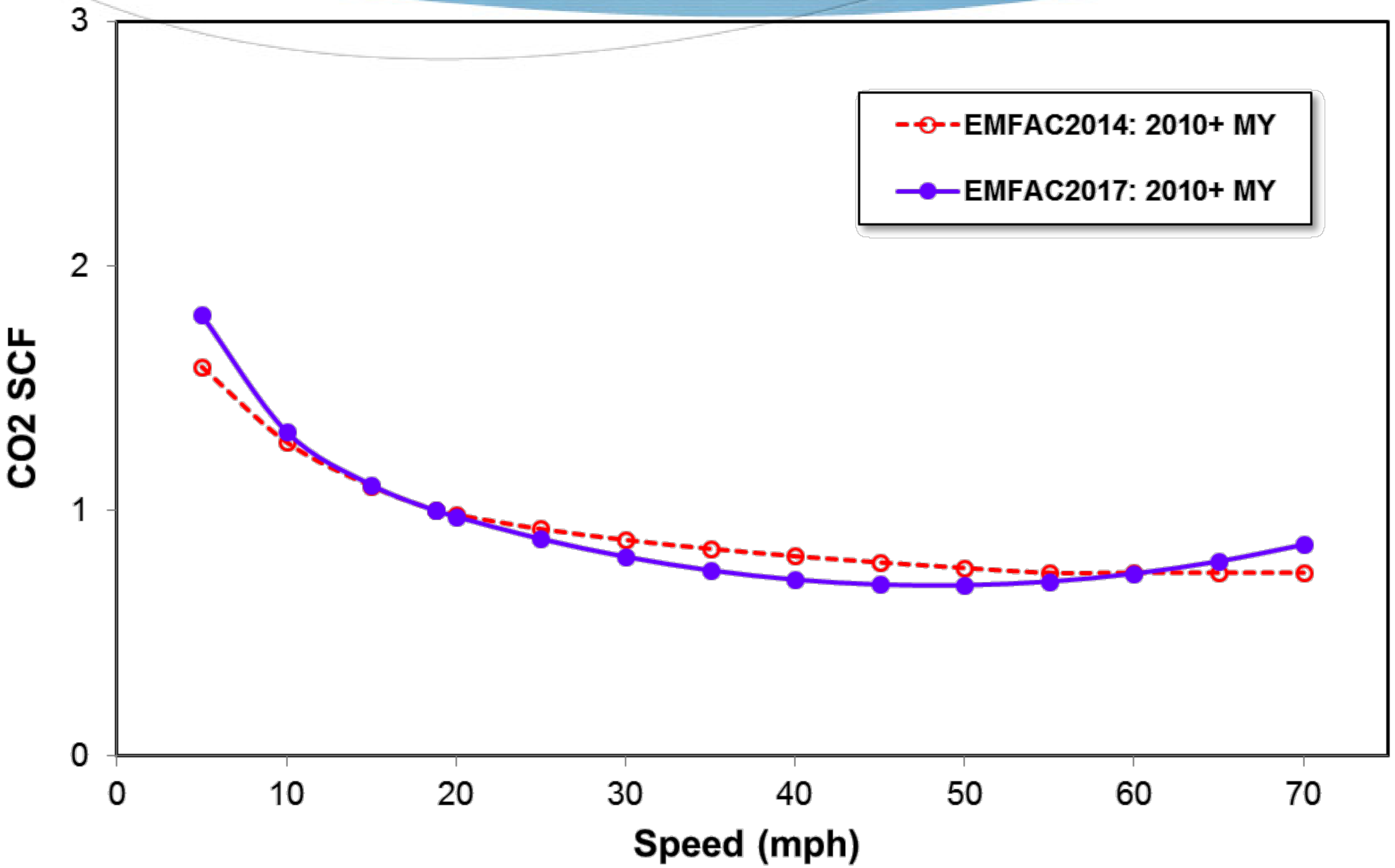
NOx Speed Correction Factor



PM Speed Correction Factor



CO2 Speed Correction Factor

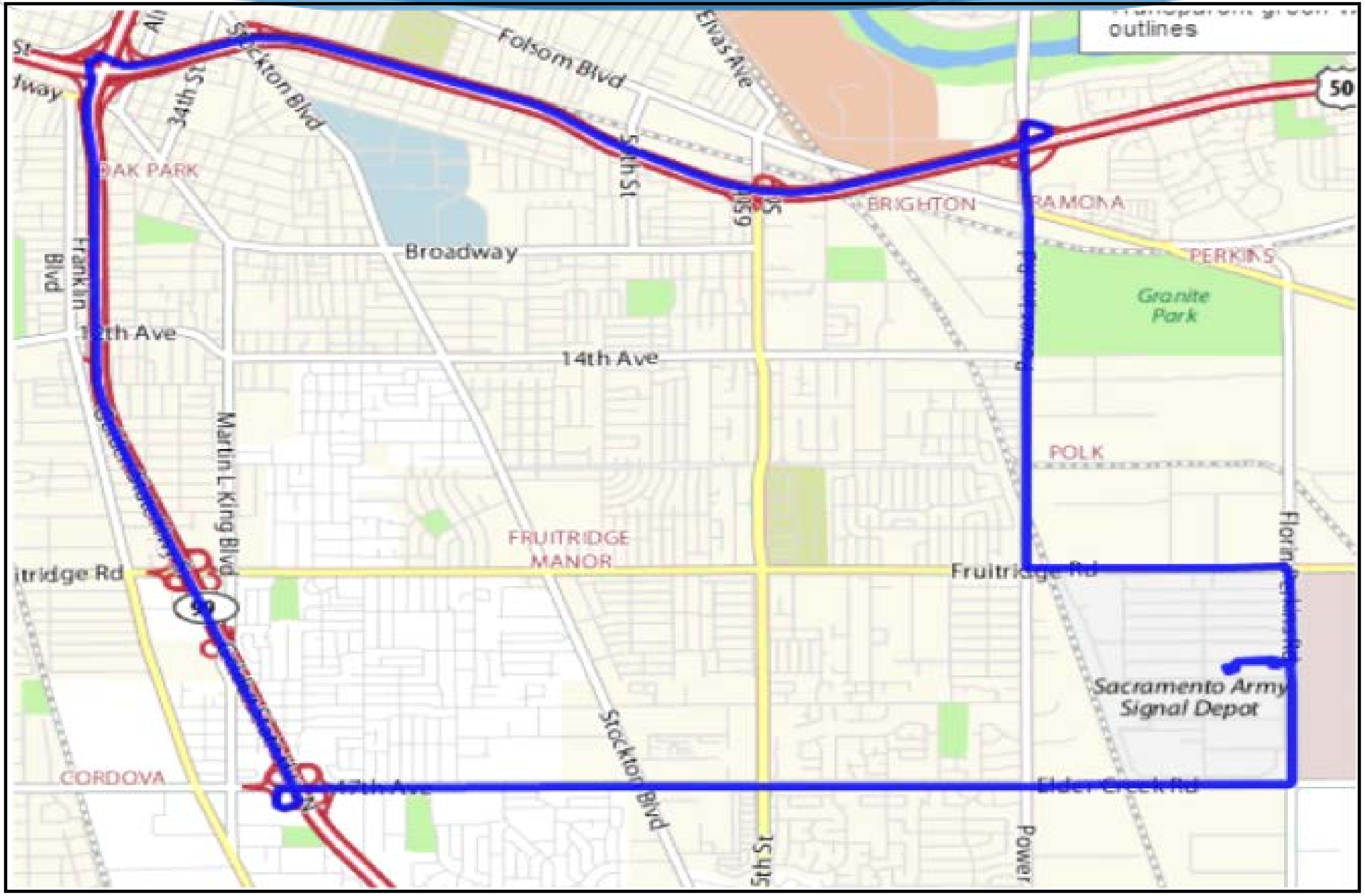


Start and Idle Emission Rates

SCR Truck Start Emissions

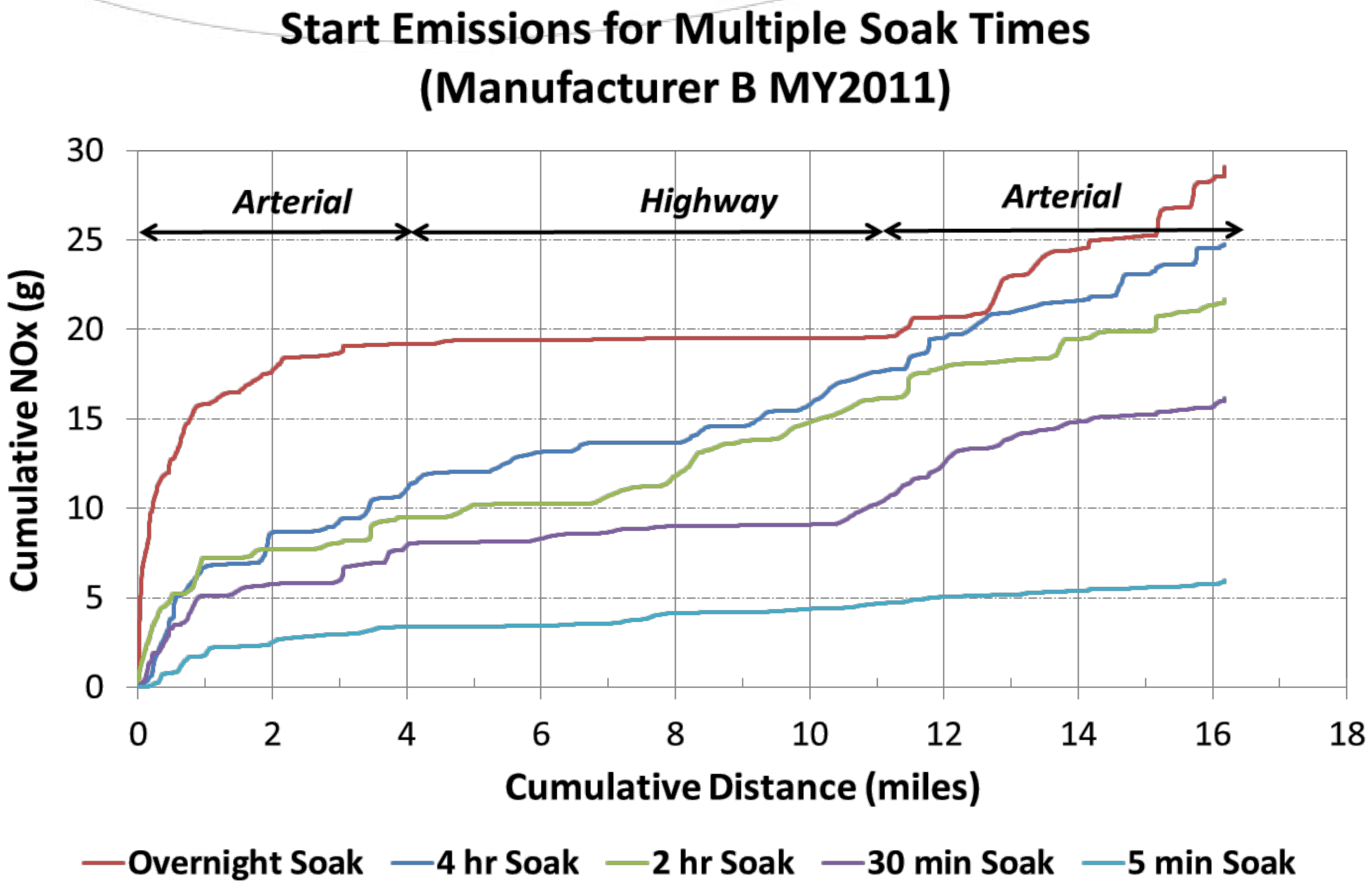
- Start emissions generated after engine start when SCR is not at working temperatures
- Start emissions are a function of
  - Start emission rate (g/start)
  - Number of starts per day
- Emission factors are based on test data from ARB over-the-road PEMS testing

PEMS Testing of Start Emissions

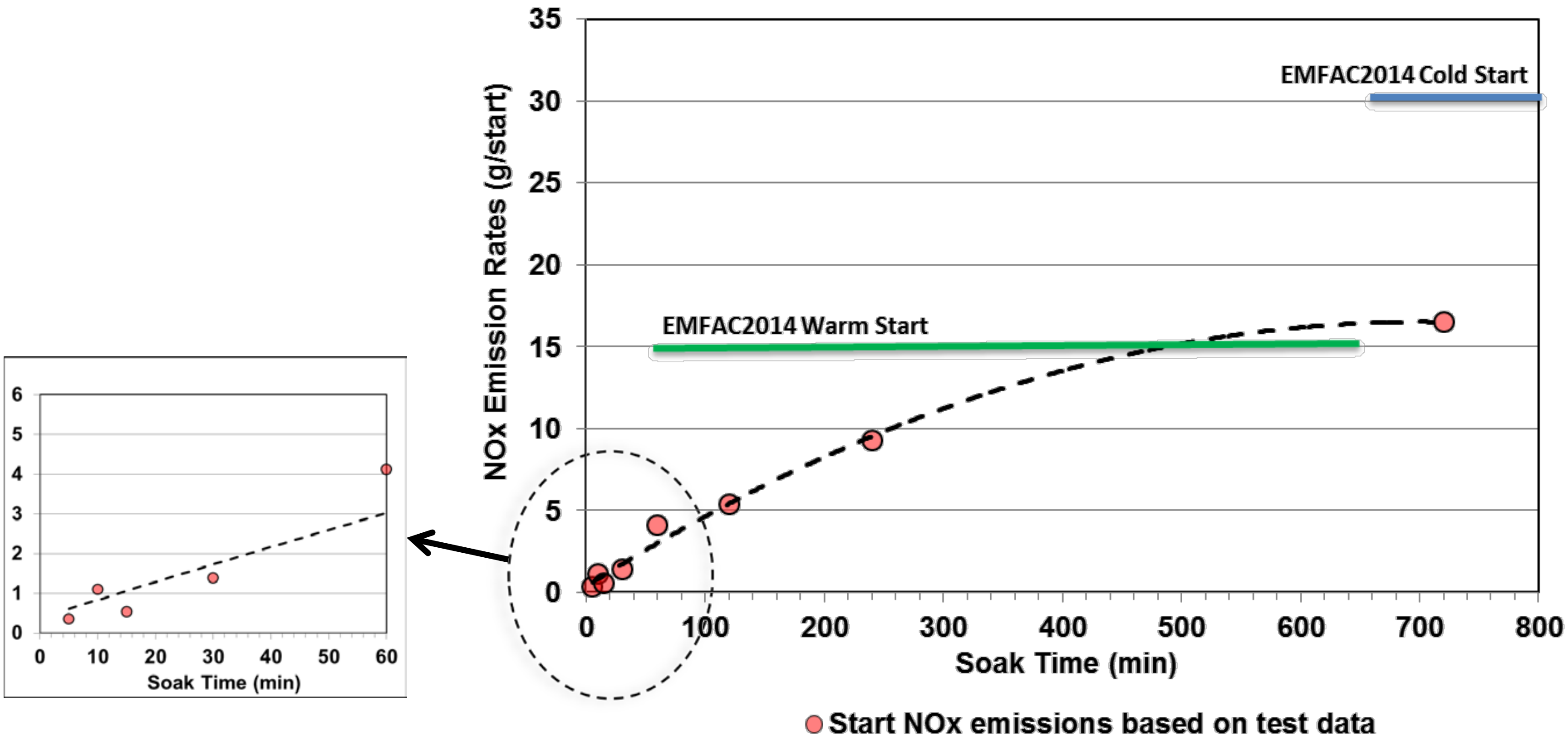


Number of trucks tested: 4 **Distance: 16 miles** **Duration: 50 minutes**

NOx Emissions of Trucks with SCR System



NOx Start Emissions vs Soak Time



Idle Emission Testing

- Idle emission rates are based on PEMS test results from ARB and TTI
- ARB tested 4 HD trucks of 2013+ MY
  - A test run consisting four 15-min segments:
    idle → idle+AC → idle → idle+heater
- Test data of 8 CA clean idle certified trucks tested by TTI were used
  - Each truck idle tested at 100°F and 30°F to simulate summer and winter conditions

Revised Idle Emission Rate for 2010+ MY

Idle Mode	EMFAC2014			EMFAC2017		
	NOx (g/hr)	PM (mg/hr)	CO2 (g/hr)	NOx (g/hr)	PM (mg/hr)	CO2 (g/hr)
Low Idle	12.1	1.0	4,574	23.2	4.1	5,646
High Idle (summer)	25.4	2.5	10,520	31.0	16.7	6,938
High Idle (winter)	21.8	4.3	8,233	39.7	23.6	7,510

Transit Bus Emission Rates

Transit Bus Emissions Testing

- WVU Integrated Bus Information System (IBIS)
  - 29 diesel buses of 1986-2003 MY
  - 10 CNG buses of 2005-2008 MY
- ARB testing for Valley Transit Agency
  - 3 diesel buses of 2011 MY (SCR)
  - 3 CNG buses of 2011-2012 MY (TWC)
- Altoona Bus Research and Testing Center funded by Federal Transportation Agency
  - 8 diesel buses of 2010-2015 MY (SCR)
  - 10 CNG buses of 2010-2015 MY (TWC)

Diesel Transit Bus Emission Rate

<table>
<tr><th rowspan="2">Model Year</th><th colspan="3">EMFAC2014</th><th colspan="3">EMFAC2017</th></tr>
<tr><th>NOx (g/mi)</th><th>PM (mg/mi)</th><th>CO2 (g/mi)</th><th>NOx (g/mi)</th><th>PM (mg/mi)</th><th>CO2 (g/mi)</th></tr>
<tr><td>2003</td><td>14.0</td><td>116</td><td>2,417</td><td rowspan="2">12.6</td><td rowspan="2">12.6</td><td rowspan="2">2,358</td></tr>
<tr><td>2004-2006</td><td>3.83</td><td>116</td><td>2,417</td></tr>
<tr><td>2007-2009</td><td rowspan="2">2.04</td><td rowspan="2">13.9</td><td rowspan="2">2,417</td><td>8.13</td><td>12.6</td><td>2,432</td></tr>
<tr><td>2010+</td><td>1.70</td><td>6.0</td><td>2,029</td></tr>
</table>

CNG Transit Bus Emission Rate

Model Year	EMFAC2014			EMFAC2017		
	NOx (g/mi)	PM (mg/mi)	CO2 (g/mi)	NOx (g/mi)	PM (mg/mi)	CO2 (g/mi)
Pre-2003	21.6	42.5	2,394	20.3	21.7	2,325
2003-2006	15.4	23.0	2,394	17.1	15.1	2,048
2007	0.65	1.3	2,305			
2008+				0.61	5.0	2,237

Adjustment to Emission Factors by Vehicle Model Year

- All emission factors were calculated on an engine model year basis weighted by sales data from different FELs
- Each vehicle model year includes several engine model years
- Truck activity data are collected by vehicle model years

DTR Data: HD Truck Engine and Vehicle Model Years

Vehicle Model Year	Engine Model Year				
	2009	2010	2011	2012	2013
2010	83%	17%			
2011	17%	67%	15%		
2012		15%	68%	17%	
2013		8%	16%	66%	10%

Lead Staff Contact

Lei Zhou
Staff Air Pollution Specialist
(626) 450-6183
lei.zhou@arb.ca.gov

or

EMFAC@arb.ca.gov

Emission Deterioration

Heavy Duty Vehicles

Outline

- Background
- Deterioration in emissions modeling
- Proposed updates
- Future steps

Background

- Discussion with stakeholders on representativeness on EMFAC assumptions being outdated
- CARB recognizes need to update assumptions but asserts the model itself is sound
- CARB staff mining new data to update emission impact rates (EIR)
- EIR is an input to EMFAC deterioration model to calculate emission rates

Emission Deterioration in EMFAC

Emission Impact Rate (EIR)	=	**Frequency** of Engine Component or After-treatment system Failure	×	**% Emission Increase** from Engine Component or After-treatment system Failure

Two Major Assumptions:

1. Emissions from diesel powered trucks remain stable in the absence of tampering, malfunctions and mal-maintenance.
2. The deterioration factors are based upon the assumption of the frequency (FREQ) of occurrence and consequence of eighteen specific instances of tampering and mal-maintenance (TMM)

EIR and Emissions Modeling

$$ZMR\ (g/mi) = \frac{ER_{avg}}{\left(1 + \boldsymbol{EIR} \times \frac{Odo_{avg}}{1{,}000{,}000}\right)} \qquad DR\ (g/mi/10k\ mi) = \frac{ZMR \times \boldsymbol{EIR}}{100}$$

$$ER\ (g/mi) = (ZMR + DR \times Odometer) \times SCF$$

- ❑ 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 factors at different driving speeds

Need for Update

- Data shows PM and NOx emissions from new technology engines increase overtime for same MY over a course of few years
- Maintaining and quantifying in-use emission performance is a critical piece of mobile source strategy
- EMFAC's deterioration model and embedded assumptions critical to assess emission benefits of regulatory activity

Action Items for EIR Update

1. In-House Data Mining to update TMM Emission increase from OBD Demonstration Reports
   - PM ↑; NOx-no change

2. Developing strategies to collect <u>voluntary</u> road-side OBD scans from MY2013+ engines and update TMM FREQ
   - Field trials successful ; focus on routine data collection strategies

3. Formulated Emissions Inventory Workgroup to share data
   - Provided EMFAC data needs. Awaiting feedback.

Action #1 – TMM Emission Increase

- Manufacturer submitted emissions test data from one or more durability demonstration test engines (DDV reports)
- Baseline FTP/RMC-followed by introduction of one malfunction at a time and reevaluating emissions
- Data therefore provides emissions increase and systems ability to detect malfunction below OBD threshold (MIL light)
- Components tested include: SCR catalyst, DEF doser, NOx sensors, DOC, EGR, fuel system, boost control and PM filter leak

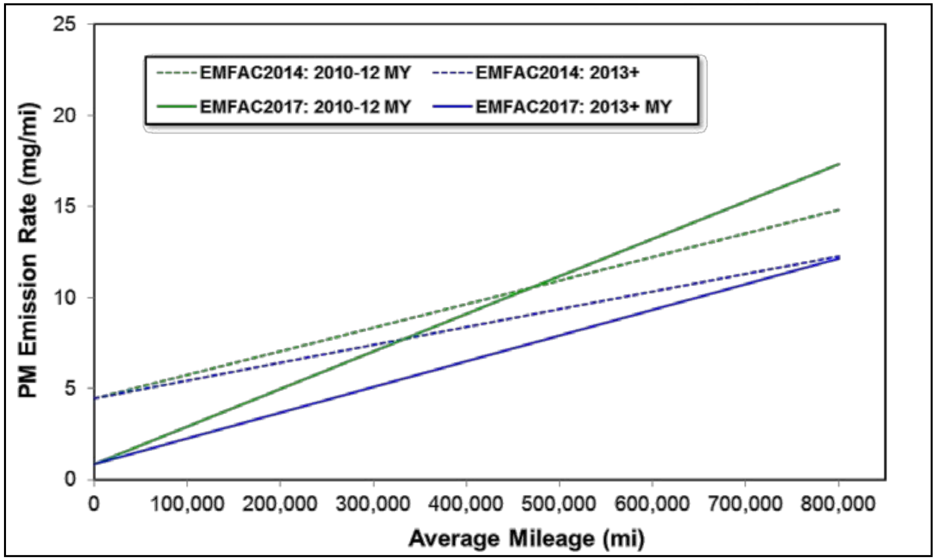
Emission Increase (%) Proposal

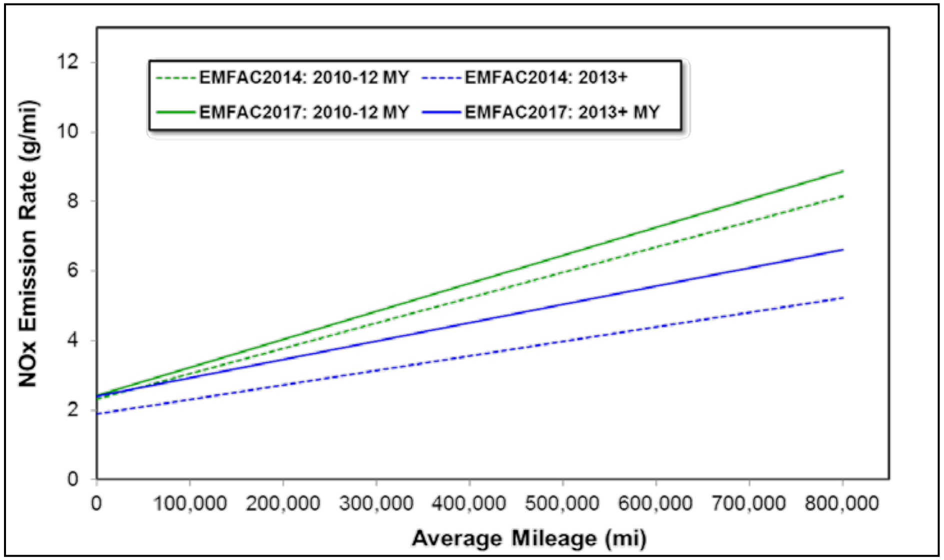
Priority	TM&M Action	FREQ[‡]	Emission Increase (%)			
			EMFAC2014		EMFAC2017	
			PM	NOx	PM	NOx
1	PM Filter leak	26.3%	600	0	5,200	0
2	PM Filter Disabled	2%	1000	0	10,000	0
3	NOx After-treatment Malfunction	33.3%	15	300	15	300
4	NOx After-treatment Sensor #1	30%	0	200	0	200
5	NOx After-treatment Sensor #2	1.5%	0	200	0	200

‡ FREQ to be updated

- ❑ PM filter leak and disabled increases by an order of magnitude
  - ❑ Reflects baseline of 0.001 g/bhp-hr (cert) vs of 0.01 g/bhp-hr (std)
  - ❑ Broken DPF emits at 0.05 g/bhp-hr and therefore 50x increase
- ❑ No changes to NOx ATS malfunction (DEF injector and SCR)
- ❑ No changes to NOx sensor malfunction

Changes to Deterioration Rates





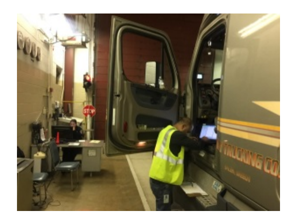
Proposed PM emissions start from a lower zero mile rate but deteriorate faster

No discernible changes to NOx deterioration for MY2013+

Action #2: TMM FREQ

1. **Repair Data**: Analyzed repair data provided by a truck repair shop in Southern California
   - ❖ Malfunctions that don't affect drivability may not get repaired

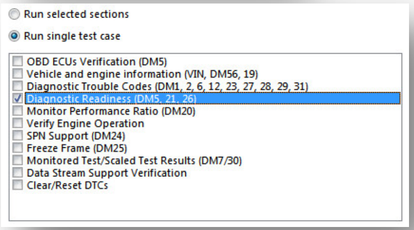
2. **OBD Scan Data:** Staff developing strategies to collect diagnostic scan data from MY2013+ engines
   - ❖ Preliminary field trials in April 2017 successful
   - ❖ Routine data collection strategy being put together



Plan for OBD Data Collection

Field Trials (Apr 2017): Number of Data Capture

	POLA		Cottonwood	
Manufacturer	**Scan Successful**	**Scan Failed**	**Scan Successful**	**Scan Failed**
Cummins	2	1	14	5
Mack	2	0	-	-
DD	2	0	5	2
Navistar	3	0	0	1
Paccar	-	-	3	1
Volvo	-	-	9	0



- ❑ Field trials show its viable to collect OBD scan data for various manufacturers
- ❑ CARB acquiring at least 8 new Silver Scan tools
- ❑ Remove any deficiencies such as inability to scan newer engines
- ❑ Initiate stand-alone studies at other CHP inspection facilities

Revise TM&M FREQ Categories to Reflect HD OBD

- EMFAC deterioration methodology is sound and updating TM&M FREQ with OBD scan data will ensure it's representative of current fleet characteristics
- OBD can also capture engine de-rate due to tampering (e.g., empty DEF tank)

EMFAC2014

TM&M Action
Timing Advanced
Timing Retarded
Injection Problems
NOx Aftertreatment Sensor #1
NOx Aftertreatment Sensor #2
PM Filter leak
PM Filter Disabled
Fuel Pressure High
Clogged Air Filter
Wrong/Worn Turbo
Intercooler Clogged
Other Air Problems
Engine Failure
Excess Oil Consumption
Electronics Failure
Electronics Tampered
Oxy Cat Malfunction
NOx Aftertreatment Malfunction
EGR Disabled/Low Flow

Future EMFAC

Priority [a]	TM&M Action	Description [b]	Category
1	PM Filter Performance	Broken DPF	Exhaust Aftertreatment System
2	PM Filter Disabled	Missing or bypassed DPF	
3	SCR Catalyst Efficiency	SCR catalyst with degraded efficiency	
4	Reductant Delivery Performance	Reduction in DEF dosing quantity	
5	DOC Catalyst/PM Filter Catalyst Conversion Efficiency	Degraded efficiency DOC/PM filter catalyst	
6	Boost Pressure Control	Over-boost, under-boost, changes to response time, or charge air cooling malfunction	Engine Components
	EGR System	Changes to flow, response time or cooler performance	
	Fuel System	Changes to injection pressure, timing or quantity	
7	NOx Sensors	Malfunction in NOx sensor performance	Sensors

[a] *priorities based upon analysis of OBD demonstration reports*

[b] *TM&M actions that generate OBD codes in MY2013+ engines*

Action #3: Stakeholders Involvement

- Includes stakeholders such as: EMA, CTA, ATA, Navistar, Detroit Diesel, Volvo, etc.
- White paper on EMFAC data needs provided to stakeholders (Feb 2017)
- CARB encourages stakeholders to provide available data:
  - Longitudinal diagnostic, and repair data (beyond warranty timeframe) from OEM's dealerships to update TM&M FREQ
  - OBD demonstration reports lacks data on the empty can

Future Steps

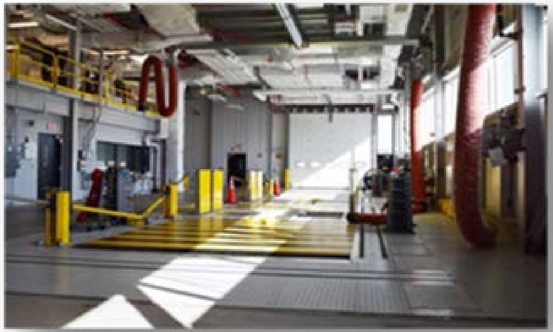
- ❑ Updates to % emission increase – Staff has high confidence in manufacturer submitted data
- ❑ Updates to TMM FREQ – Strategies to collect OBD scan data for MY2013+ engines using CARB's enforcement infrastructure across CA being implemented
- ❑ Stakeholders Involvement – Additional data via Emissions Inventory Workgroup that can fulfill gaps or strengthen in-house data mining efforts

Lead Staff Contact

Chandan Misra, PhD
Staff Air Pollution Specialist
(916) 323-1503
chandan.misra@arb.ca.gov

or

EMFAC@arb.ca.gov



Vehicle Activity Profiles

Light Duty Vehicles

Outline

- Background
- Data Source
- EMFAC Updates
  - Number of Starts per Day:
    original: 6.35 → new: 4.75
  - Start Distribution by hour
  - Soak time distribution
  - Engine-on time distribution
  - Accrual Rate

LDV Start Emissions
LDV Hot Soak Evaporative Emissions

LDV Running Loss Evaporative Emissions

VMT distribution by Age

Background

- LDV daily activity profile includes:
  - Number of starts per day: 6.35 on average in EMFAC2014
  - Start temporal distribution
  - Soak time distribution
  - Time-on distribution
- Data source for EMFAC2014 and prior versions: EPA 3-city instrumented vehicle data: Baltimore, Spokane and Atlanta (1992)

California Household Travel Survey (CHTS)

- Conducted by Caltrans
- Every 10 years
- Detailed information on the socioeconomic characteristics and travel behavior of households in all 58 counties
- Support regional and statewide travel and environmental models

2010 CHTS OBD/GPS Data

California Household Travel Survey 2010

- Time Frame: Jan 2012 –Jan 31, 2013

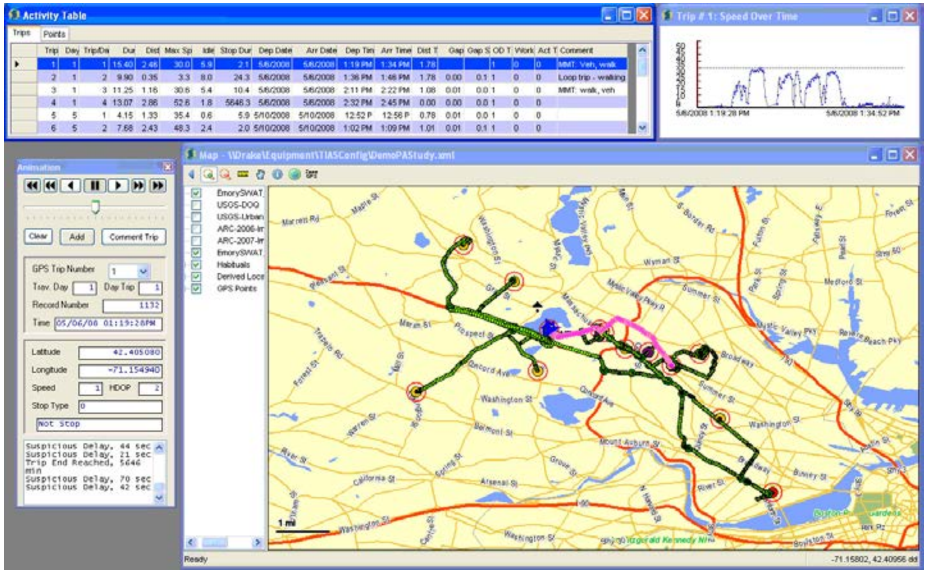
Survey Component	Duration	Full Study Size (HH)
Main Survey Diary	24-hour	42,431
Wearable GPS	3 days	3,855
Vehicle GPS	7 days	422
GPS and OBD	7 days	1,440

CHTS OBD/GPS Data

- GPS
  - Consecutively logged points -1 second frequency
  - Date, time, latitude, longitude, speed
  - Trip ends and modes matched using Trip Identification and Analysis System (TIAS)

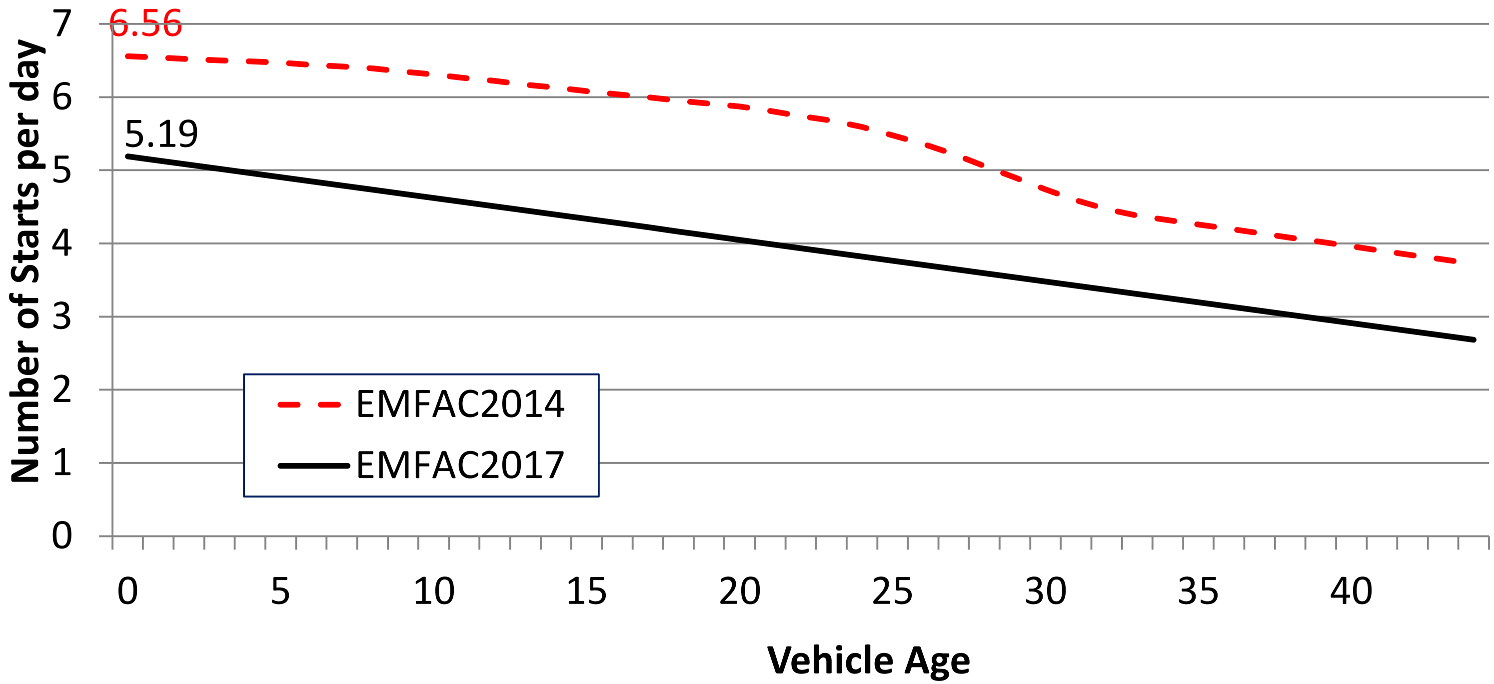
- OBD
  - at 1 second frequency : Speed
  - at 6 second frequency :
    - o Air flow rate
    - o throttle position
    - o engine load
    - o engine speed

Example: TIAS-processed data on a walk-vehicle-walk trip



Number of Starts

- Number of starts is less than previously assumed

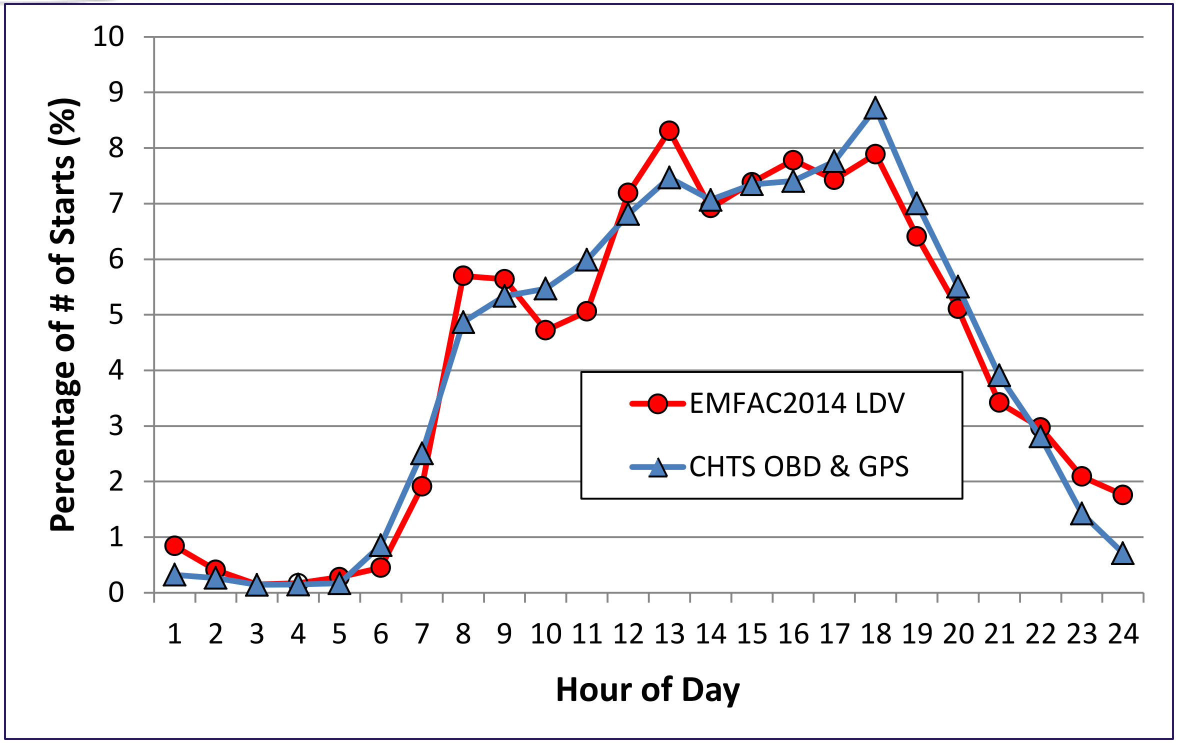


Number of Starts

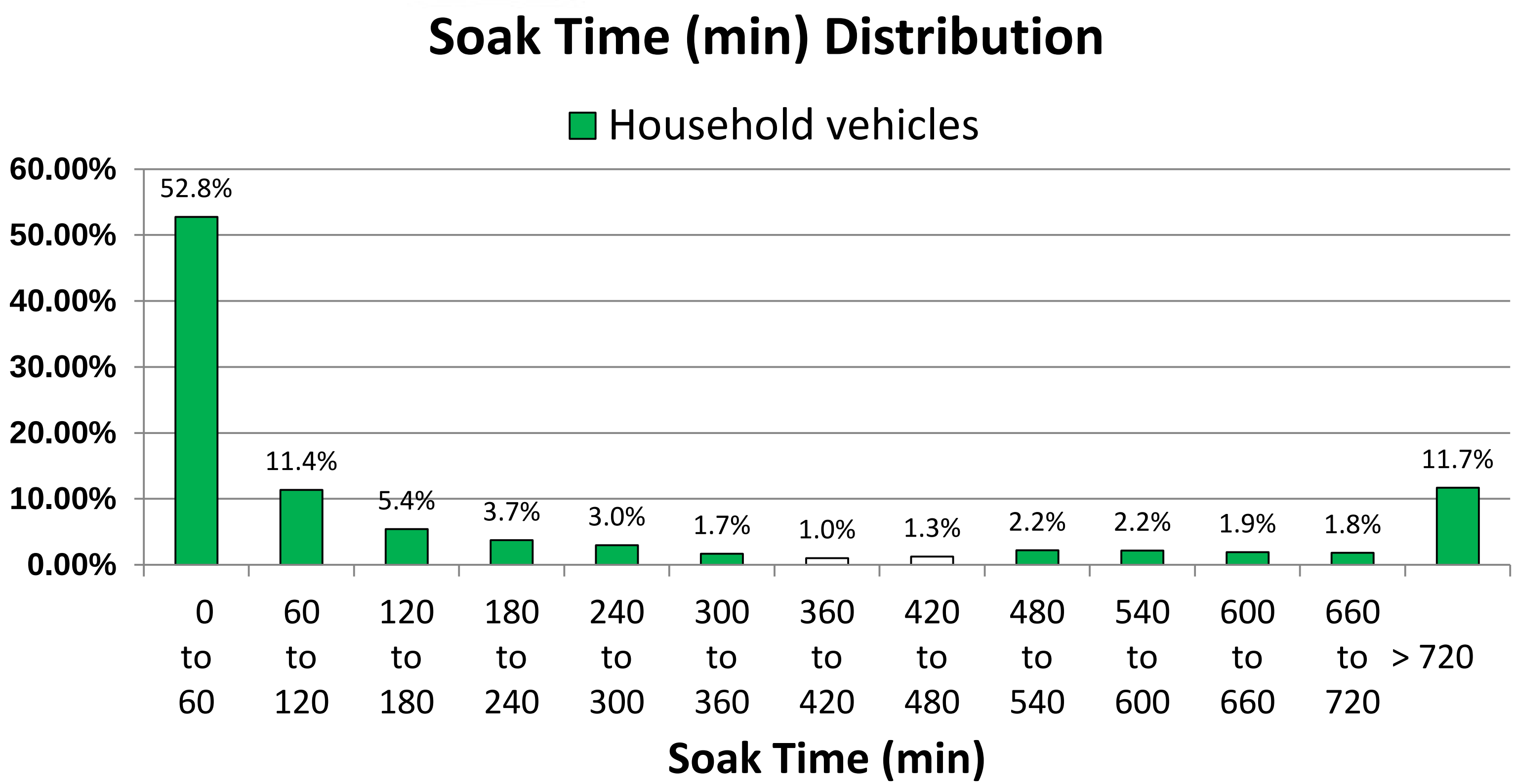
- Statistical analysis suggests number of starts per day is correlated with vehicle body type, but not necessarily fuel type (e.g., gas or diesel) or region type (urban vs. rural)
- Reduced number of starts is also corroborated by other data sources such as:
  - Telematics data from several PHEV manufacturers
  - NHTS historical data from 1969 to 2009 on daily vehicle trips
  - CHTS main survey data on household trips

LDV Number of Starts by Hour Distribution

- CHTS data suggests Californian most often make vehicle trips different from those in Atlanta, Baltimore, or Spokane in 1992



LDV Soak Time Distribution



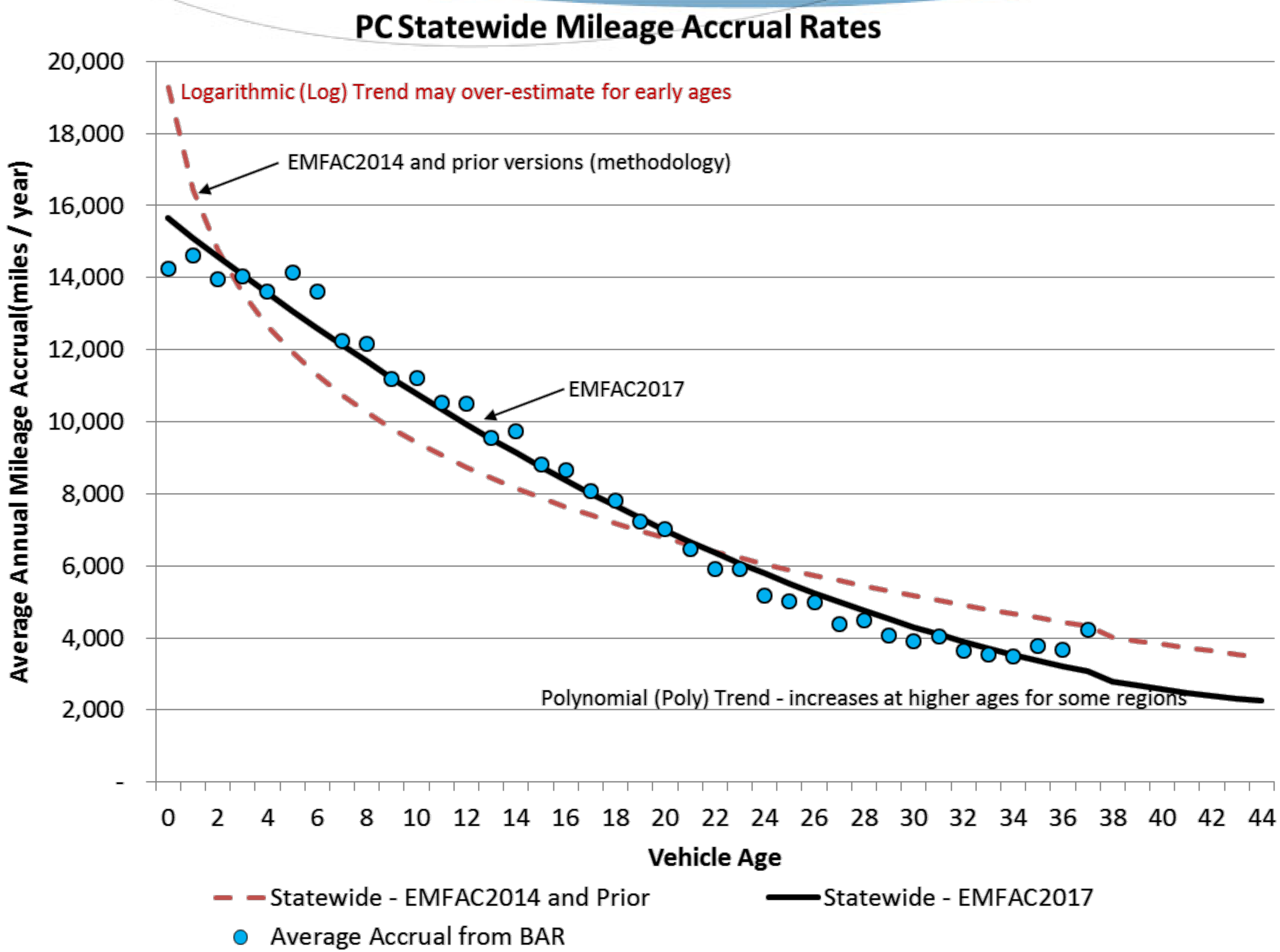
LDV Soak Time Distribution

Soak Time Period (min)	Hour of Day																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
5	0.02%	0.02%	0.00%	0.01%	0.03%	0.16%	0.33%	0.63%	0.90%	0.75%	0.81%	1.01%	1.09%	1.00%	1.11%	1.15%	1.32%	1.37%	1.00%	0.83%	0.50%	0.29%	0.20%	0.11%	14.64%
10	0.05%	0.01%	0.00%	0.00%	0.01%	0.03%	0.17%	0.29%	0.54%	0.55%	0.61%	0.74%	0.84%	0.87%	0.81%	0.83%	0.93%	0.94%	0.77%	0.49%	0.34%	0.25%	0.08%	0.03%	10.20%
20	0.01%	0.02%	0.01%	0.00%	0.00%	0.01%	0.05%	0.30%	0.42%	0.51%	0.67%	0.71%	0.86%	0.93%	0.84%	0.99%	0.84%	1.13%	0.78%	0.67%	0.35%	0.32%	0.10%	0.03%	10.58%
30	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.03%	0.08%	0.20%	0.27%	0.29%	0.45%	0.55%	0.56%	0.58%	0.56%	0.52%	0.67%	0.53%	0.39%	0.20%	0.11%	0.07%	0.05%	6.15%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.15%	0.21%	0.28%	0.28%	0.40%	0.43%	0.43%	0.36%	0.39%	0.48%	0.43%	0.35%	0.16%	0.11%	0.04%	0.03%	4.62%
50	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.03%	0.04%	0.14%	0.23%	0.24%	0.26%	0.26%	0.36%	0.31%	0.36%	0.24%	0.28%	0.35%	0.25%	0.16%	0.08%	0.02%	0.01%	3.63%
60	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.05%	0.03%	0.09%	0.16%	0.20%	0.16%	0.34%	0.27%	0.25%	0.22%	0.23%	0.22%	0.22%	0.20%	0.12%	0.10%	0.06%	0.01%	2.94%
120	0.04%	0.02%	0.01%	0.01%	0.00%	0.02%	0.04%	0.16%	0.28%	0.58%	0.69%	0.83%	0.77%	0.87%	1.01%	0.82%	0.92%	1.10%	1.02%	0.98%	0.62%	0.42%	0.16%	0.03%	11.38%
180	0.01%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.19%	0.24%	0.38%	0.45%	0.39%	0.37%	0.42%	0.39%	0.48%	0.45%	0.53%	0.38%	0.40%	0.21%	0.06%	5.41%
240	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.08%	0.17%	0.35%	0.35%	0.25%	0.21%	0.33%	0.42%	0.43%	0.32%	0.16%	0.22%	0.17%	0.10%	0.09%	3.73%
300	0.01%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%	0.17%	0.63%	0.24%	0.23%	0.18%	0.32%	0.41%	0.22%	0.17%	0.06%	0.10%	0.09%	0.06%	2.98%
360	0.02%	0.00%	0.00%	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.05%	0.13%	0.22%	0.24%	0.12%	0.11%	0.17%	0.19%	0.16%	0.07%	0.07%	0.03%	0.03%	1.68%
420	0.01%	0.01%	0.00%	0.01%	0.00%	0.00%	0.01%	0.03%	0.00%	0.00%	0.01%	0.00%	0.02%	0.05%	0.17%	0.16%	0.12%	0.16%	0.08%	0.06%	0.05%	0.03%	0.02%	0.00%	1.02%
480	0.00%	0.02%	0.00%	0.01%	0.00%	0.03%	0.02%	0.02%	0.03%	0.01%	0.00%	0.00%	0.00%	0.02%	0.11%	0.30%	0.28%	0.19%	0.09%	0.04%	0.02%	0.01%	0.03%	0.01%	1.26%
540	0.04%	0.02%	0.00%	0.01%	0.01%	0.04%	0.11%	0.10%	0.04%	0.02%	0.04%	0.01%	0.00%	0.02%	0.11%	0.29%	0.52%	0.40%	0.17%	0.14%	0.03%	0.06%	0.01%	0.01%	2.19%
600	0.01%	0.01%	0.00%	0.00%	0.01%	0.07%	0.21%	0.20%	0.13%	0.02%	0.01%	0.02%	0.00%	0.01%	0.02%	0.08%	0.36%	0.46%	0.29%	0.13%	0.08%	0.02%	0.02%	0.00%	2.18%
660	0.00%	0.00%	0.00%	0.00%	0.01%	0.10%	0.29%	0.39%	0.18%	0.09%	0.04%	0.02%	0.00%	0.00%	0.01%	0.00%	0.08%	0.24%	0.30%	0.11%	0.03%	0.01%	0.01%	0.01%	1.92%
720	0.00%	0.01%	0.00%	0.00%	0.02%	0.12%	0.28%	0.47%	0.28%	0.09%	0.06%	0.03%	0.01%	0.01%	0.02%	0.01%	0.08%	0.12%	0.09%	0.08%	0.03%	0.01%	0.00%	0.00%	1.81%
780	0.00%	0.00%	0.00%	0.00%	0.01%	0.13%	0.38%	0.44%	0.35%	0.17%	0.10%	0.02%	0.03%	0.00%	0.00%	0.01%	0.00%	0.00%	0.02%	0.02%	0.01%	0.02%	0.01%	0.00%	1.74%
840	0.00%	0.00%	0.00%	0.00%	0.01%	0.05%	0.27%	0.59%	0.38%	0.26%	0.16%	0.06%	0.03%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.03%	0.01%	0.00%	1.91%
900	0.00%	0.00%	0.00%	0.00%	0.01%	0.07%	0.15%	0.42%	0.35%	0.19%	0.09%	0.04%	0.04%	0.03%	0.02%	0.02%	0.00%	0.00%	0.01%	0.02%	0.01%	0.00%	0.00%	0.00%	1.46%
960	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.06%	0.19%	0.23%	0.15%	0.10%	0.10%	0.08%	0.05%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.03%
1020	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%	0.17%	0.12%	0.09%	0.10%	0.05%	0.08%	0.02%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.71%
1080	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.10%	0.13%	0.08%	0.07%	0.12%	0.04%	0.03%	0.05%	0.03%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.69%
1140	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.04%	0.08%	0.06%	0.06%	0.08%	0.06%	0.03%	0.01%	0.04%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.54%
1200	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.06%	0.05%	0.03%	0.05%	0.05%	0.05%	0.06%	0.03%	0.03%	0.03%	0.02%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.49%
1260	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.04%	0.05%	0.05%	0.04%	0.05%	0.04%	0.02%	0.03%	0.02%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.40%
1320	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.03%	0.03%	0.03%	0.03%	0.02%	0.04%	0.03%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.32%
1380	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.01%	0.03%	0.04%	0.04%	0.02%	0.03%	0.00%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.27%
1440	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.01%	0.02%	0.03%	0.01%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%
2880	0.00%	0.00%	0.00%	0.00%	0.01%	0.06%	0.07%	0.12%	0.12%	0.12%	0.10%	0.08%	0.09%	0.07%	0.06%	0.09%	0.08%	0.11%	0.08%	0.06%	0.02%	0.02%	0.01%	0.00%	1.37%
4320	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.07%	0.05%	0.05%	0.03%	0.01%	0.02%	0.02%	0.02%	0.01%	0.02%	0.00%	0.02%	0.01%	0.00%	0.00%	0.01%	0.00%	0.38%
5760	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%
7200	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%
8640	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
10080	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
	0.30%	0.22%	0.07%	0.09%	0.16%	0.97%	2.75%	5.07%	5.42%	5.06%	5.40%	6.22%	7.38%	6.93%	7.17%	7.50%	8.31%	9.50%	7.51%	5.92%	3.52%	2.63%	1.30%	0.60%	100.00%

Updates on Mileage Accrual Rates

- Gasoline LDVs
  - Data source: 2001-2014 BAR Smog Check data
  - Accrual between smog check tests per VIN
  - Methodology update: non-logarithmic regression instead of logarithmic regression based on age
  - Accrual trends developed at sub area, regional or statewide level depending on data availability
- Diesel LDVs:
  - Assuming same as gasoline LDVs
- Electric LDVs:
  - Data source: Telematics data from four major OEMs
  - 70% of average gasoline annual LDV accrual rate in the base year of 2016, raising to 100% by 2025

Mileage Accrual Rate Methodology



Lead Staff Contact

Zhen Dai
Air Resources Engineer
(916) 322-7455
zhen.dai@arb.ca.gov

or

EMFAC@arb.ca.gov

Vehicle Activity Profiles

Heavy Duty Vehicles

Outline

- Background
- New Data Source: CE-CERT study
- EMFAC Updates
  - ❑ Speed distribution
  - ❑ Number of starts and soak time distribution
  - ❑ Idle hours
- Summary
  - ❑ Activity profiles vary greatly by vocational category
  - ❑ More low-speed VMT than previously assumed
  - ❑ Less cold starts per day for several major categories
  - ❑ Less number of idle hours per day for most categories

Background

- HDTs activity profiles vary greatly by vocations
- 2010+ model year HDTs produce significant NOx Emissions during low speed and during cold start
  - Selective Catalytic Reduction (SCR) require to be at certain temperature to be effective.
- Lack of update on HDT activity data in EMFAC2014 and prior versions, including,
  - HDT Speed distribution in regions other than SCAG
  - Number of starts and soak time distribution
  - Idle hours

New Data Source: CE-CERT Study

- CARB's contract 13-301 (2014)
- Vehicle Sampling
  - (90) 2010 or newer HHDVs
  - (19) vocational/regional groups
- Data Collection
  - Wi-Fi or Cellular-based GPS & ECU data loggers
  - 1 Hz data frequency, a minimum of one month each
  - Vehicle and engine information
    - vehicle make, model, year, GVWR, engine model, etc.

Recruited Trucks by Vocation

- Line haul
- Drayage
- Agricultural
- Construction
- Food/beverage distribution
- Shuttle
- Refuse
- Transit buses
- Public work
- Utility
- Express buses






Speed Distribution

EMFAC2014 Speed Distribution

HHDT - SCAB

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.2	0.4	1.6	1.1	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.6	0.4	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.3	1.2	0.8	0.0	0.0	0.0
4	0.0	0.0	0.0	0.1	0.1	0.4	0.4	0.2	0.1	0.3	0.6	2.9	2.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.1	0.3	1.5	1.1	0.0	0.0	0.0
6	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.1	0.1	0.2	0.5	2.3	1.6	0.0	0.0	0.0
7	0.0	0.1	0.2	0.5	1.1	1.5	1.1	1.0	0.8	0.5	0.4	0.4	0.3	0.0	0.0	0.0
8	0.0	0.1	0.2	0.4	0.9	1.2	0.9	0.8	0.6	0.4	0.4	0.4	0.3	0.0	0.0	0.0
9	0.0	0.0	0.1	0.3	0.7	1.0	0.8	0.7	0.5	0.3	0.3	0.3	0.2	0.0	0.0	0.0
10	0.0	0.0	0.0	0.2	0.5	0.8	0.6	0.8	1.0	0.9	0.6	0.5	0.4	0.0	0.0	0.0
11	0.0	0.0	0.0	0.2	0.6	0.8	0.6	0.8	1.0	0.9	0.6	0.5	0.5	0.0	0.0	0.0
12	0.0	0.0	0.0	0.2	0.5	0.8	0.6	0.8	1.0	0.9	0.6	0.5	0.4	0.0	0.0	0.0
13	0.0	0.0	0.0	0.2	0.5	0.7	0.5	0.7	0.9	0.8	0.5	0.4	0.4	0.0	0.0	0.0
14	0.0	0.0	0.0	0.2	0.5	0.7	0.5	0.7	0.9	0.8	0.5	0.4	0.4	0.0	0.0	0.0
15	0.0	0.0	0.0	0.1	0.4	0.5	0.4	0.5	0.7	0.6	0.4	0.3	0.3	0.0	0.0	0.0
16	0.0	0.1	0.2	0.4	0.6	0.5	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
17	0.0	0.1	0.2	0.5	0.8	0.7	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.0	0.0	0.0
18	0.0	0.0	0.1	0.2	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0
19	0.0	0.1	0.2	0.4	0.6	0.5	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.5	0.3	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.1	0.3	1.4	1.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.1	0.3	1.3	0.9	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.5	0.4	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.5	0.4	0.0	0.0	0.0

HHDT – Non SCAB/MDAB

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.2	0.0	0.1	0.3	0.3	0.9	0.9	0.7	0.3	0.2	0.0	0.0	0.0
2	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0
3	0.0	0.0	0.0	0.2	0.0	0.1	0.2	0.3	0.7	0.7	0.5	0.2	0.1	0.0	0.0	0.0
4	0.0	0.0	0.1	0.4	0.1	0.2	0.4	0.6	1.7	1.6	1.3	0.5	0.3	0.0	0.0	0.0
5	0.0	0.0	0.0	0.2	0.0	0.1	0.2	0.3	0.9	0.8	0.7	0.3	0.2	0.0	0.0	0.0
6	0.0	0.0	0.0	0.3	0.0	0.2	0.4	0.5	1.3	1.2	1.0	0.4	0.2	0.0	0.0	0.0
7	0.1	0.2	0.2	0.4	0.6	0.8	1.4	0.9	1.3	0.8	0.9	0.2	0.2	0.0	0.0	0.0
8	0.1	0.2	0.2	0.3	0.5	0.7	1.1	0.7	1.1	0.6	0.7	0.1	0.1	0.0	0.0	0.0
9	0.0	0.1	0.1	0.3	0.4	0.6	0.9	0.6	0.9	0.5	0.6	0.1	0.1	0.0	0.0	0.0
10	0.0	0.2	0.2	0.3	0.3	0.6	0.9	1.0	0.5	0.9	1.2	0.1	0.2	0.0	0.0	0.0
11	0.0	0.2	0.2	0.3	0.3	0.7	0.9	1.0	0.5	0.9	1.2	0.1	0.2	0.0	0.0	0.0
12	0.0	0.2	0.2	0.3	0.3	0.6	0.9	1.0	0.5	0.9	1.2	0.1	0.2	0.0	0.0	0.0
13	0.0	0.0	0.1	0.2	0.2	0.3	0.8	0.7	0.9	0.8	1.4	0.2	0.1	0.0	0.0	0.0
14	0.0	0.0	0.1	0.2	0.2	0.3	0.8	0.7	0.9	0.8	1.5	0.2	0.1	0.0	0.0	0.0
15	0.0	0.0	0.1	0.1	0.2	0.2	0.6	0.5	0.7	0.6	1.1	0.1	0.1	0.0	0.0	0.0
16	0.0	0.0	0.0	0.1	0.1	0.3	0.6	0.4	0.4	0.2	0.5	0.1	0.0	0.0	0.0	0.0
17	0.0	0.0	0.1	0.1	0.1	0.4	0.9	0.5	0.5	0.2	0.8	0.1	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.2	0.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.2	0.7	0.7	0.5	0.2	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3	0.8	0.9	0.7	0.2	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3	0.8	0.9	0.6	0.2	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.3	0.1	0.0	0.0	0.0

- Speed profiles vary in SCAG vs. non-SCAG areas
  - Updated HD speed profiles will only apply to non-SCAG areas
- No VMT above 70 mph
- Barely any VMT in low speed bins (5~15 mph) : 2~3%
- Activities spread out through the day

New Vocational Speed Distributions

In-State HHD Tractor

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.3	1.2	1.3	0.4	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.2	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.8	1.0	0.5	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	1.1	3.0	2.0	0.1	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	1.0	1.4	0.6	0.0	0.0
6	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.6	1.8	1.4	0.6	0.0	0.0
7	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.5	1.0	2.5	1.8	0.6	0.0	0.0
8	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.8	2.2	1.4	0.1	0.0	0.0
9	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.7	2.3	0.8	0.2	0.0	0.0
10	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	1.1	2.8	1.0	0.1	0.0	0.0
11	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.9	3.0	1.1	0.1	0.0	0.0
12	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.4	1.0	2.8	1.1	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.8	2.7	0.9	0.1	0.0	0.0
14	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.7	2.8	1.1	0.2	0.0	0.0
15	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	2.0	0.7	0.2	0.0	0.0
16	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.3	1.0	0.7	0.0	0.0	0.0
17	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.5	1.3	0.9	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.7	0.9	0.1	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.1	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.5	1.2	0.9	0.2	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.9	0.9	0.4	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.2	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.3	0.0	0.0

In-State HHD Single

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.8	1.9	0.7	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	1.3	0.8	0.1	0.0	0.0	0.0
4	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	3.0	2.5	0.1	0.0	0.0	0.0
5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.4	1.2	0.0	0.0	0.0	0.0
6	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.3	0.3	0.7	1.4	1.2	0.3	0.0	0.0	0.0
7	0.1	0.3	0.3	0.4	0.4	0.5	0.4	0.3	0.3	0.6	1.7	1.4	1.1	0.1	0.0	0.0
8	0.1	0.2	0.3	0.4	0.6	0.7	0.6	0.4	0.3	0.4	0.7	1.0	0.7	0.0	0.0	0.0
9	0.1	0.2	0.3	0.4	0.5	0.7	0.5	0.3	0.2	0.3	0.6	0.8	0.4	0.0	0.0	0.0
10	0.2	0.3	0.4	0.6	0.8	1.0	0.8	0.4	0.2	0.3	0.5	0.4	0.3	0.0	0.0	0.0
11	0.2	0.3	0.4	0.6	0.8	1.2	1.0	0.5	0.2	0.2	0.3	0.3	0.6	0.0	0.0	0.0
12	0.2	0.3	0.4	0.6	0.9	1.1	0.9	0.4	0.2	0.2	0.4	0.4	0.4	0.0	0.0	0.0
13	0.1	0.2	0.3	0.5	0.7	0.9	0.7	0.4	0.2	0.2	0.4	0.5	0.4	0.1	0.0	0.0
14	0.1	0.3	0.3	0.5	0.6	0.8	0.7	0.4	0.3	0.3	0.6	0.4	0.4	0.0	0.0	0.0
15	0.0	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.6	1.1	0.4	0.2	0.0	0.0	0.0
16	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.3	0.7	0.5	0.0	0.0	0.0	0.0
17	0.0	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.8	1.0	0.2	0.0	0.0	0.0
18	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.1	0.0	0.0	0.0
19	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.8	0.5	0.1	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.3	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.6	1.4	0.7	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.4	1.5	0.7	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.6	0.2	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.3	0.0	0.0	0.0	0.0

- Activity patterns vary greatly by vocation
- More observations in both high and low end of speed bins than EMFAC2014 assumption. In particular, 2~21 % VMT observed in low speed bins (5-15 mph) depending on vocational category
- Wide spread activity in all hours of a day implies the lack of “cold starts”

New Vocational Speed Distributions

Inter-State HHDT

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.4	2.2	0.7	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.8	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.9	1.4	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.7	2.5	3.4	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	1.0	2.4	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	1.6	3.2	0.0	0.0	0.0
7	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.5	1.7	4.9	0.0	0.0	0.0
8	0.1	0.2	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.3	0.5	1.2	2.1	0.0	0.0	0.0
9	0.1	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.3	1.2	1.3	0.0	0.0	0.0
10	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.4	1.8	2.7	0.0	0.0	0.0
11	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.4	2.0	3.4	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.5	1.9	3.2	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.5	1.6	3.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.5	1.6	2.9	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.4	1.1	2.2	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.6	1.4	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.8	1.9	0.1	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.9	0.1	0.0	0.0
19	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.6	0.1	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.1	0.0	0.0
21	0.2	0.7	0.3	1.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.6	2.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.8	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.6	0.0	0.0	0.0

SWCV

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.1	1.7	1.6	1.1	1.2	0.8	0.6	0.5	0.3	0.2	0.1	0.3	0.0	0.0	0.0	0.0
7	1.3	1.6	1.7	0.9	0.9	0.9	0.8	0.6	0.6	0.5	0.5	1.2	0.0	0.0	0.0	0.0
8	1.2	1.3	1.3	1.0	1.2	1.2	1.3	1.5	1.7	1.8	1.5	2.7	0.0	0.0	0.0	0.0
9	1.3	1.6	1.4	1.0	1.1	1.1	1.1	1.0	1.0	1.1	0.8	0.7	0.0	0.0	0.0	0.0
10	1.2	1.5	1.4	1.0	1.2	1.2	1.3	1.3	1.0	0.9	0.6	1.0	0.0	0.0	0.0	0.0
11	0.9	1.1	1.2	1.2	1.6	1.5	1.8	2.1	2.3	2.0	1.2	1.2	0.0	0.0	0.0	0.0
12	0.5	0.4	0.5	0.7	1.0	1.0	1.1	1.2	1.3	1.0	0.8	0.8	0.0	0.0	0.0	0.0
13	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.2	0.1	0.0	0.0	0.0
14	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
15	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Construction HHDT

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.7	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.3	0.2	0.2	1.5	0.0	0.0	0.0	0.0
4	0.1	0.1	0.1	0.1	0.3	0.3	0.4	0.5	0.7	0.3	0.5	3.2	0.5	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.6	0.4	1.1	0.9	0.0
6	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.5	1.4	1.2	0.6	0.6	0.1
7	0.1	0.2	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	2.9	1.6	0.0	0.0	0.0
8	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.6	0.6	0.6	1.8	0.7	0.0	0.0	0.0
9	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.5	1.8	0.9	0.1	0.0	0.0
10	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	2.1	0.9	0.0	0.0	0.0
11	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.6	2.3	1.0	0.0	0.0	0.0
12	0.1	0.2	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.7	2.0	1.0	0.0	0.0	0.0
13	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.6	1.8	1.0	0.0	0.0	0.0
14	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.6	1.8	1.0	0.0	0.0	0.0
15	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	1.0	0.8	0.2	0.1	0.0
16	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.5	0.3	0.2	0.0
17	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.7	0.9	0.3	0.1	0.0
18	0.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	1.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	1.7	1.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	1.4	1.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Utility HHDT

Hour of Day	Speed Bin 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1	0.0	0.1	0.2	0.1	0.2	0.2	0.2	0.5	0.4	0.4	1.0	0.7	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0
3	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.5	0.8	0.3	0.0	0.0	0.0	0.0
4	0.1	0.1	0.2	0.2	0.1	0.3	0.3	0.7	0.7	1.0	1.5	1.8	0.0	0.0	0.0	0.0
5	0.0	0.1	0.1	0.1	0.2	0.2	0.5	0.9	0.5	0.2	0.6	0.2	0.0	0.0	0.0	0.0
6	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.5	0.7	1.2	1.8	0.0	0.0	0.0	0.0
7	0.3	2.0	1.0	0.2	0.3	0.4	0.5	0.7	0.8	0.7	1.0	0.2	0.0	0.0	0.0	0.0
8	0.1	0.4	0.3	0.3	0.4	0.6	0.7	0.9	1.0	0.8	0.7	0.2	0.0	0.0	0.0	0.0
9	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.8	0.8	0.6	0.6	0.2	0.0	0.0	0.0	0.0
10	0.1	0.3	0.3	0.3	0.3	0.4	0.5	0.8	0.8	0.7	1.2	0.7	0.0	0.0	0.0	0.0
11	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.7	0.7	1.1	0.9	0.0	0.0	0.0	0.0
12	0.1	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	1.1	0.8	0.0	0.0	0.0	0.0
13	0.1	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	1.1	0.8	0.0	0.0	0.0	0.0
14	0.1	0.2	0.3	0.3	0.3	0.4	0.5	0.6	0.6	0.6	1.1	0.8	0.0	0.0	0.0	0.0
15	0.0	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.8	0.6	0.0	0.0	0.0	0.0
16	0.0	0.1	0.2	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.0	0.0	0.0	0.0
17	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.4	0.4	0.3	0.0	0.0	0.0	0.0
18	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
19	0.0	0.1	0.2	0.1	0.2	0.2	0.3	0.4	0.2	0.1	0.4	0.4	0.0	0.0	0.0	0.0
20	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.0
21	0.0	0.1	0.2	0.1	0.2	0.3	0.3	0.3	0.4	0.3	0.5	0.5	0.0	0.0	0.0	0.0
22	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.5	0.4	0.4	0.5	0.1	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.4	0.1	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.4	0.2	0.0	0.0	0.0	0.0

HD Starts per day
&
Soak Time Distribution

EMFAC 2014 Assumptions

- Source: CE-CERT 2009 telematics data
- Number of starts per day

Truck Service Type	Cold Start	Warm Start	Cold and Warm Total
Long-Haul	1	1.53	2.53
Short-Haul	1	1.04	2.04
Drayage	1	1.76	2.76

- A cold start is defined as an engine start after soaking for 12 hours or longer (overnight soak)
- A warm start is defined as an engine start after soaking for 30 minutes or longer but less than 12 hours
- Starts with soaking time less than 30 minutes are not accounted for

New Starts per Day Assumption

Truck Vocational Category	Starts per Day *
Inter-State Trucks	10.80
In-State Tractor Trucks	14.80
In-State Single Trucks	11.66
Drayage Trucks	12.40
Agriculture Trucks	4.10
Construction Trucks	5.91
Solid Waste Collection Trucks	3.80
Public Trucks	2.24
Utility Trucks	10.90

* Starts here includes all hot, warm and cold starts

Soak Time Distribution

Examples

Instate Tractor

Hour of Day	Soak Time (minutes)																		
	5	10	20	30	40	50	60	120	180	240	300	360	420	480	540	600	660	720	721+
1	3.7	0.7	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
2	5.4	1.0	0.4	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
3	0.7	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.3	0.2	0.7	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5	1.1	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2
6	2.1	0.7	0.3	0.1	0.1	0.1	0.1	0.3	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.3
7	1.5	0.3	0.7	0.1	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
8	2.3	0.7	0.6	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
9	3.1	0.3	0.6	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	2.4	0.7	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
11	4.1	0.7	0.5	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
12	3.6	0.7	0.7	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	3.5	0.4	0.5	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
14	2.7	1.1	0.4	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
15	3.1	0.5	0.7	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
16	1.9	0.7	0.4	0.3	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	2.2	0.6	0.3	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
18	2.4	0.7	0.4	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	2.4	0.3	0.3	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
20	2.9	0.5	0.3	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	2.8	0.5	0.3	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
22	2.6	0.4	0.3	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	3.7	0.6	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
24	3.1	0.5	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

- 1.3 starts (9%) with greater than 30 minutes soak (cold or warm starts)
- Continuous operation throughout the day

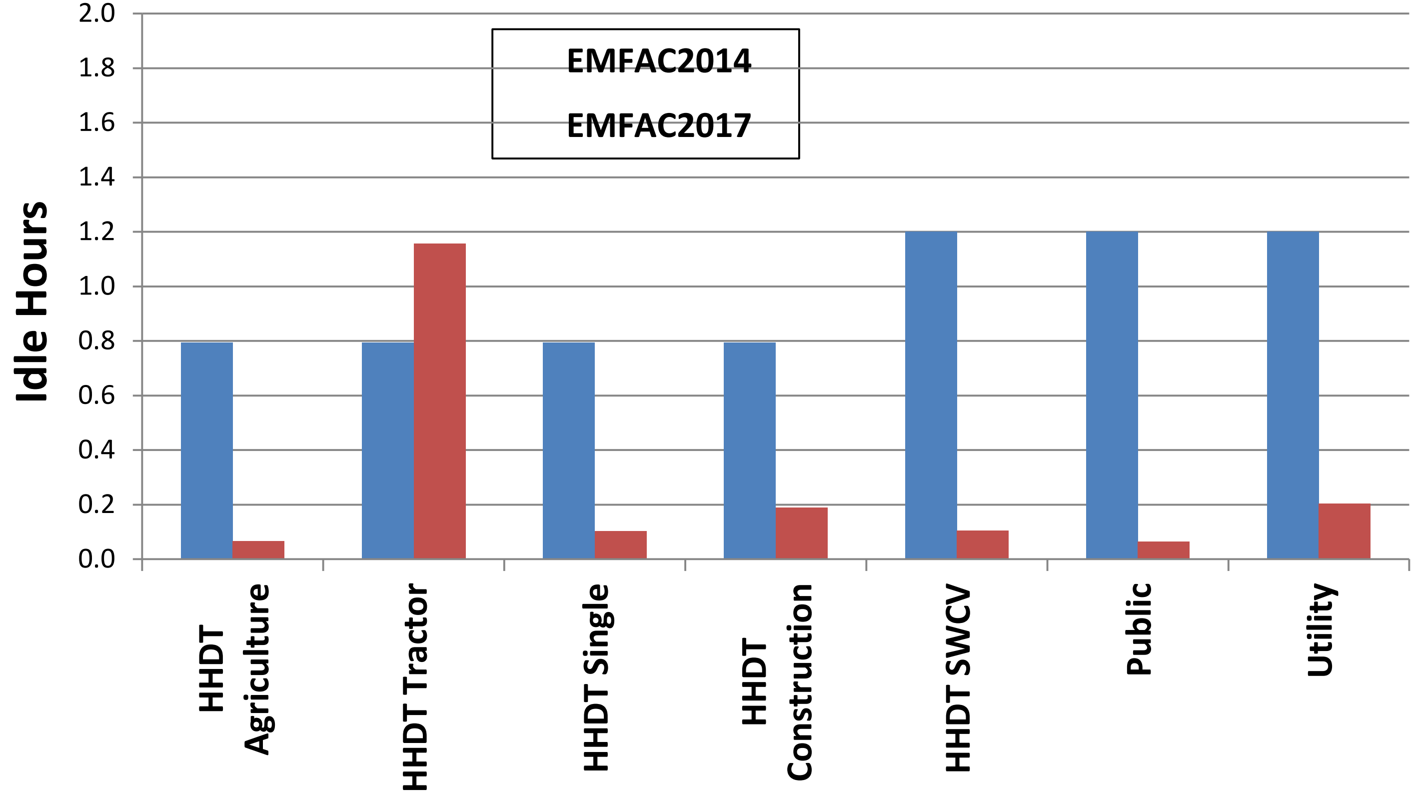
Instate Singles

Hour of Day	Soak Time (minutes)																		
	5	10	20	30	40	50	60	120	180	240	300	360	420	480	540	600	660	720	721+
1	2.3	0.6	0.6	0.1	0.2	0.3	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
2	1.7	0.5	0.5	0.2	0.1	0.2	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
3	1.2	0.5	0.3	0.1	0.2	0.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.3	0.6	0.2	0.1	0.2	0.1	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.9	0.4	0.3	0.1	0.1	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6	0.9	0.5	0.3	0.0	0.1	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3
7	0.9	0.4	0.4	0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.7
8	0.6	0.5	0.6	0.2	0.1	0.1	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4
9	0.6	0.3	0.6	0.2	0.1	0.2	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10	0.4	0.2	0.4	0.3	0.2	0.1	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
11	0.4	0.3	0.4	0.3	0.2	0.2	0.1	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.4	0.2	0.5	0.3	0.2	0.2	0.1	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.4	0.2	0.4	0.2	0.2	0.2	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	1.5	0.8	0.4	0.3	0.2	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.3
15	1.9	0.6	0.4	0.3	0.2	0.2	0.1	0.3	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.3
16	2.7	0.5	0.3	0.2	0.2	0.1	0.1	0.4	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
17	2.5	0.4	0.5	0.2	0.2	0.1	0.0	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
18	2.7	0.4	0.2	0.2	0.3	0.1	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
19	2.4	0.4	0.4	0.3	0.2	0.1	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
20	3.9	0.7	0.6	0.4	0.3	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.4
21	3.2	0.5	0.7	0.6	0.3	0.2	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22	2.1	0.7	0.7	0.4	0.4	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
23	2.3	0.4	0.7	0.3	0.4	0.3	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	2.5	0.3	0.5	0.3	0.3	0.2	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

- 3.7 starts (32%) with greater than 30 minutes soak
- Likely more start emissions

Idle hours

Extended Idle Hours per Day



- 2008+ model year HHDTs in calendar year 2008 and beyond

Summary

- Activity profiles vary greatly by vocational category
- For most categories, greater portion of low-speed activities observed than previous EMFAC's assumption
- Lower number of cold starts per day for several major categories including line hauls and drayage trucks
- Lower number of idle hours per day for most categories

Lead Staff Contact

Zhen Dai
Air Resources Engineer
(916) 322-7455
zhen.dai@arb.ca.gov

or

EMFAC@arb.ca.gov

GHG Module

Introduction

- CO_2 emissions can be estimated in EMFAC2014 or prior, but they do not represent CARB's official GHG inventory.
- CH_4 is directly estimated in EMFAC2014, using organic gas speciation profiles.
- N_2O is not included in EMFAC2014 or prior.
- GHG estimation will be improved in EMFAC2017 in order to support official CARB efforts.
- EMFAC2017 will include 3 GHGs: CO_2, CH_4, N_2O.
  - F-gases are not included in EMFAC as they are already provided from CARB's ODS Substitutes Emissions Model.

Major updates to EMFAC

- CO_2 will be calculated based on complete combustion of fuel.
- EMFAC2017 fuel consumption will be matched to BOE fuel sales.
- Fuel efficiency assumptions have been updated based on federal fuel efficiency data.
- Analysis of HD testing data indicates HD N_2O emission factors significantly higher than previously thought.
  - CARB, WVU, and SCAQMD testing data, UC Berkeley study
- Preliminary results show that the new methodology will increase total on-road CO2e emissions estimated in EMFAC by ~5%.
  - CO_2 estimates increase by ~3%, CH_4 essentially no change, N_2O increase by ~1.5x

CO_2 calculation approach

- CO_2 currently calculated in EMFAC2014 and prior, using g/mi emission rates from vehicle testing data.
- EMFAC2017 will calculate CO_2 emissions based on complete combustion of fuel.
- The new method is consistent with CARB's official GHG emission inventory, U.S. EPA, and IPCC recommended approaches.
- CO_2 estimates from complete combustion of fuel will be slightly (~3%) higher than in EMFAC2014.

CO_2 calculation approach (Cont'd)

- The new approach will disaggregate a fuel blend into major components, and then calculate CO_2 from each component of the fuel. Add up all components to get total CO_2 emissions.

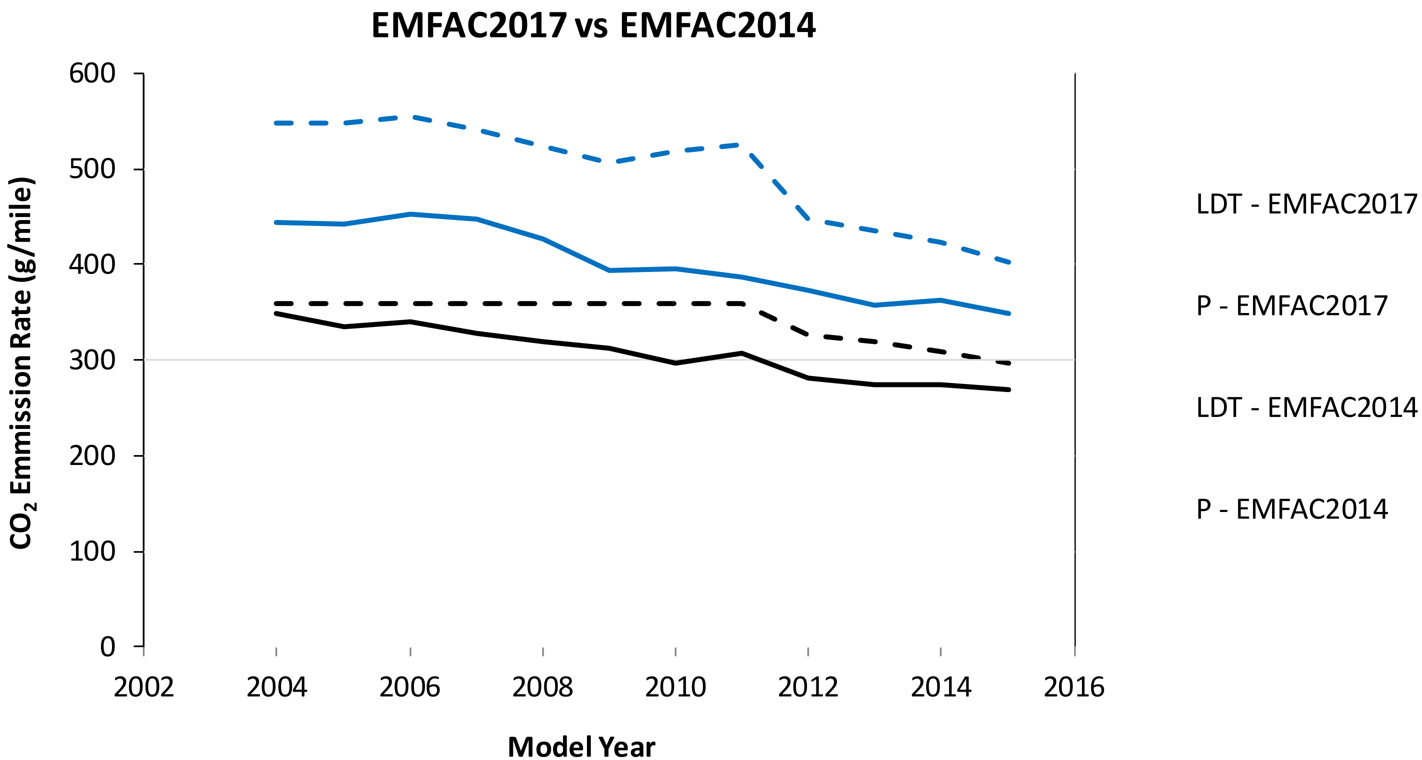
CO_2 = Fuel Consumption * Blend Proportion * CO_2 Emission Factor * Heat Content

- Uses BOE, MRR, CEC, U.S. EPA data sources.
- EMFAC2017 fuel consumption is matched to BOE numbers to ensure CO_2 estimates aligned with real-world official mobile fuel sales in California.

Fleet average fuel efficiency and CO_2 emission rates

- Identify the fuel efficiency rating for California's vehicle fleet:
  - Decode VIN numbers in DMV registration data to obtain make, model, and other vehicle attributes
  - Match make, model, and vehicle attributes to a record in fueleconomy.gov to obtain EPA rated fuel efficiency for each individual vehicle.
- The EPA rated fuel efficiency values are then used to calculate the California fleet average fuel efficiency and CO_2 emission rates.

Comparison of fleet average CO_2 emission rates



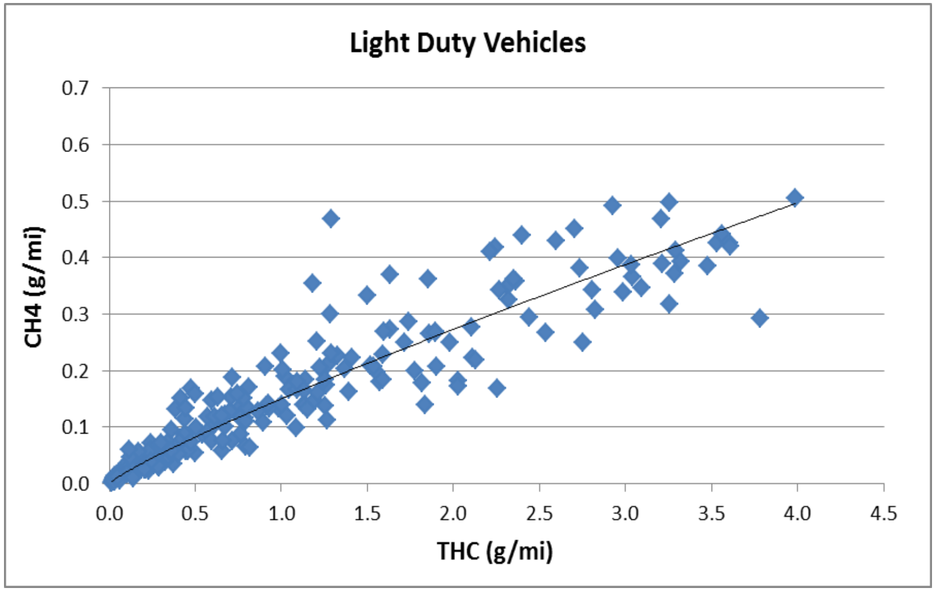
Updated fleet average CO_2 emission rates by model year are lower in EMFAC2017.

CH_4 calculation approach

- CH_4 currently calculated in EMFAC2014 and prior from THC, using speciation profiles.
- EMFAC2017 will
  - estimate LDV CH_4 as a function of THC emissions.
  - continue using speciation to estimate HD CH_4 emissions.
- Utilize the latest available ARB vehicle testing data.

CH_4 calculation approach (cont'd)

- Use FTP composite emission rates, considered as weighted average of major emission processes.
- Develop a relationship of CH_4 and THC from LDVs.
- A power function better captures the majority of activity which occurs at low THC emission rate levels.



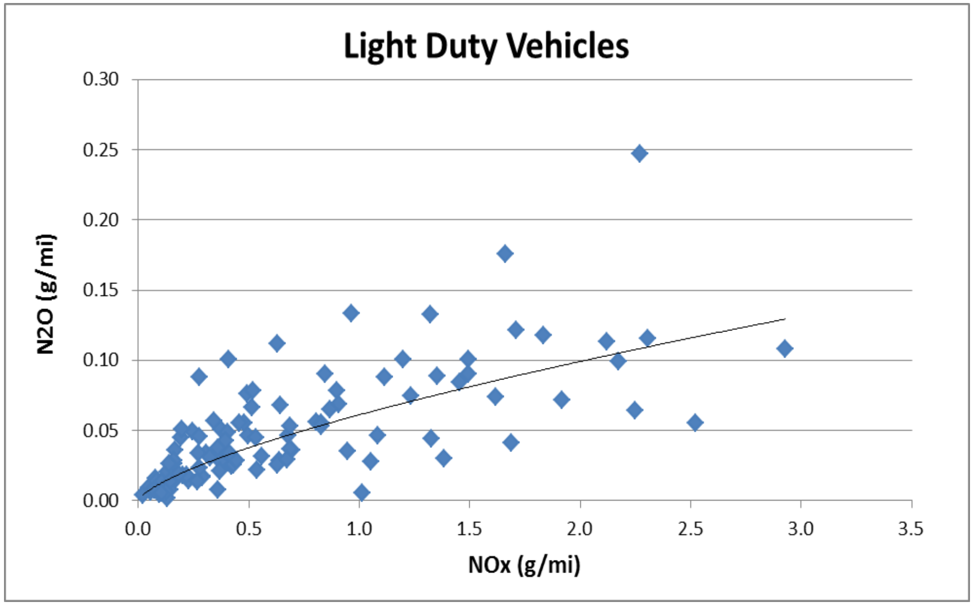
Source: CARB VEDS Data

N_2O calculation approach

- N_2O was not directly estimated in EMFAC2014 or prior.
- Currently, N_2O is calculated off-model.
- EMFAC2017 will
  - estimate LDV N_2O as a function of NOx emissions.
  - estimate HD diesel N_2O using fuel consumption and an improved fuel-based emission factor.
- Utilize the latest available vehicle testing data:
  - CARB Surveillance Data (for LDV)
  - "Cross California" campaign data (for HD)

LDV N_2O calculation approach

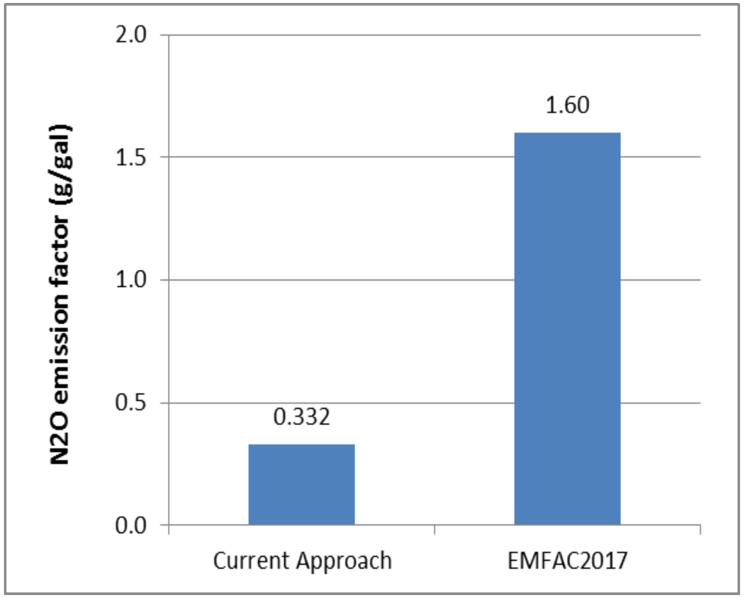
- As with the CH_4 analysis, use FTP composite emission rates.
- Develop a relationship of N_2O and NOx from LDVs.
- A power function better captures the majority of activity which occurs at low NOx emission rate levels.



Source: CARB Surveillance Data

HD N_2O calculation approach

- Currently, HD N_2O is calculated assuming 0.332 g/gal diesel.
- EMFAC2017 will estimate HD diesel N_2O using an improved fuel-based emission factor (1.60 g/gal).
- The updated emission factor is derived from the latest available vehicle testing data: "Cross California" campaign by CARB and WVU.



- The update is consistent with UC Berkeley's recent study on Port of Oakland truck emissions data.

CO_2 equivalent (CO2e)

- GHGs will also be provided in EMFAC2017 in units of CO2e, i.e., CO_2 equivalent.
- Use 100-year time horizon global warming potentials (GWPs) from Intergovernmental Panel on Climate Change's (IPCC) Forth Assessment Report (AR4).
- Consistent with the latest official GHG inventory of CARB.

Annualizing GHG estimates

- Use vehicle category-specific operation days to convert EMFAC's weekday output to annual.
- The GHG module will be able to generate annual emission estimates; e.g., in MMT CO2e per year.
- Annual fuel use estimates in EMFAC2017 match BOE fuel sales.

Summary

- The GHG module is a new addition to EMFAC, with methodology consistent with CARB's official GHG inventory.
- EMFAC2017 will include 3 GHGs from on-road mobile sources: CO_2, CH_4, and N_2O (as well as CO2e).
- EMFAC2017 will use a new method for calculating CO_2 from complete combustion of fuel.
- N_2O estimation will be substantially improved using new testing data for LDVs and HD vehicles.
- The overall change to CO2e in EMFAC from the new methodology is a ~5% increase, mainly driven by CO_2.

Lead Staff Contact

Guihua Wang, Ph.D.
Air Resources Engineer
(916) 324-9264
guihua.wang@arb.ca.gov

or

EMFAC@arb.ca.gov

Forecasting

Outline

- Introduction
- Modeling approach and data sources
- Historical and projected input data
- Overview of modeling results
- Summary and next steps

Introduction

- The project objective is to develop methodologies to forecast default VMT and vehicle population through 2050 for EMFAC.
- Use statewide historical socioeconomic data with regression analysis to develop California-specific econometric models.
- Apply the statistical models, along with projected input data, to forecast future statewide VMT, diesel consumption, and new sales of light-duty vehicles.
- EMFAC default VMT does not reflect the impact of SB 375.
- For air quality and climate change planning, CARB uses MPOs' data.

Statistical modeling approach

- Econometric approach
- Ordinary Least Squares (OLS)
- Linear functional forms
- Historical time series data through 2015
  - Historical data to be updated soon to include 2016

Statistical modeling approach (Cont'd)

- Selection of variables: consistent with economic theory
  - Reasonableness of coefficient magnitudes and signs
  - Significance criteria: t-statistic
  - R-squared and goodness of fit
- Consistent with published literature:
  - Lin and Zeng, 2013;
  - Lin and Prince, 2013;
  - Hughes, Knittel, and Sperling, 2008.

Data sources

- Data mostly from public agencies/entities
  - Department of Finance (DOF)
  - Board of Equalization (BOE)
  - Department of Motor Vehicles (DMV)
  - California Energy Commission (CEC)
  - U.S. Energy Information Administration (EIA)
  - U.S. Bureau of Economic Analysis (BEA)
  - UCLA Anderson Forecast

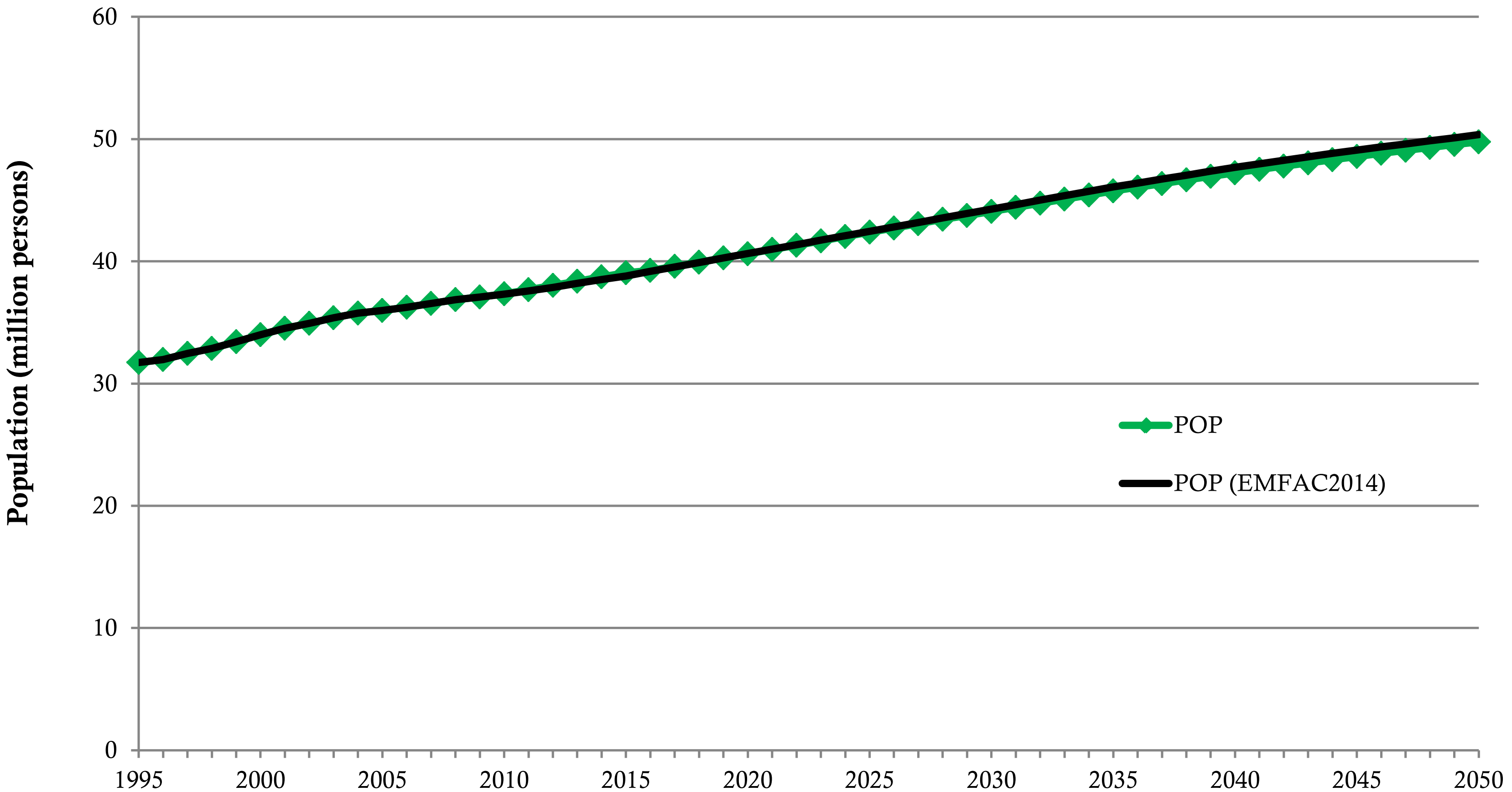
Historical & Projected Input Data

- Historical: 1995-2015
- Projected: 2016-2050

Preliminary regression models for EMFAC2017

- New LDV sales growth
  f (*Unemployment rate, Population, Housing starts*)
- LDV VMT growth
  f (*Unemployment rate, Population, Housing starts, Gas price*)
- HD VMT growth
  f (*Unemployment rate, Disposable income*)

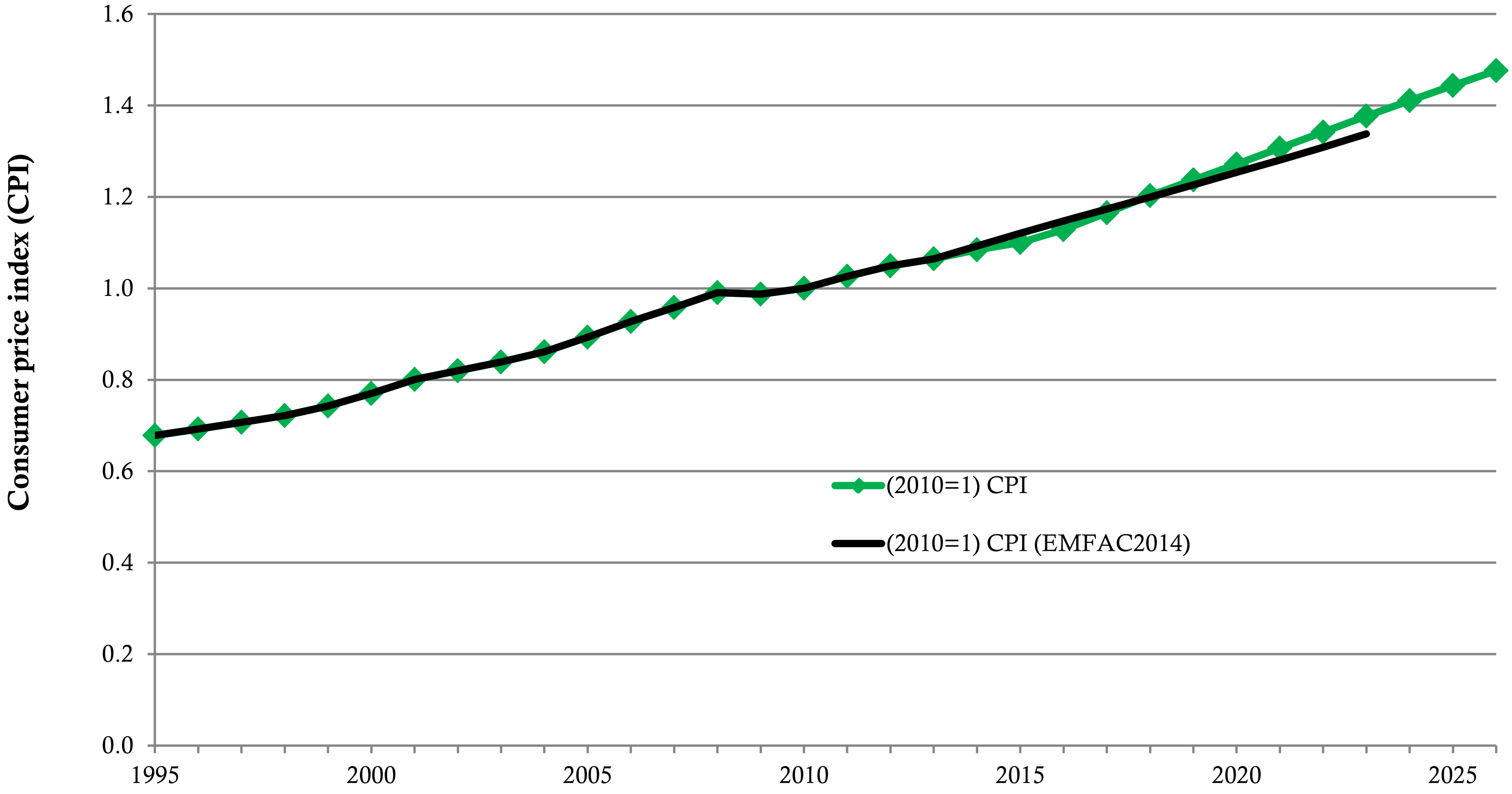
Human population



Human population:
DOF (1995-2015), DOF (2016-2050)

Human population (EMFAC2014):
DOF (1995-2013), DOF (2014-2050)

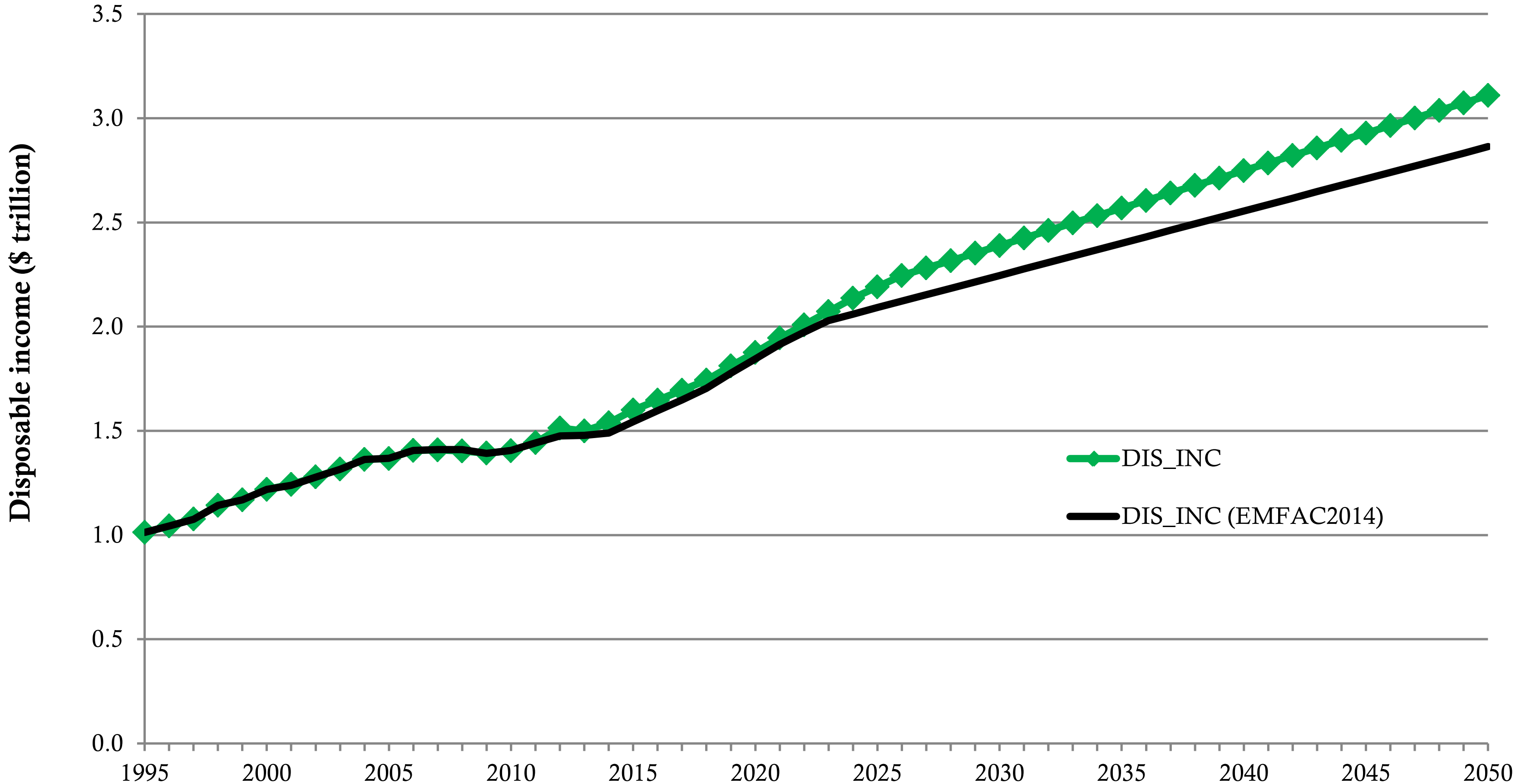
Consumer price index (CPI)



CPI: DOF (1995-2015), UCLA (2016-2026)

CPI: DOF (1995-2013), UCLA (2014-2023)

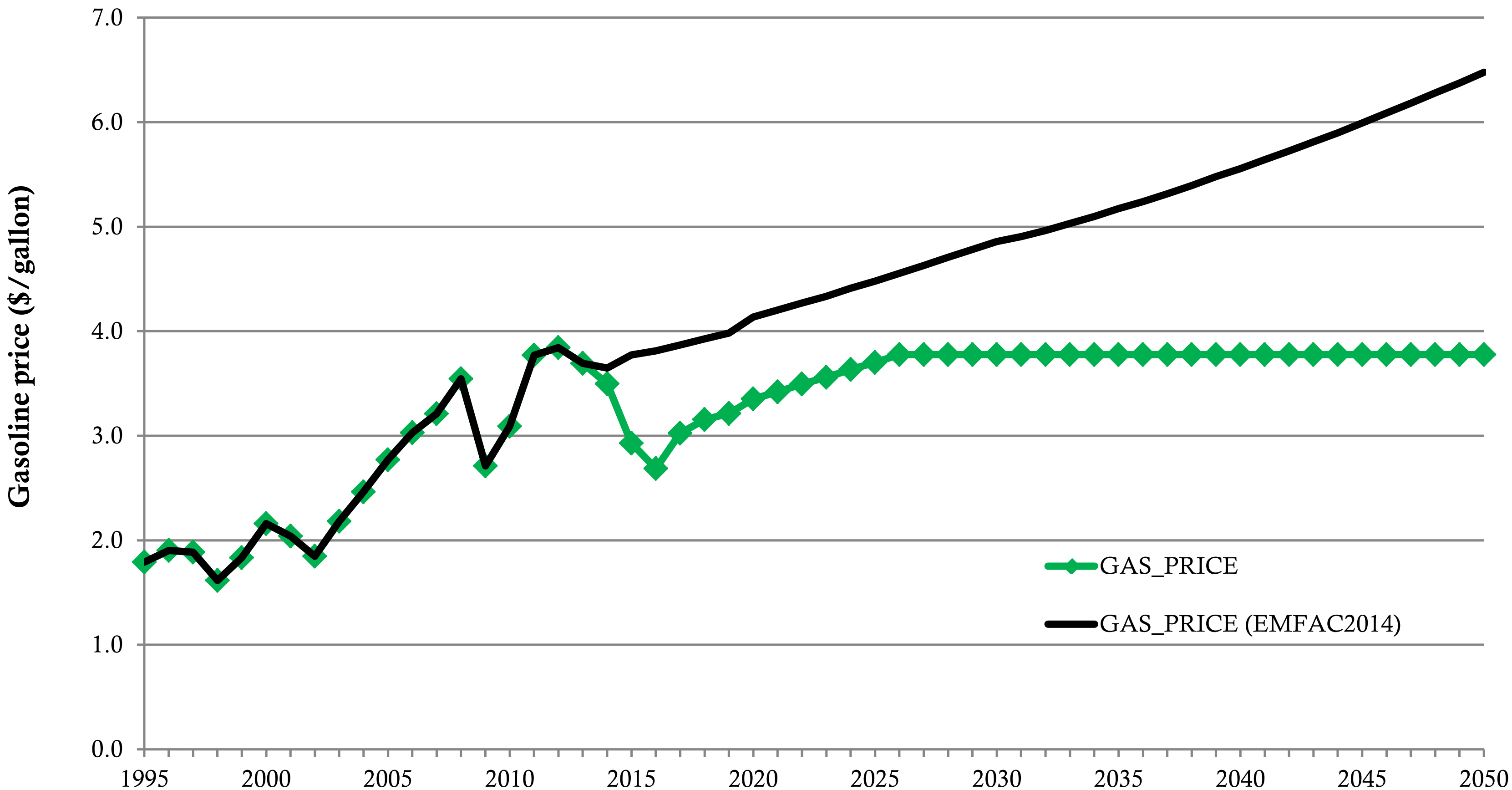
Disposable personal income



Disposable Income:
BEA (1995-2015), UCLA (2016-2026)
Linear Extrapolation of 1995-2026 for 2027+

Disposable Income (EMFAC2014):
BEA (1995-2013), UCLA (2014-2023)
Linear Extrapolation of 1995-2023 for 2024+

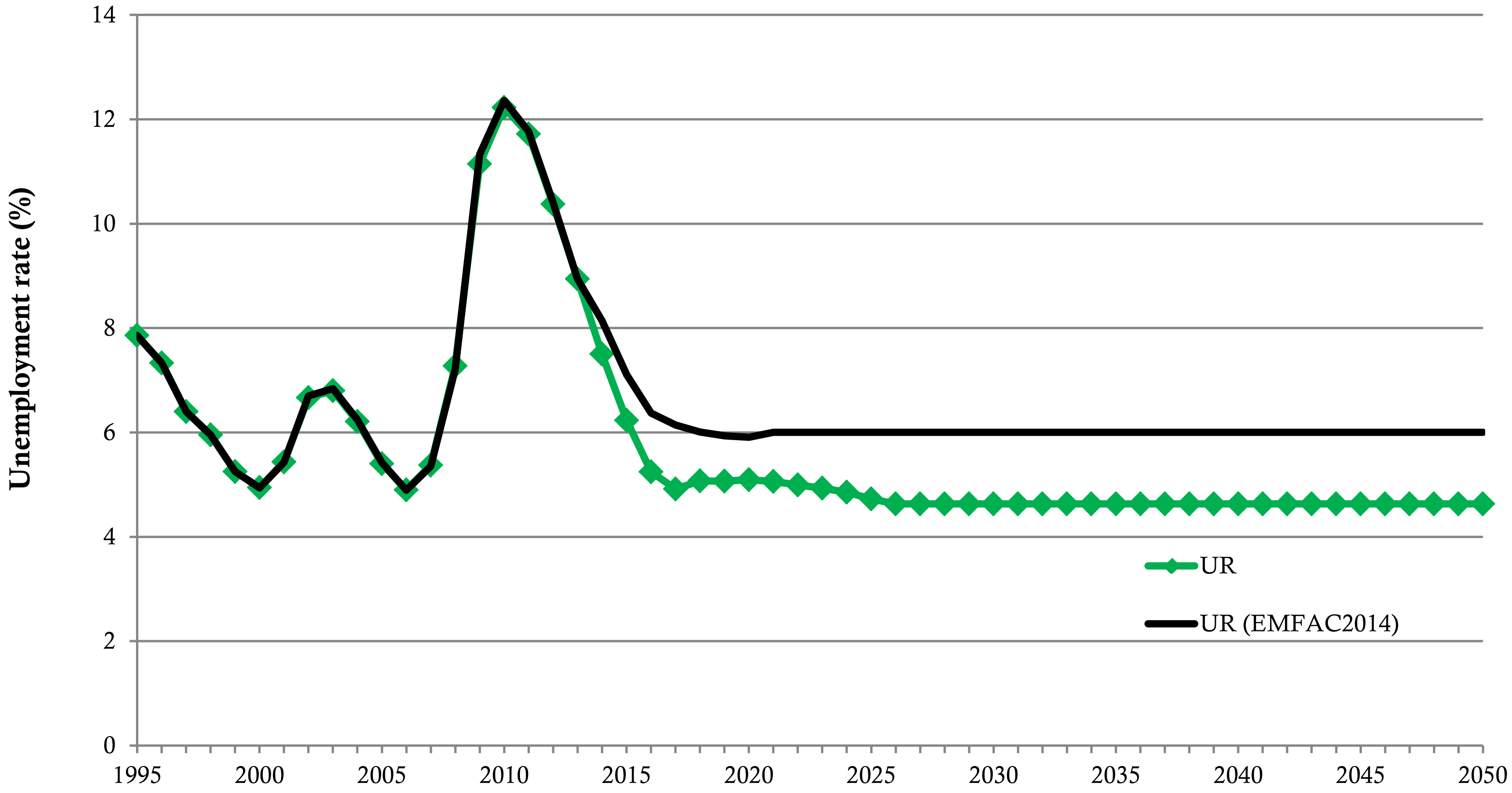
Gasoline price



GAS PRICE:
CEC (1995-2012), EIA (2013-2015), CEC (2016-2026)
Remain at the 2026 level for 2027+

GAS PRICE (EMFAC2014):
CEC (1995-2012), EIA (2013), CEC (2014-2050)

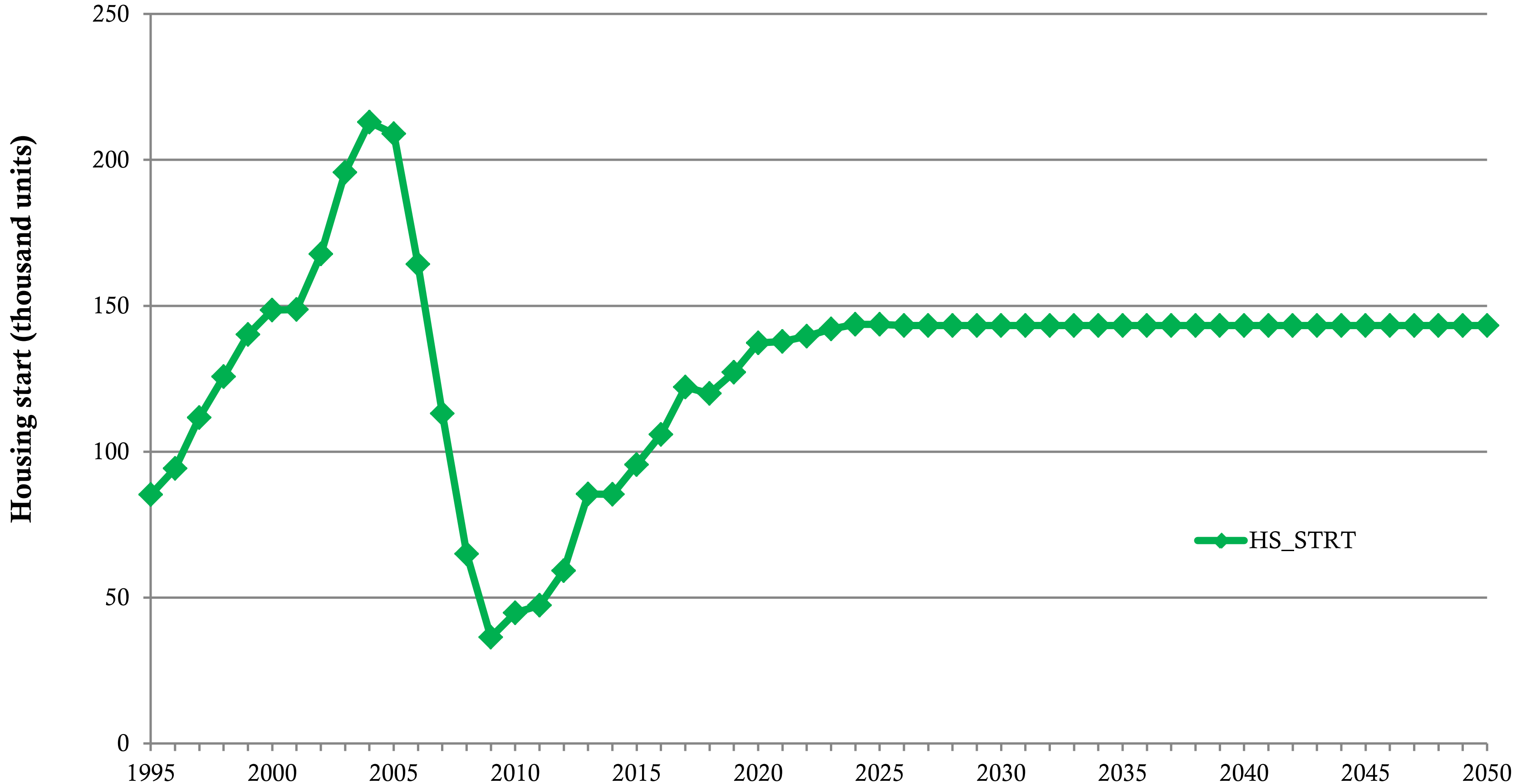
Unemployment rate



Unemployment Rate:
DOF (1995-2015), UCLA (2016-2026)
Remain at the 2026 level for 2027+

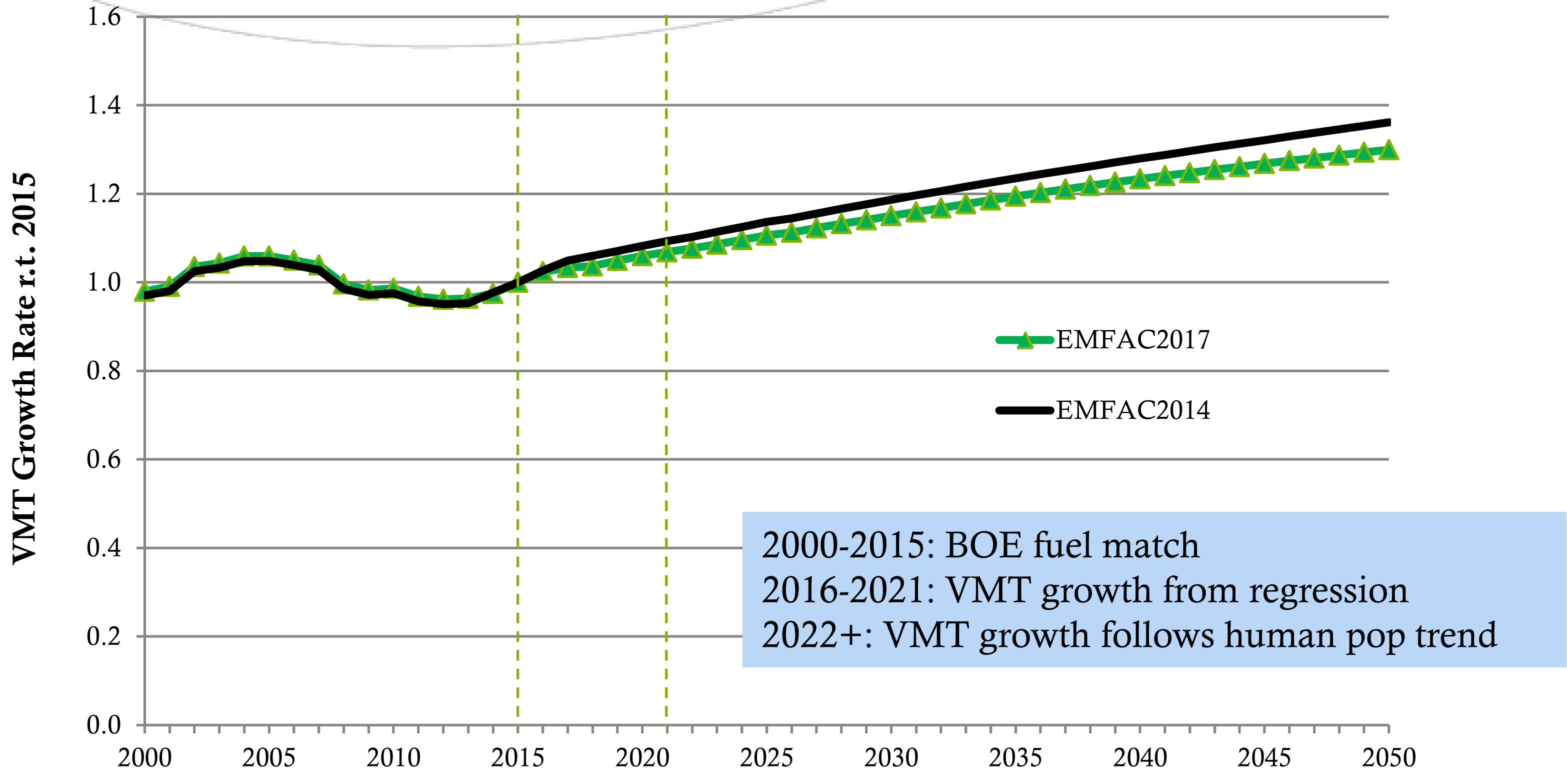
Unemployment Rate (EMFAC2014):
DOF (1995-2013), UCLA (2014-2020)
Remain constant for 2021+

Housing starts



Housing starts:
DOF (1995-2015), UCLA (2016-2026). Assume the national level growth ratio r.t. 2015 applies to CA). Remain at the 2026 level for 2027+

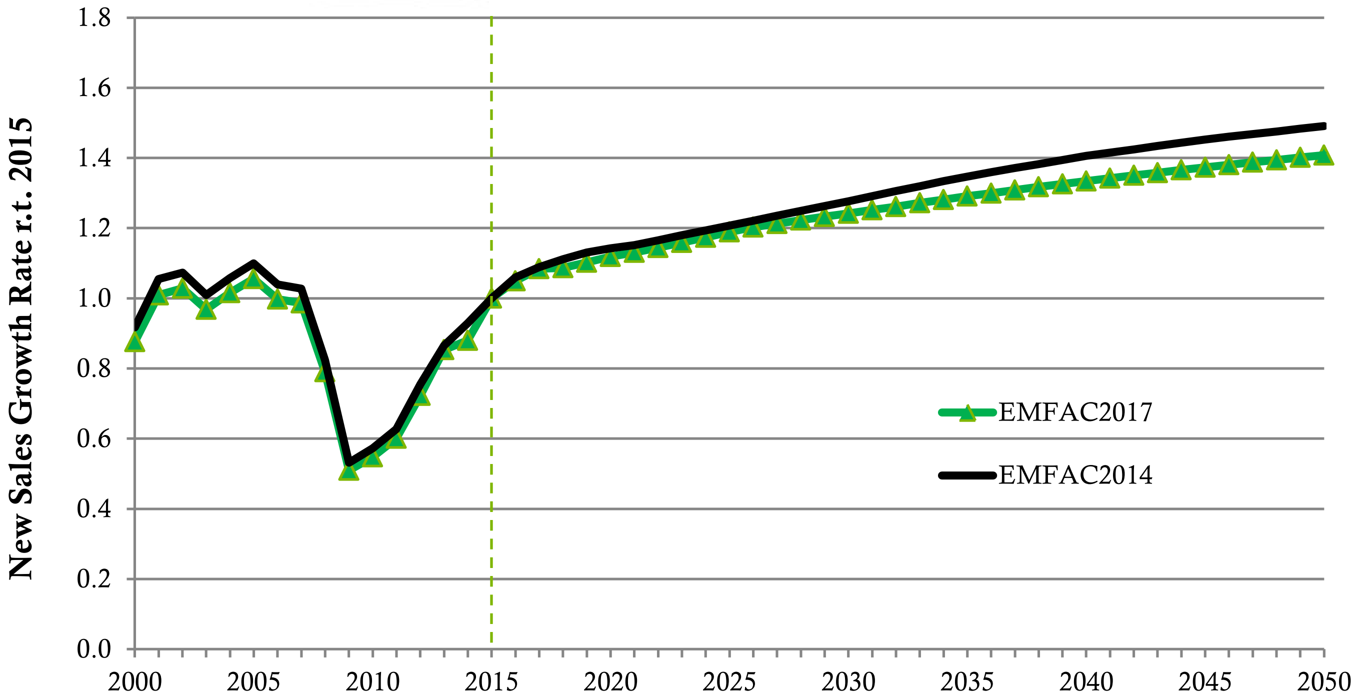
LDV VMT growth rates



LDV VMT for EMFAC2017 = f(Unemployment rate, Population, Housing start, Gas price)

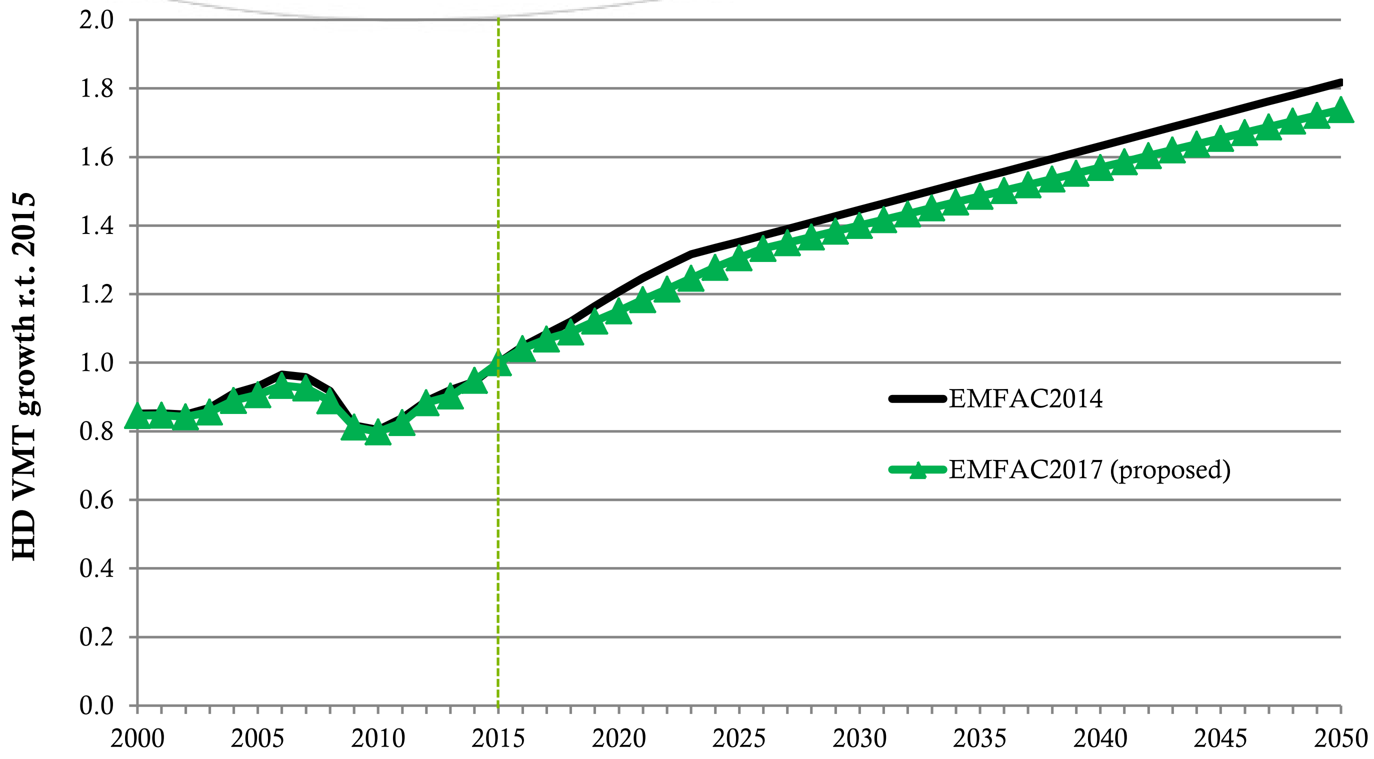
LDV VMT for EMFAC2014 = f(Disposable income, Nonfarm jobs, Gas price)

LDV new sales growth rates



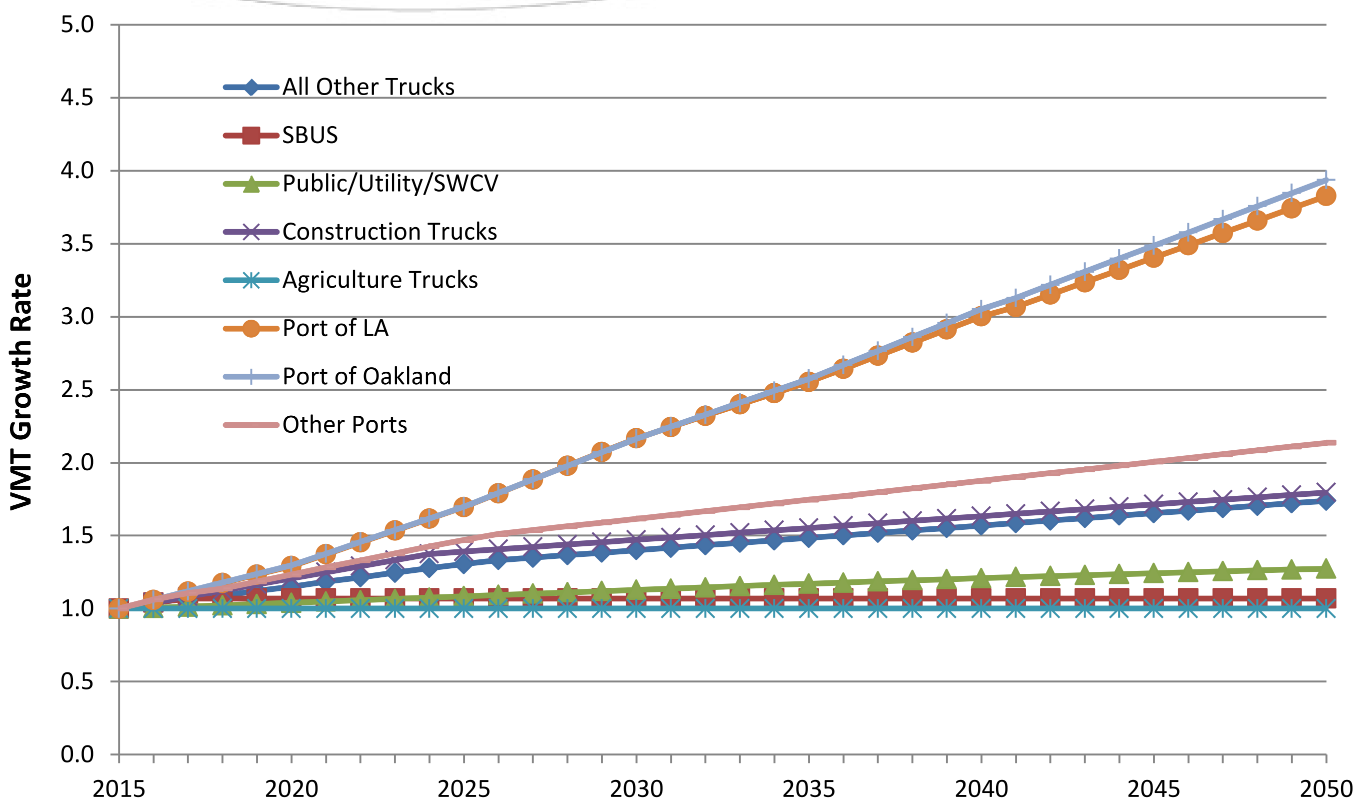
New LDV sales for EMFAC2017 = f(Unemployment rate, Population, Housing start)
New LDV sales for EMFAC2014 = f(Unemployment rate, Population, Gas price)

HD VMT growth rates



HD VMT for EMFAC2017 = f(Unemployment rate, Disposable income)
HD VMT for EMFAC2014 = f(Unemployment rate, Disposable income)

Vocation-specific HD VMT growth rates for EMFAC2017



HD new sales growth

- Same methodology as in EMFAC2014
- New sales growth for HD using AEO new sales data
- Vocation-specific growth rates for HD new sales (and VMT)

$$California\ New\ Sales\ growth\ rate\ =$$

$$AEO\ New\ Sales\ Growth\ Rate \times \frac{California\ VMT\ Growth\ Rate}{AEO\ Nationl\ VMT\ Growth\ rate}$$

Summary

- Multivariate regression analysis for vehicle activity forecasting.
  - Similar to the EMFAC2014 methodology
- The regression equations are based on historical data, so the forecasts are for business-as-usual (BAU) future conditions.
  - Default scenario of EMFAC2017
- LDV VMT growth follows the regression trend (short-term) and the human population growth trend (long-term).
- LDV new sales growth follows the regression trend.
- HD VMT and new sales growth trends are vocation-specific.

Next steps

- Include the latest available historical data: 2016 data become available
- Reflect the most recent economic forecast trends: 2016 forecasts
- Develop the best statistical models considering new available data
- Ongoing literature review

Lead Staff Contact

Guihua Wang, Ph.D.
Air Resources Engineer
(916) 324-9264
guihua.wang@arb.ca.gov

or

EMFAC@arb.ca.gov

Next Steps

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- Alpha Testing
  - ❑ An un-completed version of the model will be released to ARB's designated beta testers for beta testing
- Beta Testing
  - ❑ A revised version of the model reflecting feedback from beta testers.
- October Workshop
  - ❑ We'll have another workshop in October to mainly discuss impact of updates on criteria and GHG emission inventories

Preliminary Agenda for October's Workshop

i. Impact of Updates on PM, NOx, HC, and CO2 Inventories

ii. Final data updates (heavy duty truck emission rates and deterioration)

iii. Development of Advanced Transit Module

iv. Natural Gas Fleet in EMFAC2017

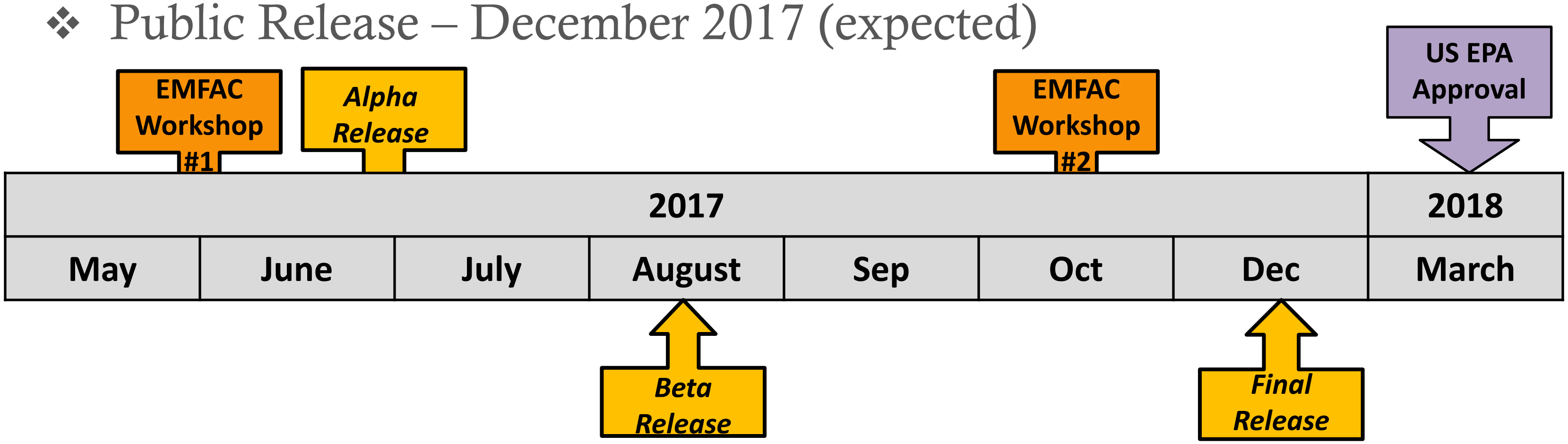
v. Update EMFAC2017 Assumptions Based on Findings from LEV 3 Midterm Review

vi. Methodologies to Reflect Impact of Regulations

vii. Future Plan for EMFAC202x

EMFAC2017 Schedule – Workshops/ Model Release

- Workshops
  - ❖ 1st Workshop (Methodology) – June 1, 2017
  - ❖ 2nd Workshop (Results) – October 2017
- Releases
  - ❖ Alpha Release –Mid-June 2017
  - ❖ Beta Release – August 2017
  - ❖ Public Release – December 2017 (expected)



On-going Data Collection

- Collaborating with industry partners to collect representative data for use in light and heavy duty modules of EMFAC
- Expanding vehicle emission testing
  - ❑ Dyno testing of late model cars and trucks
  - ❑ Truck & Bus Surveillance Program
  - ❑ PEMS testing of late model heavy duty trucks
  - ❑ Contracted field studies (real world emissions from heavy duty trucks)
  - ❑ High emitter evaporative emission testing

Questions and Comments

- For questions and comments please contact us at:

EMFAC@arb.ca.gov

- You can also visit our website at:

https://www.arb.ca.gov/msei/msei.htm