Workshop #2:
Reducing Residual Risk from Transport Refrigeration Units by Transitioning to Zero-Emission Technologies

California Air Resources Board

Overview

- Review
  - What is a TRU?
  - What are the Goals?
  - Background: Existing TRU Airborne Toxic Control Measure
  - Residual Public Health Risk
  - Questions So Far?
- Emission Inventory Update
- Surveys
- Incentive Programs
- Questions So Far?
- Control Measure Concepts
- Next Steps
- Questions and Discussion

Review

What Is a TRU?

- TRUs are refrigeration systems powered by an internal combustion engine (inside the housing)
- Control the environment of temperature sensitive products that are transported in refrigerated trucks, trailers, railcars, or shipping containers

Trailer and Truck TRUs

Railcar and Domestic Shipping Container TRUs

What Is a TRU Genset?

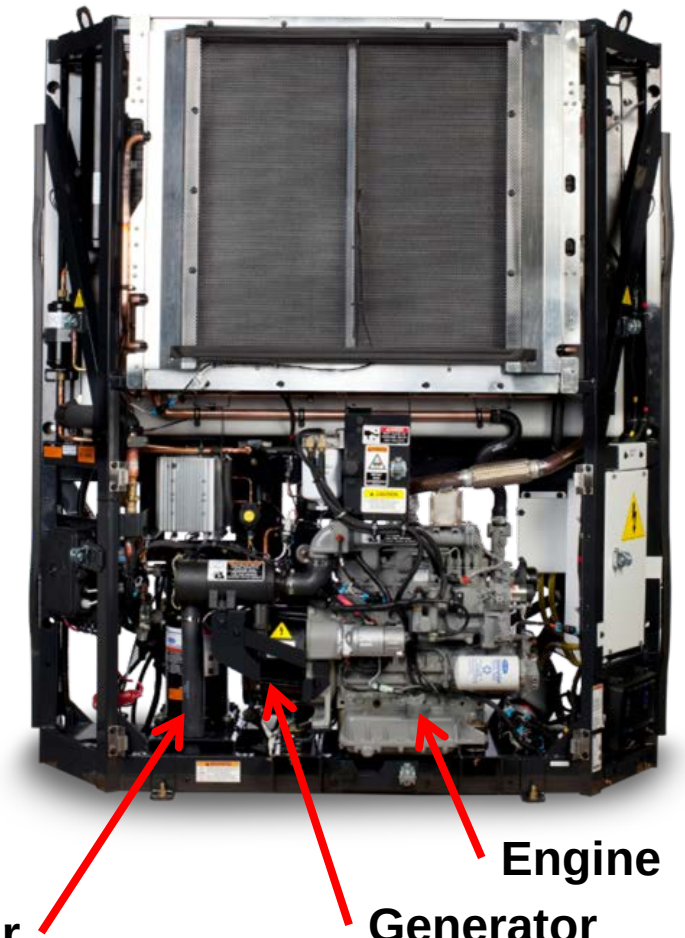
- TRU generator sets are generators powered by an internal combustion engine (inside the housing) designed and used to provide electric power to electrically driven refrigeration units of any kind
- This includes electrically powered refrigeration systems for semi-trailer vans and shipping containers

TRU Gensets

What Is an eTRU?

- "**Hybrid-electric TRUs**" are eTRUs powered by an integral diesel-fueled internal combustion engine, coupled to an electric generator that provides power to an electric motor-driven refrigeration system and fans within the same housing, and controls the environment of temperature sensitive products

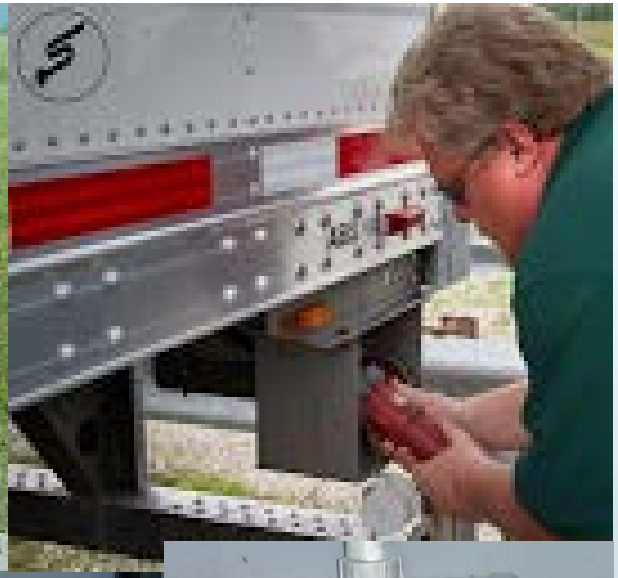
Carrier Vector 8500



What Is an eTRU? (cont'd)

- "**Electric-Standby-Equipped TRUs**" are TRUs that are equipped with an integral diesel-fueled internal combustion engine and electric-powered motor so the refrigeration system may be driven by either the diesel-fueled internal combustion engine or the integral electric motor

eTRU Plug-In Infrastructure



What are the Goals?

- Reduce exposure to air toxics
- Advance zero and near-zero emission technologies and support infrastructure
- Reduce smog-forming emissions by 80% in South Coast
- Reduce consumption of petroleum-based fuels by 50%, Statewide
- Deploy over 100,000 freight vehicles and equipment capable of zero emissions by 2030
- Reduce GHG emissions 40% below 1990 by 2030
- Reduce GHG emissions 80% below 1990 by 2050

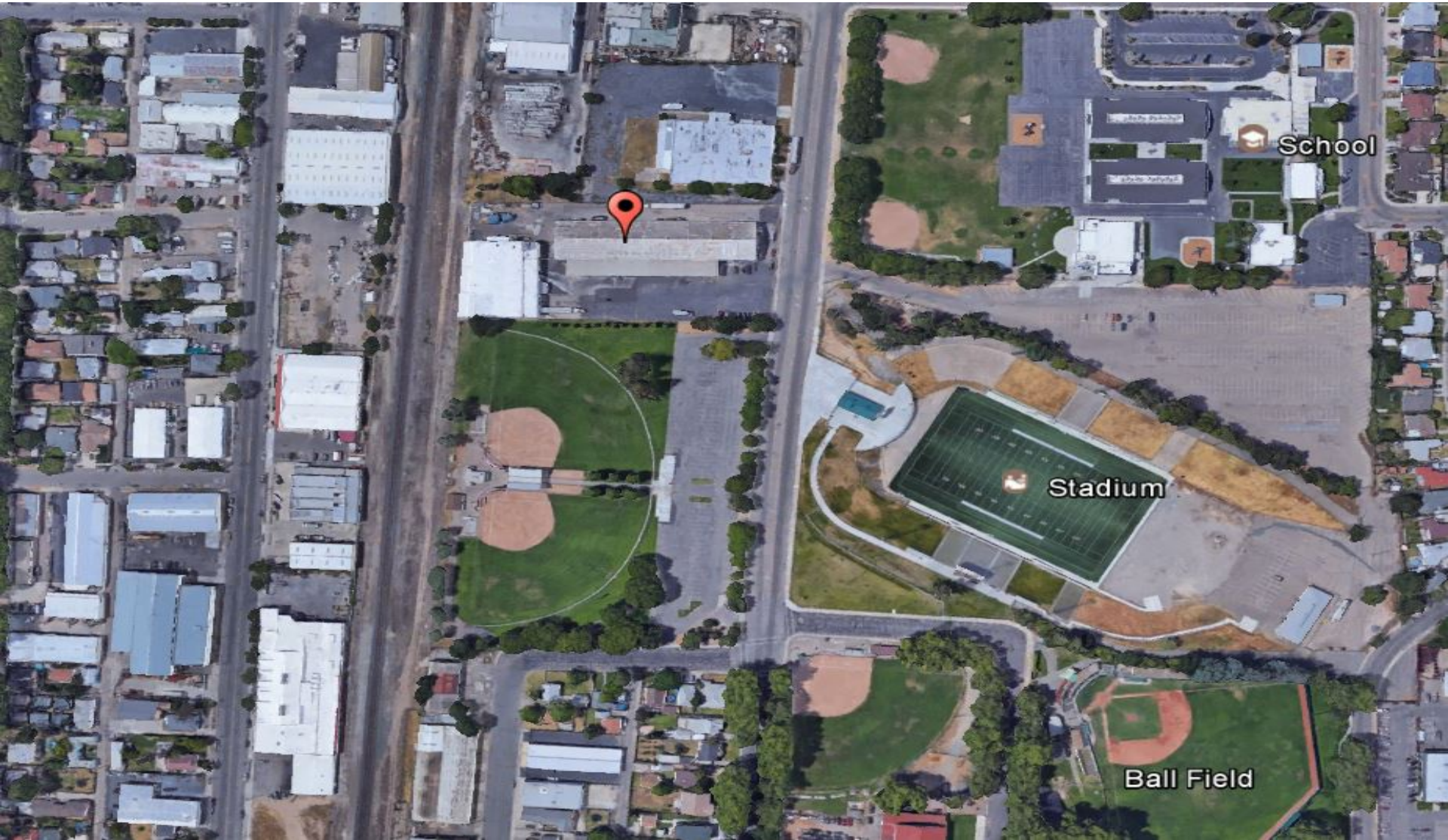
Background: Existing TRU Airborne Toxic Control Measure

- Originally adopted in 2003
- Purpose: reduce diesel PM emissions by at least 85%
- Engine must meet in-use performance standards by the end of the 7th year after the engine model year or TRU manufacture year
- All TRUs and TRU generator sets must eventually meet the Ultra-Low-Emission TRU In-Use Performance Standard
  - Example: MY 2010 TRU engines must meet the Ultra-Low-Emission TRU in-use performance standard by the end of 2017
- All California-based TRUs and TRU generator sets must be registered in ARB's Equipment Registration (ARBER) system
- Amended in 2010 and 2011

Residual Public Health Risk

- Preliminary analysis shows significant residual public health risk that is greater than action thresholds
- Examples:
  - Distribution centers
  - Grocery stores
  - Freight corridors

Residual Risk Near People



How Are TRUs Used?

- TRUs are used in the transport of many types of perishable products, including:
  - Food
  - Beverages
  - Pharmaceuticals
  - Flowers
  - Medical products
  - Industrial chemicals
- Cold storage

Why Are TRUs Used for Cold Storage?

- Used to meet needs when cold storage facility is full
- Supplement grocery store cold storage capacity
  - Grocery stores run out of built-in cold storage capacity around major holidays
- Loaded trailer wait times
  - Waiting for a loading dock to open
  - Loading days before Monday morning dispatch
- Event concessions
- Truck stops and rest areas

Questions, so far?

Emission Inventory Update

How Many TRUs and TRU Gensets Operate in California?

In 2017, ARBER data indicates:

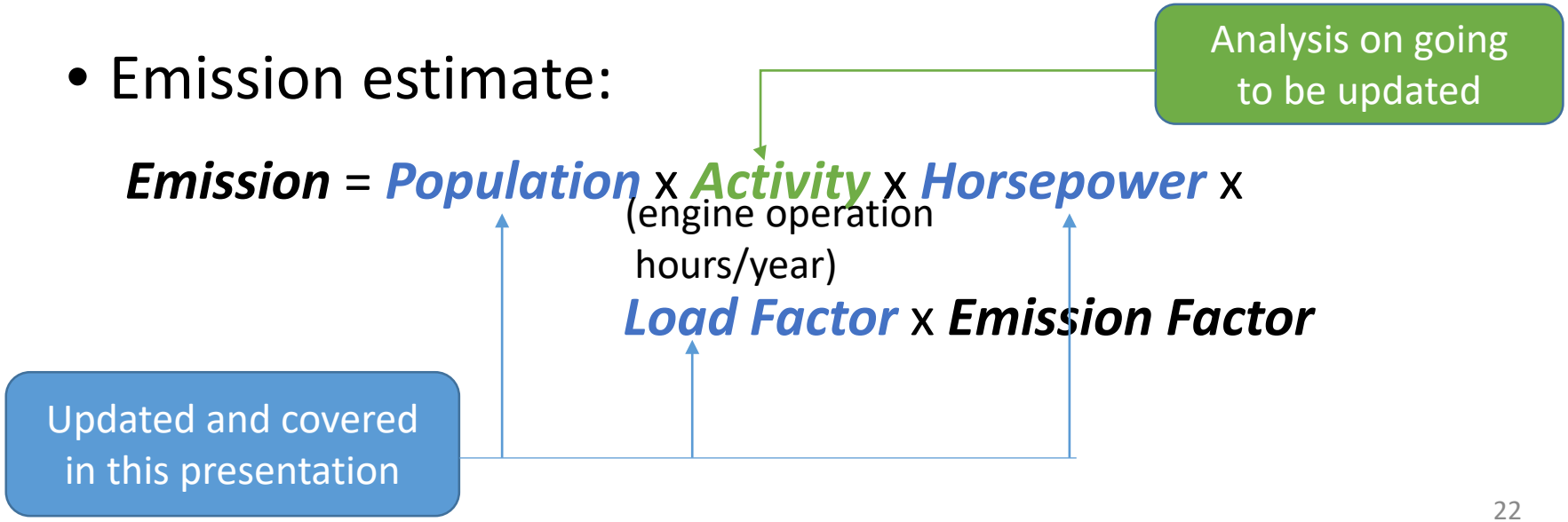
- About 44,000 California-based TRUs/gensets
- About 147,000 Out-of-state-based TRUs/gensets periodically operate in California
  - About 18,000 of these are operating in California on any given day
- About 9,000 refrigerated railcars and domestic shipping containers periodically operate in California
  - About 1,700 of these are operating in California on any given day

What Do TRUs & TRU Gensets Emit?

- Estimated 2017 emissions from all TRUs (including railcar TRUs and domestic shipping container TRUs) and TRU gensets operating in California
  - Diesel PM 2.5: 230 tons per year
  - NOx: 6,100 tons per year
  - GHG: 770,000 tons per year (CO_2e)

2017 TRU Inventory: Draft Version

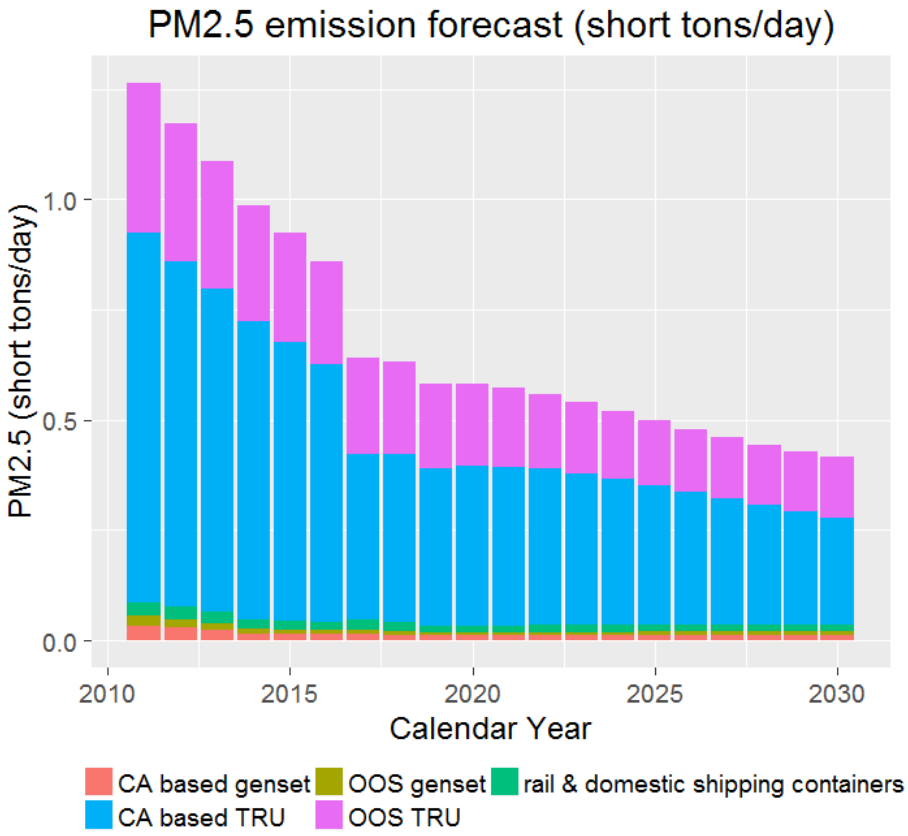
- TRU Inventory: Model of current and future TRU populations, activity, emissions. Includes natural turnover and any rulemaking scenarios
- Detailed write up and full model release in the future
- Questions & comments appreciated
- Emission estimate:

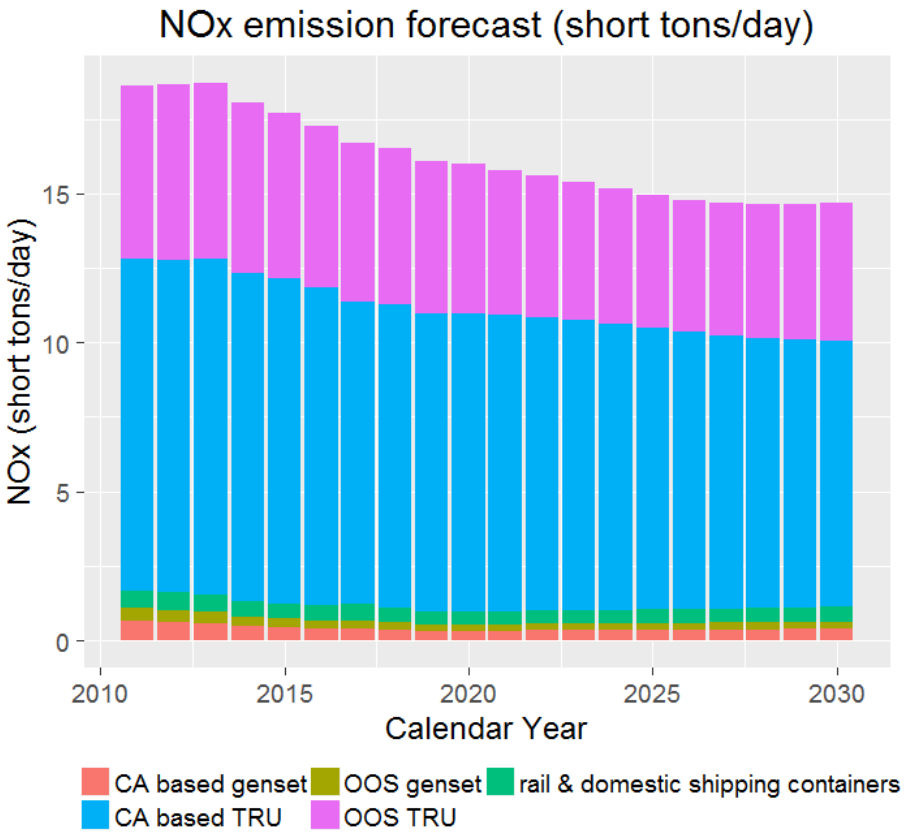


2017 TRU Inventory Draft: Summary of Updates

- TRU inventory updated in 2017, previous version 2011
- **Population:** Update based on March, 2017 ARBER database TRU reports
- **Population Growth:** Annual population growth projected at 1.6% based on ACT research's data and IBISWorld reports
- **Horsepower:** A new horsepower bin created for units just under 25 horsepower. In 2017, accounts for 12 % of CA based trailers and 28% of out-of-state trailers
- **Load Factor:** Efficiency improvement of 17% for model year 2013 and newer trailer units vs 2011 inventory
- **Activity**: Activity to be updated based on recent surveys, detailed analysis in progress

Emission Forecast: Draft



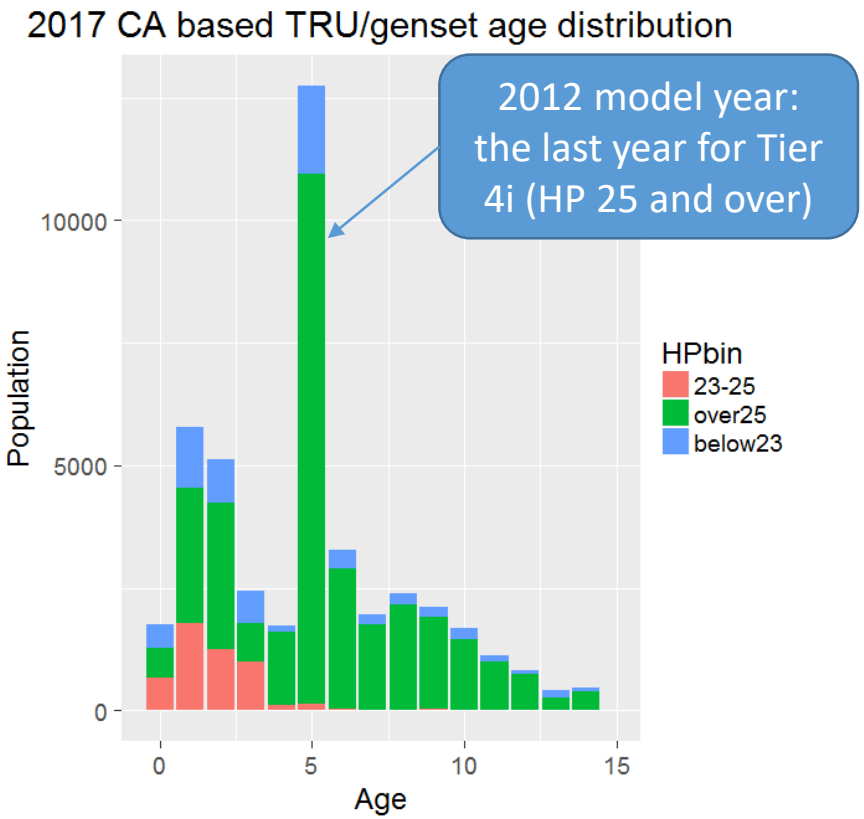


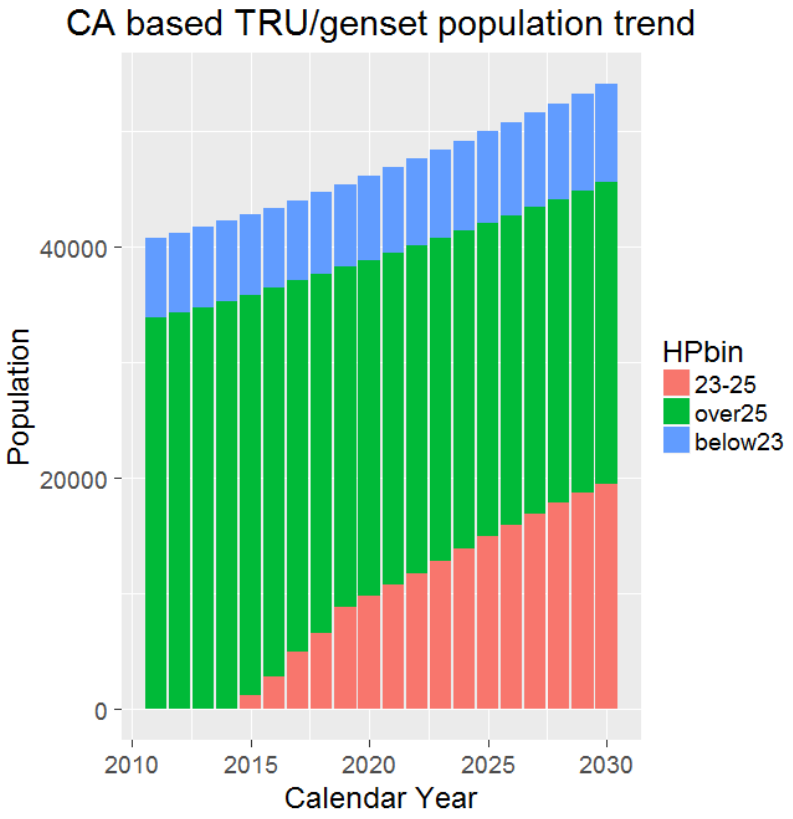
- Emissions based on previous activity reports, will be updated as survey analysis is complete
- Categories listed in the next slide

TRU Category Summary

Category	Horsepower bin	Typical application
CA-based TRU	25 and over	Trailers based in CA
	Between 23-25	
	Below 23	Refrigerated trucks and vans used in California
CA-based Genset	25 and over	Generator sets (diesel powered generators to provide electricity) for refrigerated trailers or containers based in California
	Between 23-25	
OOS TRU	25 and over	Trailers used for long-haul or interstate commerce
	Between 23-25	
OOS Genset	25 and over	Generator sets (diesel powered generators to provide electricity) for refrigerated trailers or containers based out of California
	Between 23-25	
Railcar + DSC	25 and over	Refrigerated railcars and Domestic Shipping Containers (DSC)
	Between 23-25	

CA Based TRU/Genset Population Trend: Draft





- Population growth rate projected at 1.6% for each category
- New purchase split between sub-25 horsepower units and traditional 30-34 horsepower engines

TABLE New purchase Split

CA based Trailers (25+/23-25)	Out of State Trailer & Genset (25+/23-25)
60/40	20/80

Population Forecasting Concept

- The iteration consists of three steps; turnover, growth and compliance.
  - **Turnover**: model estimates which units are retired in the year utilizing the survival curve, which characterize the retirement behavior for different ages.
  - **Growth**: based on the population growth factor, newly purchased units are calculated to simulate the population growth.
  - **Compliance**: Lastly, the population is adjusted by compliance actions such as forced retirement and/or replacement.

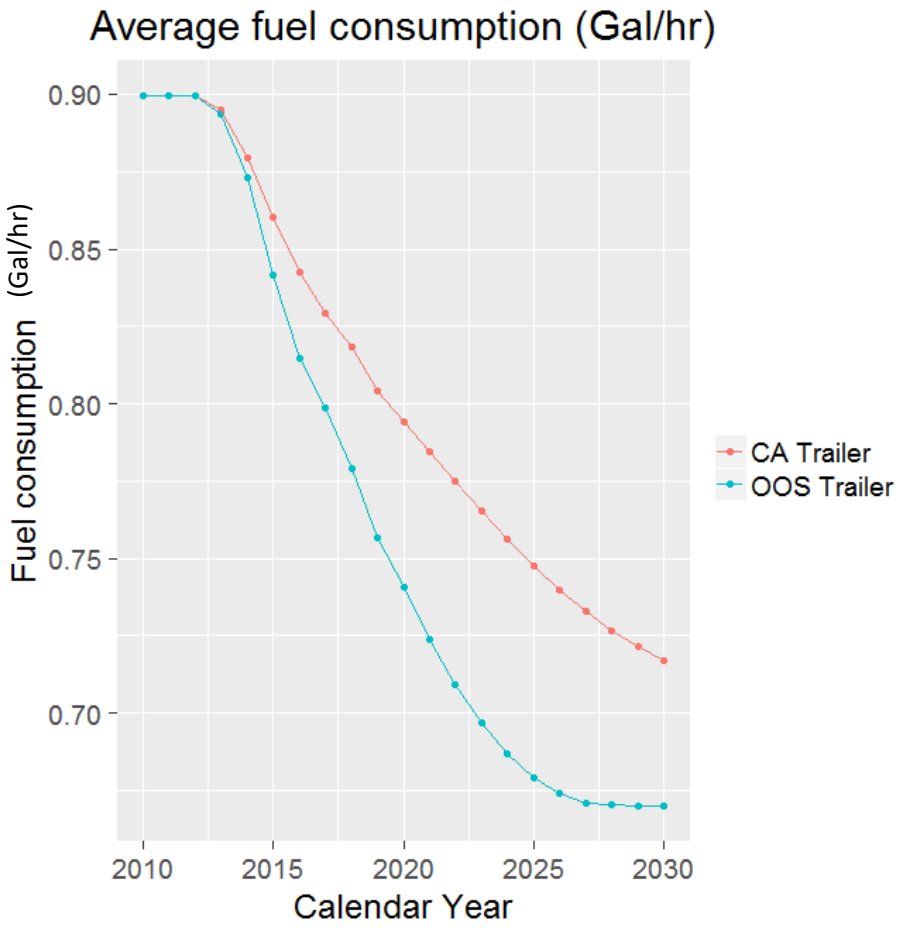
Growth Factor & Compliance Parameters: Draft

- Population growth rate set at 1.6% for each category
  - 1997-2016 ACT research's nationwide reefer population 1.6%
  - NAICS Details from IBISWorld report 2016
    - Manufacturing: Frozen food production in the US 1.6%
    - Retail: Supermarkets & Grocery Stores in the US 1.6%
  - Additional sources suggest wider range
    - ARBER 2008-2016 showed a 2.4 percent annual growth
    - NAICS Sectors in frozen foods vary from 0.5 to 4.5 percent growth annually
- Compliance behavior modeled from 2011ARBER data and 2017ARBER data comparison (CA based Truck and Trailers)

actions	Trailer	Truck
Install level 3 retrofit	65%	42%
Alt technology	0%	9%
Replace → additional purchase driven by the rule	35%	49%

Load Factor: Draft

- Load factor is measure of how hard an engine is run on average
- 17 % reduction In Load factor based on efficiency improvement for model year 2013 and newer with engines HP over 25
- 24.8 HP rated engine generates equivalent output of 30 HP engine with 17% efficiency improvement applied to 30 HP engine
- The estimated fuel consumption forecast is supported by the survey data



Trailer load factor

	MY 2012 and older	MY 2013 and newer
HP 25+	0.46	0.38
HP 23-25	NA	0.46

Next Steps

- Reconcile activity between recent surveys and other data sources
- Reflect Stationary Operating Time Limit impact on industry and emissions benefits
- Release inventory in increased detail and with supporting documentation

Questions and Comments

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Surveys

Surveys Conducted (2016-2017)

- TRU original equipment manufacturers (OEM) and dealers
- Electric plug infrastructure providers
- Grocery Stores
- Refrigerated Fleets
- Packing houses
- Cold Storage Warehouses
- Truck stops

Survey Results - Average Costs

- Respondents: TRU OEMs, dealers, fleets, distribution centers, air districts, installers, and suppliers
- Conventional diesel trailer TRUs cost roughly $28,000 - $30,000
  - Trailer eTRUs cost more by $4,000-$6,000
- Zero-Emission (ZE) all-electric stationary cold storage TRUs cost $15,000-$23,000 per unit
- Electric power plug receptacles:
  - Dock-side plug: ~$6,000-$8,000
  - Parking area pedestal (dual-plugs): ~$7,000-$9,000 plus $100/foot of trench

Survey Results - Average Costs (cont'd)

- Electronic tracking system (ETS): Automated monitoring, recordkeeping, and reporting system that uses Global Positioning Systems, equipment sensors, and software to report dates, times, locations of TRU operations
  - Installed cost: ~$500 per unit
  - Activation fees: $0 to $50 per unit
  - Recurring costs (cell communications and server data storage space): ~$300 per year per unit

Survey Results - eTRU Performance

- All eTRUs have sufficient capacity for initial cargo box chill-down
- Percent of TRUs sold in 2017 equipped to plug in:
  - Truck >60%; Trailer 17%
  - Trend toward increasing percentages
- Percent of eTRUs that actually plug in: roughly 60%
- eTRU weight penalty:
  - Truck ~130 lb; Trailer ~ 200 lb

Survey Results
Grocery Stores

- Most deliveries to grocery stores use semi-trailer TRUs
- 17% of grocery stores use TRUs for cold storage in advance of Halloween, Thanksgiving, and Christmas
  - ~20% of these stores operate diesel-powered TRUs 24/7
  - ~80% of these stores use all-electric plug-in and hybrid-electric TRUs
- Cold storage trailers are staged in parking areas (often closer to people) more than at loading docks

Survey Results
Refrigerated Fleets

- 357 Respondents
  - 46% Private fleets
  - 52% For-hire fleets
  - 2% Rental/Lease fleets
- Private fleets own the freight they haul
- For-hire fleets do not own the freight they haul
- Rental/Lease fleets do not haul freight, they rent or lease equipment to the other two market segments
- Almost 50% of private fleet loads dispatched on Monday are loaded one or more days in advance

Survey Results
Refrigerated Fleets (cont'd)

- Operations at distribution centers (DC):
  - Outbound loads operate an average of 2.75 hours while waiting for dispatch
  - Inbound loads operate an average of 2.2 hours while waiting for a loading dock assignment
  - Private fleets ~ 20% of TRU engine run time is at DC
  - For-hire fleets ~ 30% of TRU engine run time is at DC

Survey Results
Refrigerated Fleets (cont'd)

- Activity and fuel use (trailer TRUs):

Fleet Type	Hr/Yr	Gal/Yr	Gal/Hr
Private	1,528	1,143	0.75
For-Hire	1,858	1,171	0.63
Average	1,700	1,158	0.68

- Distribution center loads
  - Inbound loads: 70% by for-hire carriers
  - Outbound loads: 50% by for-hire carriers

Survey Results
Refrigerated Fleets (cont'd)

	Private	For-Hire
Required to pre-chill prior to loading?	50% - Yes	90% - Yes
Where is pre-chilling done?		
At loading dock	54%	26%
At parking area	28%	56%
At dock using facility cold air	8%	11%
Enroute	10%	7%
Required to run TRU while loading/unloading at DC?	50% - Yes	90% - Yes
Do you own eTRUs?	33% - Yes	12% - Yes
If yes, do you always plug in?	65% - Yes	5% - Yes
Are electric power plugs provided at DC?	20% - Yes	5% - Yes

Survey Results - Packing Houses

- 44 Facilities responded
- 11% own TRUs but in small numbers
- 20% of inbound loads are refrigerated
- 15% run TRUs while unloading
- 40% require cargo space pre-chill before loading
- 50% of pre-chill is done in parking area, 25% at dock

- 45% require TRU to run while loading
- 50% of loads operate ~1 hour while waiting for dispatch
- 50% of loads are dispatched immediately
- eTRUs are used very little at packing houses

Survey Results
Cold Storage Warehouses

- Most inbound and outbound loads are full truckloads
- Detention time is 20 to 45 minutes
  - Applies to both inbound and outbound loads
- TRUs are required to run while loading/unloading sometimes

- Some eTRU/shipping container plugs are provided
- Most facilities serviced by rail sidings (rail spurs)
- No plugs provided for railcar TRUs

Survey Results
Truck Stops

- None of the survey respondents indicated they provide electric power plugs for TRUs

Surveys In-Process and Pending

- Seaports
- Third-party logistics (3PL) facilities
  - A company's use of *third party* businesses to outsource elements of the company's distribution and fulfillment services (e.g. operation, warehousing, and transportation)
- Cross-dock facilities
  - Facilities that transfer freight from one trailer to several trailers without the freight going into cold storage
- Transload facilities
  - Facilities that transfer freight from shipping container to domestic shipping container, refrigerated trailer, or railcar (and the reverse)
- Railyards and intermodal rail facilities
- Border crossings
- State and county fairs
- Public rest stops

Business Case Study

- Contract awarded to Eastern Research Group:
  - Gather data on TRU operations in California
  - Conduct business case study for eTRUs
  - Develop spreadsheet tool for calculating return on investment for eTRUs
    - Fleet-specific operating inputs
    - Equipment cost inputs
    - Payback period outputs

Current Incentive Programs

Program	Zero-Emission TRs	Infrastructure
Low Carbon Transportation/Air Quality Improvement Program		
www.arb.ca.gov/msprog/aqip/fundplan/fundplan.htm		
Proposition 1B: Goods Movement Emission Reduction Program		
www.arb.ca.gov/bonds/gmbond/gmbond.htm		
Carl Moyer Program		
www.arb.ca.gov/msprog/moyer/moyer.htm		

Questions, so far?

Control Measure Concept

Registration - Phase 1 (Concept)

Effective Date	Requirements	Applicability
2-1-2020	Register equipment in ARBER	All TRUs, ZE TRUs, Near-ZE TRUs and TRU Gensets that operate in California
	Register facilities in ARBER	All applicable facilities in California where TRUs and TRU gensets operate

Stationary Operating Time Limit (Concept)

- "Stationary Operating Time Limit" = the maximum amount of time that a TRU or TRU generator set internal combustion engine can operate at a stationary location
  - Switching to a zero-emission mode of operation might be necessary for the remainder of the time it is at that facility
- A given TRU's Stationary Operating Time Limit might be reset after it leaves that facility and enters another applicable facility or returns to the same facility, but on a different calendar day

Stationary Operating Time Limits - Phases 2 and 4 (Concept)

Phase	Effective Date	Stationary Operating Time Limit	Applicable California Facilities Being considered
2	2-1-2023	6 hours	Grocery stores, fairgrounds, festivals, special events, stadiums, distribution centers, cold storage warehouses, truck stops, public rest areas, packing houses, cross-dock facilities, third party logistics facilities, and facilities serviced by railroad sidings
4	2-1-2029	15 minutes	Same as Phase 2

Zero-Emission Mode Operating Time (Concept)

- "Zero-Emission Mode Operating Time (ZEMOT)" = the time when a transport refrigerator is operating in a zero-emission mode
  - Plug-in an eTRU or power with on-board batteries
  - Use cryogenic cooling system or hybrid cryogenic system

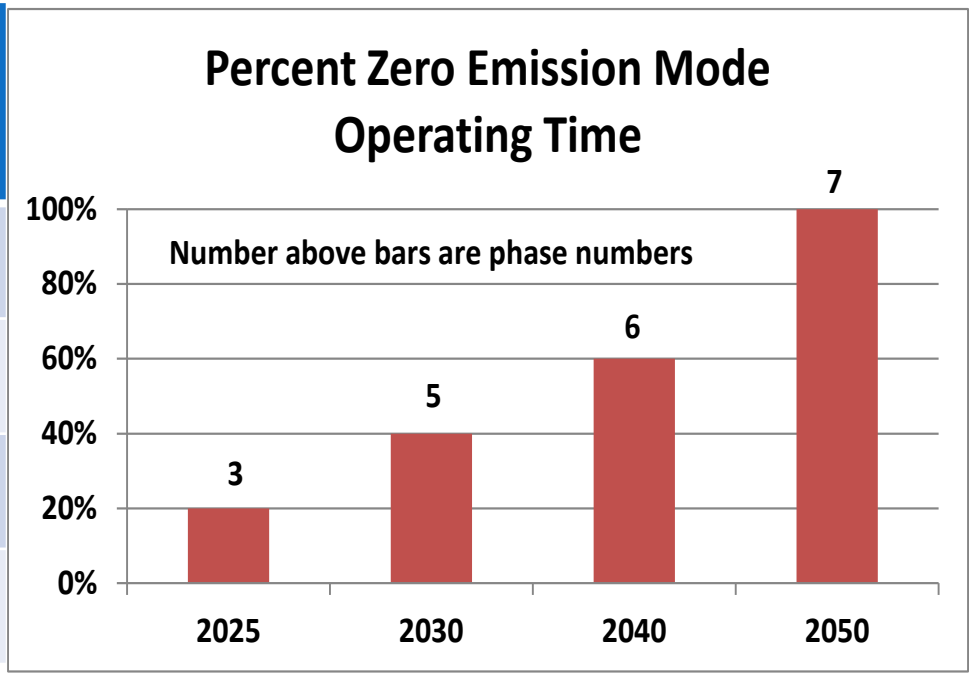
- "IC Engine Operating Time (ICEOT) = the time when an IC Engine provides power to drive the refrigeration system

- "Refrigeration System Operating Time": RSOT = ZEMOT + ICEOT

- $\boldsymbol{Percent\ ZEMOT} = \frac{\boldsymbol{ZEMOT}}{\boldsymbol{RSOT}}$ X 100

Zero-Emission Mode Operating Time Possible Phases (Concept)

Phase	Effective Date	Percent ZEMOT
3	2-1-2025	20%
5	2-1-2030	40%
6	2-1-2040	60%
7	2-1-2050	100%



Combined Phases (Concept)

Phase	Effective Date	Requirements	Applicability
1	2-1-2020	Register in ARBER	All TRUs, ZE TRUs, Near-ZE TRUs, and TRU Gensets that operate in California
		Register in ARBER	All Phase 2 and 3 applicable facilities located in California
2	2-1-2023	Stationary Operating Time Limit = 6-hours	Grocery stores, fairgrounds, festivals, stadiums, and special events Distribution centers, cold storage warehouses, truck stops, public rest areas, packing houses, cross-dock facilities, third party logistics facilities, and facilities serviced by railroad sidings. All TRUs that visit applicable facilities
3	2-1-2025	%-ZEMOT = 20%	All TRUs, ZE TRUs, Near-ZE TRUs, and TRU Gensets that operate in California
4	2-1-2029	Stationary Operating Time Limit = 15 minutes	Same as Phase 2 and 3 applicable facilities and fleets
5	2-1-2030	%-ZEMOT = 40%	All TRUs, ZE TRUs, Near-ZE TRUs, and TRU Gensets that operate in California
6	2-1-2040	%-ZEMOT = 60%	All TRUs, ZE TRUs, Near-ZE TRUs, and TRU Gensets that operate in California
7	2-1-2050	%-ZEMOT = 100%	All TRUs, ZE TRUs, Near-ZE TRUs, and TRU Gensets that operate in California

Enforcement

Electronic Tracking System Concept

- ETS provides automated tracking, recordkeeping and reporting:
  - Acquires date, time, and location data
  - Determines if unit is within an applicable facility's fenceline
  - Records TRU/Genset engine, electric motor, and refrigeration system's hour meter readings or run times
  - Determines the unit's engine run time inside each applicable facility's responsibility zone
  - Determines the unit's Zero-Emission Mode Operating Time and Percent ZEMOT
  - Transmits data to ETS supplier's secure server
  - Reports to ARB

ETS Standard (Concept)

- All TRUs, Near-ZE TRUs, and TRU gensets that operate in California might need to be equipped with an ARB-approved ETS by February 1, 2023
- Zero-Emission TRUs (ZE TRU): No engine in housing and no vehicle engine-associated emissions
  - No ETS required for ZE TRUs
  - But, still registration in ARBER

Possible Compliance Technologies

- Transportation Management Systems
- Equipment that has ZE operating mode
  - eTRUs (plug in while stationary)
  - Cryogenic TRUs (no engine)
  - Hybrid cryogenic TRUs - use cryogenic temperature control system while stationary and conventional internal combustion engine-powered TRU while on road
  - All-electric stationary TRU (no engine in housing)
  - ZE plug-in electric, battery-powered TRU with possible range extender strategies:
    - Solar panels
    - Hydrogen fuel cell

TRU ATCM 2019 Bubble

- The number of TRUs that must comply with ULETRU in 2019 is much higher than average because more model year (MY) 2012 engines are now in use
  - Older MY 2005, 2006, 2007 units complied with TRU regulation by replacing old Tier 2 engines with Tier 4i replacement engines (MY 2012)
  - TRU OEM installed flexibility engines that met prior tier standards – effective model year 2012
- **ARB recommends owners consider replacing older units with eTRUs to anticipate Stationary Operating Time Limits and Percent ZEMOTs**

Next Steps

Next Steps

- Complete rest of surveys
- Continue stakeholder outreach
- Complete California data gathering and business case study for eTRUs
- Public workshops later this year and next year
- Board adoption hearing in mid-2019 (tentative)

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Transition to Zero Emission Technologies for TRUs Website:

www.arb.ca.gov/cc/cold-storage/cold-storage.htm

Thank You

Discussion - Questions & Comments?