CLEAN FUELS PROGRAM ADVISORY GROUP AGENDA
SEPTEMBER 15, 9:00 AM – 4:00 PM
South Coast AQMD - Remote Meeting

INSTRUCTIONS FOR ELECTRONIC PARTICIPATION
Join Zoom Webinar Meeting - from PC or Laptop
https://scaqmd.zoom.us/j/91964955642
Zoom Webinar ID: 919 6495 5642 (applies to all)
Teleconference Dial In +1 669 900 6833
One tap mobile +16699006833, 91964955642#

Audience will be allowed to provide public comment through telephone or Zoom connection.

Pursuant to Governor Newsom’s Executive Orders N-25-20 (March 12, 2020) and N-29-20 (March 17, 2020), the South Coast AQMD Clean Fuels Program Advisory Group meeting will only be conducted via video conferencing and by telephone. Please follow the instructions below to join the meeting remotely.

AGENDA

Members of the public may address this body concerning any agenda item before or during consideration of that item (Gov't. Code Section 54954.3(a)). If you wish to speak, raise your hand on Zoom or press Star 9 if participating by telephone. All agendas for regular meetings are posted at South Coast AQMD Headquarters, 21865 Copley Drive, Diamond Bar, California, at least 72 hours in advance of the regular meeting. Speakers may be limited to three (3) minutes each.

Welcome & Overview - 9:00 – 10:30 AM
(a) Welcome & Introductions
   Matt Miyasato, Ph.D., Deputy Executive Officer
(b) Overview of Emission Reduction Goals & Strategy
   Aaron Katzenstein, Ph.D., Assistant Deputy Executive Officer
(c) Grid Impacts and Solutions for Battery Electric Drayage Fleets
   Mark Duvall, Ph.D., Director, Electrification and Customer Solutions, EPRI
(d) Goals for the day
   Joseph Impullitti, Technology Demonstration Manager
(e) Feedback and Discussion
   All

Areas of South Coast AQMD Focus
1. Zero Emission HD Trucks - Demonstration to Commercialization
   10:30 AM – 12:30 PM
(a) Volvo Electric Truck Development Projects
   Seungbum Ha, PhD, Program Supervisor
(b) Daimler Electric Truck Development Projects
   Phil Barroca, Program Supervisor
(c) Drayage Truck Pilot Project
   Patricia Kwon, Program Supervisor
(d) Feedback and Discussion
   All

Lunch 12:30 PM – 1:30 PM

2. Zero and Near Zero Emission Development and Deployment Projects
   1:30 PM – 3:30 PM
(a) Fuel Cell Truck Development Projects
   Seungbum Ha, Ph.D., Program Supervisor
(b) Hydrogen Infrastructure for Heavy Duty Trucks
   Lisa Mirisola, Program Supervisor
(c) Near Zero Engine Development & NZE Deployment Projects
   Joseph Lopat, Program Supervisor
(d) 200 Vehicle In-Use Emission Study
   Sam Cao, Ph.D., Air Quality Specialist
3. Wrap-up – 3:30 PM – 4:00 PM

(a) 2022 CF Proposed Plan Update Discussion & Wrap-up  
    Joseph Impullitti

(b) Advisor and Expert Comments  
    All

Other Business
Any member of the Advisory Group, or its staff, on his or her own initiative or in response to questions posed by the public, may ask a question for clarification; may make a brief announcement or report on his or her own activities, provide a reference to staff regarding factual information, request staff to report back at a subsequent meeting concerning any matter, or may take action to direct staff to place a matter of business on a future agenda. (Gov’t. Code Section 54954.2)

Public Comment Period
At the end of the regular meeting agenda, an opportunity is provided for the public to speak on any subject within the Advisory Group’s authority that is not on the agenda. Speakers may be limited to three (3) minutes each.

Document Availability
All documents (1) constituting non-exempt public records; (ii) relating to an item on the agenda for a regular meeting; and (iii) having been distributed to at least a majority of the Advisory Group after the agenda is posted, are available by contacting Donna Vernon at 909-396-3097 from 7:00 a.m. to 5:30 p.m., Tuesday through Friday, or send the request to dvernon@aqmd.gov.

Americans with Disabilities Act
Disability and language-related accommodations can be requested to allow participation in the Clean Fuels Program Advisory Group meeting. The agenda will be made available, upon request, in appropriate alternative formats to assist persons with a disability (Gov’t Code Section 54954.2(a)). In addition, other documents may be requested in alternative formats and languages. Any disability or language-related accommodation must be requested as soon as practicable. Requests will be accommodated unless providing the accommodation would result in a fundamental alteration or undue burden to South Coast AQMD. Please contact Donna Vernon at 909-396-3097 from 7:00 a.m. to 5:30 p.m., Tuesday through Friday, or send the request to dvernon@aqmd.gov.

INSTRUCTIONS FOR ELECTRONIC PARTICIPATION

Instructions for Participating in a Virtual Meeting as an Attendee
As an attendee, you will have the opportunity to virtually raise your hand and provide public comment.

Before joining the call, please silence your other communication devices such as your cell or desk phone. This will prevent any feedback or interruptions during the meeting.

Please note: During the meeting, all participants will be placed on Mute by the host. You will not be able to mute or unmute your lines manually.

After each agenda item, the Chairman will announce public comment.

Speakers will be limited to a total of three (3) minutes for the Consent Calendar and Board Calendar, and three (3) minutes or less for other agenda items.
A countdown timer will be displayed on the screen for each public comment.

If interpretation is needed, more time will be allotted.

Once you raise your hand to provide public comment, your name will be added to the speaker list. Your name will be called when it is your turn to comment. The host will then unmute your line.
Directions for Video ZOOM on a DESKTOP/LAPTOP:
- If you would like to make a public comment, please click on the “Raise Hand” button on the bottom of the screen.
- This will signal to the host that you would like to provide a public comment and you will be added to the list.

Directions for Video Zoom on a SMARTPHONE:
- If you would like to make a public comment, please click on the “Raise Hand” button on the bottom of your screen.
- This will signal to the host that you would like to provide a public comment and you will be added to the list.

Directions for TELEPHONE line only:
- If you would like to make public comment, please dial *9 on your keypad to signal that you would like to comment.
Overview of Emission Reduction Goals & Strategy

Clean Fuels Retreat
September 15th, 2021

Aaron Katzenstein, Ph.D
Assistant Deputy Executive Officer
Technology Advancement Office
Overview

- Update & overview of ozone attainment challenges
  - 2022 AQMP
  - MATES Study
  - Warehouse Indirect Source Rule

- Federal/State Actions

- Infrastructure – Governor’s Emergency Proclamation
Ozone
Attainment
Challenges

Mobile Sources >80% of NOx inventory for 2023
Ozone Concentrations Relative to NOx & VOC

Glendora (Based on 2016 AQMP modeling platform)

2020 Business-As-Usual
2015 8hr ozone standard (70ppb)

Attainment deadline 2038

Control Approach

• Transition to near zero and zero
• Cleanest available if NZE/ZE not feasible
• Regulatory measures
• Incentives (new & existing)
• Seek legislative authority where applicable

South Coast AQMD
2022 Air Quality Management Plan
Multiple Air Toxics Exposure Study (MATES V)

- **Time period:**
  - May 1, 2018-April 30, 2019

- **Monitoring stations:**
  - 10 fixed sites
  - >100 pollutants measured
Air Toxic Cancer Risk – Modeling Data

**MATES IV (population-weighted):**
South Coast Air Basin: 997-in-a-million
Coachella Valley: 357-in-a-million

**MATES V (population-weighted):**
South Coast Air Basin: 455-in-a-million
Coachella Valley: 250-in-a-million

**Maps:**
- **2012**
- **2018**
Diesel Particulate Matter Trends
MATES V Data Visualization Tool & Air Monitoring Dashboard
South Coast AQMD
Rule 2305 – Warehouse Indirect Source Rule

• Adopted May 7, 2021
• Applicable to warehouse owners and operators ≥ 100,000 sq. ft
• Phased in approach based on warehouse size

<table>
<thead>
<tr>
<th>Year</th>
<th>Warehouse Size</th>
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<tbody>
<tr>
<td>2022</td>
<td>≥ 250,000 sq. ft</td>
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<tr>
<td>2023</td>
<td>≥ 150,000 – 249,999 sq. ft</td>
</tr>
<tr>
<td>2024</td>
<td>≥ 100,000 – 149,999 sq. ft</td>
</tr>
</tbody>
</table>

• Warehouse owners must report warehouse size, location, details.
• Warehouse operators responsible for compliance
  • Based on Weighted Annual Truck Trips (WATTS)
  • Use WATTS to determine WAIRE Points Compliance Obligation
Federal/State Actions

EPA
  • Funding
  • Clean Trucks Initiative

CARB
  • Advanced Clean Fleets
  • Transport Refrigeration Unit
Infrastructure

Drought.gov

Lake Oroville
Infrastructure

- Governor’s State of Emergency Proclamation
  - July 30th
- Estimated 3,500 MW generation shortfall during afternoon peak
  - 5,000 MW anticipated next summer
- Allows IOUs to incentivize:
  - Reduced demand
  - Use of backup generators
CARB

• Advanced Clean Fleets https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets
• TRU Rulemaking https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit
• Mobile Source Strategy https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit

EPA


South Coast AQMD

MATES V http://www.aqmd.gov/home/air-quality/air-quality-studies/health-studies/mates-v

AQMP http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan

Warehouse ISR:

Infrastructure for Medium and Heavy-Duty Electric Vehicles

Electric service and charging requirements for fleets.

Mark Duvall
Director, Electrification and Customer Solutions
Electric Power Research Institute

September 15, 2021
<table>
<thead>
<tr>
<th>Class</th>
<th>Weight Range</th>
<th>Types</th>
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</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>6,000 lbs or less</td>
<td>MINIVAN, CARGO VAN, SUV, PICKUP TRUCK</td>
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<tr>
<td>Class 2</td>
<td>6,001 lbs to 10,000 lbs</td>
<td>MINIVAN, CARGO VAN, FULL-SIZED PICKUP, STEP VAN</td>
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<td>Class 3</td>
<td>10,001 lbs to 14,000 lbs</td>
<td>WALK-IN, BOX TRUCK, CITY DELIVERY, HEAVY-DUTY PICKUP</td>
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<td>Class 4</td>
<td>14,001 lbs to 16,000 lbs</td>
<td>LARGE WALK-IN, BOX TRUCK, CITY DELIVERY</td>
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<td>Class 5</td>
<td>16,001 lbs to 19,500 lbs</td>
<td>BUCKET TRUCK, LARGE WALK-IN, CITY DELIVERY</td>
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<td>Class 6</td>
<td>19,501 lbs to 26,000 lbs</td>
<td>BEVERAGE TRUCK, SINGLE-AXLE, SCHOOL BUS, RACK TRUCK</td>
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<td>Class 7</td>
<td>16,001 lbs to 33,000 lbs</td>
<td>REFUSE, FURNITURE, CITY TRANSIT BUS, TRUCK TRACTOR</td>
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<tr>
<td>Class 8</td>
<td>33,001 lbs Up</td>
<td>CEMENT TRUCK, TRUCK TRACTOR, DUMP TRUCK, SLEEPER CAB</td>
</tr>
</tbody>
</table>
EPRI with Co-lead CALSTART Receiving CEC Funding for Research Hub for Electric Technologies in Truck Applications (RHETTA)

Focused on the development, advancement, and deployment of innovative medium- and heavy-duty (MDHD) high-power charging infrastructure along key freight corridors that promote the adoption of Class 7 and 8 battery electric zero-emission (ZE) trucks.

- **CEC Funding:** $23M ($13M phase 1, $10M phase 2)
- **Timing:** Phase 1 – Through Q1 2025, Phase 2 – Through Q2 2028
Research Hub for Electric Technologies in Truck Applications (RHETTA)

Funding (anticipated – won and in negotiation): $21.1M total ($13M from CEC to EPRI, $2.8M in-kind partners, $5.3M internal EPRI sources). Phase 2 funding available: $10M.

Objective: Fleet Electrification. Through RD&D, create a Research Hub for Electric Technologies in Truck Applications. The research hub will engage broad stakeholders including pollution burdened and impacted communities, truck fleets, charging equipment and service providers, electric utilities, and planning agencies to advance high power charging components systems, and to plan, design, and deploy innovative public corridor charging strategies that extend the range and increase the operational flexibility of battery electric trucks.

Key Activities

- Community Engagement and Workforce Development
- Fleet Needs and Technology Maturity Assessment
- Advanced High-Powered Charger System R&D
- Phase 1 Pilot Deployment
- Plan for Phase 2 Public Corridor Network
- Phase 2 Implementation
- Technology/Knowledge Transfer Activities
Fleet Needs Assessment & Travel Data

There are approximately 18,000 MHD trucks serving the Southern California ports. To showcase this trend, freight corridors for out of state and inner city commerce between major metropolitan hubs are highlighted.
Expansion of SCE’s Laboratory Facilities
R&D for High-Power Charging

Targeted Level of Performance

• Capable of providing 100 miles of range for a HD BEV drayage truck in less than 10 minutes;
• Uses only open standards for connectors and communications to increase interoperability across different vehicles and control systems;
• Modular design that can be scaled up with future BEV truck deployment;
• Delivered at a total cost below 500 $/kW.
Pilot Site - Ontario, California
Objectives of Fleet Planning Tools

The Process of Balancing The Unique Fleet Power Requirements With Available Capacity on the Distribution Grid

Fleet operator choices influence the power requirements:
- Number of vehicles
- Fleet vehicle choices
- Fleet route choices
- Fleet operating practices
- Charger power levels
- Charge management strategies
- Onsite Resources

Distribution system capabilities are unique at each location:
- Distribution primary voltage
- Rating of distribution feeder equipment
- Pre-existing power loads / sources
- Ease of line extension or upgrades
- Substation capacity
Fleet Planning Tools Help Inform Balancing Power Requirements With Capacity

Fleet operator choices influence power requirements

Distribution system capabilities are unique at each location
Developing Tools Which Enable Informed Decision Making

Co–Optimization: 100 Bus Transit Depot Example

Baseline

Site Power Requirements: 12 MW
Utility Line Extension Estimates: $27 M

~80% Reduction in Peak Power Requirements
(Achievable With Lower Power Level Charging or Charge Management)

Results in a ~98% Reduction in Utility Line Extension Costs

Optimized Solution

Site Power Requirements: 2.5 MW
Utility Line Extension Estimates: $0.6 M

Baseline data from: http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/8525797c00471adb8525842000559bff?OpenDocument
Infrastructure Enables Adoption...Research Needs

**Fast Charging and Energy Storage**
- Technology
- Design
- DC as a Service
- Energy Storage Integration
- Value Assessment

**Fleet Electrification**
- Data Analytics
- Design
- Economics
- Charging Infrastructure Integration
- Coordination with Fleet Operators

**Planning and Operations**
- Advanced Planning Tools and Methods
- Models for EV Charging Systems
- DERMS Requirements
- Non-wires Alternatives
- Flexibility

**Interoperability**
- Infrastructure Between Charging Systems (Customer)
- Charging System/Grid
- Vehicle/Grid

**Resiliency**
- Environmental solutions to support resiliency strategies

Customer Perspective is Crucial
Integrating Fleet Calculator with Distribution Planning Tools

Available distribution capacity to support EV

Output from the Fleet Calculator can be layered into distribution capacity profiles

Unmanaged Charging
Managed Charging

Time—varying distribution capacity

Distribution Planning Tools Also Inform Fleet Planning and Charging Approach
Projected Energy Requirements for MD/HD are High
Electric Transportation Market

Number of Vehicles (millions)

- 45% Passenger Cars: 265
- 4% SUV and Pickup Trucks
- 5% Heavy and Medium Freight
- 4% Others (light commercial/school/transit)

Final Energy Use (quad btus)

- 41% Passenger Cars: 22.5
- 25% SUV and Pickup Trucks
- 5% Heavy and Medium Freight
- 5% Others (light commercial/school/transit)

Source: 2015 US highway transportation data

Fleet Segments

- School buses
- Transit buses
- Delivery vehicles
- Garbage trucks
- Ferries
- Mining equipment
- Construction equipment
- Aviation
- Etc.

Source: 2015 US highway transportation data
What is the U.S. market size (TWh) for light-duty EVs?

Depends on rate of adoption

**Total EVs in Operation**

**U.S. Systemwide Electricity Consumption**
What is the U.S. market size (TWh) for large EVs?

Electricity Consumption: U.S. Medium- and Heavy-Duty Vehicles

- Low
- Medium
- High

2020: Low
2021: Medium
2022: Low
2023: Low
2024: Low
2025: Low
2026: Medium
2027: Medium
2028: Medium
2029: High
2030: High
Fleet Electrification Characterization
Fleet Electrification Characterization

Fleet Operation and Needs Assessment

Challenges / Needs:

- Each fleet segment will have different types of vehicles (efficiency, range, etc.)
- Fleets operation can vary based on its industry (driving time, driving distance, frequency of stops, payload, etc.)

Approach:

- Assessing fleet characteristics / operation for each fleet segments:
  - Travel patterns (distance, duration, etc.),
  - Vehicle types,
  - Quantities, etc.
Fleet Electrification Characterization
Technology Maturity Assessment

Challenges / Needs:
- What is the state of the market?
- What technologies are already available vs coming soon?
- Are fast chargers currently available for fleets?

Approach:
- Assess the state of the market for:
  - Electric vehicle technology
  - High-power charging equipment
  - Required supporting infrastructure
Fleet Electrification Characterization

Charging Strategies and Applications

Challenges / Needs:
- What type of charging strategies exist?
- How do different incentives / programs affect the charge schedule?
- Does certain fleet segments have specific charging strategies?

Approach:
- Assessing charging strategies and applications:
  - Charging behavior for each fleet segments
  - En-route vs depot-based charging
  - Charge management strategies
  - Market-based vs incentive-based operations
Framework
Q#1: Fleet Locations

- Where are existing fleet depots?
- Where are new depots being considered?
- ...

Q#2: Fleet characteristics

- How many vehicles are at the location?
- What type of vehicles are parked at the location?
- How large is the warehouse/depot/distribution center?
- How many miles do they drive each day?
- When are they parked at the warehouse?
- ...

Q#3: Electrification timeline

- When will they electrify?
- Is the technology mature?
- Is the infrastructure ready?
- ...

Q#4: Fleet Electrical Demand

- What is the peak demand, load shape, energy needs?
- Can charge management reduce the impact?
- Can customer-sided solutions provide help?
- ...

FRAMEWORK: Forecasting fleet electrification
Fleet location state-wide (Maryland)

- Number of fleets: 15,145 fleets
- Number of vehicles: 100,040 vehicles

Caveat: This is for illustrative purposes, FleetSeek only provides company headquarters, not exact location of warehouse.
City-level fleet location

Circle based on fleet size:

Objective: Comparing fleet location with grid capacity
FRAMEWORK: Forecasting fleet electrification

Q#1: Fleet Locations

Q#2: Fleet characteristics

Q#3: Electrification timeline

Q#4: Fleet Electrical Demand

Fleet Forecaster

Fleet Physical Characteristics

Fleet Operational Characteristics

FleetCalc
Grid Planning for Fleet Electrification
Grid Planning for Fleet Electrification
Assess wide-area grid electrification opportunity

Challenges / Needs:
- Which feeders should be prioritized for electrification?
- Which feeders have limited electrification opportunity?
- How much capacity and energy is available during off-peak hours for fleet electrification?
- How much additional fleets could be hosted with charge management?

Approach:
- Identify existing capabilities across a wide-area
- Identify areas with under-/over-utilized assets
- Prioritize grid investments for areas with limited capabilities
Grid Planning for Fleet Electrification

Future Fleet Electrification Assessment

Challenges / Needs:

- With limited information available from the customer, how can we estimate a site’s future fleet electrification?
- How many vehicles are there?
- What type of vehicles would operate at that location?
- How does that translate into demand profiles?

Approach:

- Identify potential fleet vehicles sites
- Estimate the number and type of vehicles using aerial imagery and additional data streams
- Estimate demand / energy needs at up to 10 locations

Potential Future Fleet EV Loads

Illustration purposes only

EV Fleet demand/energy
Smaller
Larger
Grid Planning for Fleet Electrification

Grid Readiness and Integration Assessment

Challenges / Needs:

- Grid capacity and fleet electrification may not occur in the same area on the feeder
- Grid constraints can vary from feeder to feeder and can occur at different times of the day
- Charge management from the fleet operator could avoid infrastructure investment

Approach:

- Merging future fleet forecast parameters with system-wide grid assessment
- High-level assessment of grid investment options and integration costs
Determining Grid Impacts
Fleet EV Hosting Capacity is Location Dependent

Factors that affect the grids ability to support Fleet EV

- Grid topology
- Equipment ratings
- Feeder configuration
- Existing + forecasted load
- DER
- Etc.

~2 MW of add. load

~1 MW of add. load

~200 kW of add. load
Fleet EV Hosting Capacity Is also Time Dependent

Hosting capability will vary based on the **season** and **time-of-the-day**.
Supporting Fleet EV Charging

**Unmanaged charging:**
Fleet can charge up to a fixed demand level

**Managed charging:**
Fleet can charge up to the operational limits of the grid if managed (dispatched)

The amount of energy available for fleet charging will depend on the charging behaviour.
Fleet EV Charging – Grid’s Energy Availability Maps

Energy Map – Unmanaged charging

Energy Map – Managed charging

New analytical capabilities being developed in DRIVE
Planning Use Case:
Identifying common low-cost mitigation to integrate Load or Generation at multiple buses or across multiple feeders
Mitigation Scenario Evaluation using ADAPT

1. Charging cases derived from Fleet-VET
   - Net Load Profile

2. System constraint severity analysis
   - Diagram showing system constraint severity

3. Automated wires & non-wire alternative design and evaluation
   - Determine and rank solutions by total behind the meter & system solution costs
Application of the ADAPT Toolset

Electrification scenarios

System assessment

Alternative design

Multi-year alternative evaluation

Multi-scenario evaluations

Automated evaluation of traditional and non-wires mitigation options and costs

Quickly assess different electric fleet charging cases
Grid electrification capability depends on charging behavior:

- **Unconstrained charging**: Charging station can operate at any time of the day as long as the demand remains below a certain power level.
Grid electrification capability depends on charging behavior:

- **Unconstrained charging**: Charging station can operate at any time of the day as long as the demand remains below a certain power level.

- **Scheduled-based charging**: Charging would occur during some hours allowing additional vehicles to simultaneously charge during that period (compared to the unconstrained charging).
Grid electrification capability depends on charging behavior:

- **Unconstrained charging**: Charging station can operate at any time of the day as long as the demand remains below a certain power level.

- **Scheduled-based charging**: Charging would occur during some hours allowing additional vehicles to simultaneously charge during that period (compared to the unconstrained charging).

- **Constraint-based charging**: Charging station can charge within the operational limits of the system but available energy would depend on the feeder load condition.

![Graph showing additional load HC vs. time]
Energy availability maps

Energy Map – Unconstrained charging

Energy avail. > 80.000MWh / day
Energy avail. > 70.000MWh / day
Energy avail. > 60.000MWh / day
Energy avail. > 50.000MWh / day
Energy avail. > 40.000MWh / day
Energy avail. > 30.000MWh / day
Energy avail. > 20.000MWh / day
Energy avail. > 10.000MWh / day
Energy avail. < 10.000MWh / day
Energy availability maps

Energy Map – **Unconstrained** charging

Energy Map – **Constraint-based** charging

Characterising fleets
Calculating impacts
Evaluating solutions
Forecasting fleets
Enabling industry
Clean Fuels Program
Advisory Group Meeting
September 15, 2021
Joseph Impullitti,
Technology Demonstration Manager
The War on Southern California Smog
NOx Reductions Needed

45-55% NOx Tons/Day

2023

2032

Heavy-Duty Diesel Trucks
Off-Road Mobile Equipment
Ocean Going Vessels
Locomotives
Cars/Light-Duty Trucks/SUVs
Aircraft
RECLAIM
Residential Fuel Combustion
Buses
Recreational Boats
Other

NOx Tons/Day
Clean Fuels Fund Program

- Established in 1988
- $1 fee on DMV registrations ($~12M/yr)
- Stationary source fee (~$400k/yr)
- Research, develop, demonstrate, and deploy clean technologies
Clean Fuels Fund Program

- Established in 1988
- $1 fee on DMV registrations (~$12M/yr)
- Stationary source fee (~$400k/yr)
- Research, develop, demonstrate, and deploy clean technologies
2021 Key Funding Partners

Total = $40.9M

Targeted Airshed – CATI - DERA
Draft 2022 Plan Update
(Key Technical Areas)

• Focus priorities on large demonstrations of zero emissions drayage trucks to test and validate OEM readiness and infrastructure viability
• Defining technology pathways via special projects - the Ultra-Low Emissions Engine Program
• Near-zero emission (gaseous and liquid fuel) engine systems, with a focus on high HP HD engine technology
• Long range fuel cell electric truck development and demonstration
• Hydrogen production, dispensing and mobile refueling
• Maintain other areas of emphasis
Draft 2022 Plan Update
Proposed Projects

• Large deployment projects of HD zero emission battery electric trucks and infrastructure
• Continue microgrid demonstrations to support large HD truck deployment projects
• Support advanced high power quick charge infrastructure to support HD BET’s
• Development and demonstration for long range fuel cell electric trucks
• Develop pathways and demonstrate green hydrogen production
• Heavy-duty diesel truck replacements with near-zero emissions natural gas trucks
• Engine System Technologies:
  - Development and demonstration of 15L HD Low-Nox engine
  - On-road demonstration of Low Nox diesel engine
  - Ethanol/H2 combustion studies
Proposed 2022 Plan Distribution

- Hydrogen & Fuel Cell Tech. & Infra.: 20%
- Electric/Hybrid Tech. & Infra.: 31%
- Engine Systems/Technologies: 14%
- Infrastructure & Deployment (NG/RNG): 15%
- Fuel/Emissions Studies: 5%
- Stationary CF Technologies: 5%
- Emissions Control Technologies: 4%
- Health Impacts Studies: 2%
- Tech Transfer & Outreach: 4%
- Hydrogen & Fuel Cell Tech. & Infra.: 20%

Total: $23.8M
Plan Update Comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Distribution 2021 Plan</th>
<th>Distribution 2022 Plan</th>
<th>2021 Plan ($17.9M)</th>
<th>2022 Plan ($23.8)</th>
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<tbody>
<tr>
<td>Hydrogen &amp; Fuel Cells</td>
<td>27%</td>
<td>20%</td>
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<tr>
<td>Electric &amp; Hybrids</td>
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<td>Engine Systems</td>
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<tr>
<td>Infra &amp; Deploy NG/Renew.</td>
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<td>Tech Transfer &amp; Outreach</td>
<td>4%</td>
<td>4%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Proposed Distribution

<table>
<thead>
<tr>
<th>Area</th>
<th>2021 Plan</th>
<th>Draft 2022 Plan</th>
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</thead>
<tbody>
<tr>
<td>Hydrogen &amp; Fuel Cell Tech. &amp; Infra.</td>
<td>27%</td>
<td>↓ 20%</td>
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<tr>
<td>Engine Systems/Technologies</td>
<td>18%</td>
<td>↓ 14%</td>
</tr>
<tr>
<td>Electric/Hybrid Tech. &amp; Infra.</td>
<td>20%</td>
<td>↑ 31%</td>
</tr>
<tr>
<td>Infrastructure &amp; Deployment (NG/RNG)</td>
<td>11%</td>
<td>↑ 15%</td>
</tr>
<tr>
<td>Stationary CF Technologies</td>
<td>7%</td>
<td>↓ 5%</td>
</tr>
<tr>
<td>Fuel/Emissions Studies</td>
<td>6%</td>
<td>↓ 5%</td>
</tr>
<tr>
<td>Emissions Control Technologies</td>
<td>5%</td>
<td>↓ 4%</td>
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<tr>
<td>Tech Transfer &amp; Outreach</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Health Impacts Studies</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Feedback

Email
Aaron Katzenstein
akatzenstein@aqmd.gov
or
Joseph Impullitti
jimpullitti@aqmd.gov
Volvo LIGHTS

Technology Advancement Office
Program Supervisor

Seungbum Ha
Volvo LIGHTS
- Heavy-Duty Battery Electric Trucks & Infrastructure

- Volvo LIGHTS (Low Impact Green Heavy Transport Solutions)
- 23 battery electric trucks, 29 off-road equipment, solar for zero emission freight handling
- Funding: $44.8M CARB/CCI, $4M South Coast AQMD, $41.6M Volvo & Partners – Total: $90.4M
- Battery electric forklifts, yard tractors at fleets
Volvo LIGHTS
- Heavy-Duty Battery Electric Trucks & Infrastructure

- 5 Trucks under operation (TEC, NFI, DHE)
- Chargers installed at fleets, SCE Charge Ready Transport
  - 7.2 kW, 15 kW for EVs, forklifts
  - 22 kW AC, 50 kW DCFC for yard tractors
  - 150 kW DCFC for trucks
- Solar installed at DHE
- Completed additional 15 trucks
## Truck Demo Data

**Total Mileage:** 128,427

<table>
<thead>
<tr>
<th>Customer</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEC</td>
<td>TEC Fontana – TEC La Mirada 90 miles, mostly flat</td>
</tr>
<tr>
<td>NFI</td>
<td>NFI Chino – Ports 102 miles, mostly flat (170m)</td>
</tr>
<tr>
<td>DHE</td>
<td>DHE – mixed drop off locations 80 miles, mostly flat</td>
</tr>
<tr>
<td>DHE</td>
<td>DHE – mixed drop off locations including Apple Valley 110 miles, big mountain climb (600m)</td>
</tr>
<tr>
<td>NFI</td>
<td>NFI Chino – Ports 102 miles, mostly flat</td>
</tr>
</tbody>
</table>
Accumulated Mileage
## Charging Energy Summary

### Fleet

<table>
<thead>
<tr>
<th>Fleet</th>
<th>Total Sessions</th>
<th>Total Energy(kWh)</th>
<th>Avg Energy/Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>191</td>
<td>12,333.9</td>
<td>64.6</td>
</tr>
<tr>
<td>B</td>
<td>187</td>
<td>11,512.0</td>
<td>61.6</td>
</tr>
<tr>
<td>C</td>
<td>42</td>
<td>2,368.4</td>
<td>56.4</td>
</tr>
</tbody>
</table>

### Vehicle

<table>
<thead>
<tr>
<th>Total Sessions</th>
<th>Avg Sessions per Day</th>
<th>Total kWh charged</th>
<th>Avg kWh per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>1.13</td>
<td>2,377.9</td>
<td>103.4</td>
</tr>
<tr>
<td>32</td>
<td>1.07</td>
<td>2,689.5</td>
<td>89.7</td>
</tr>
<tr>
<td>31</td>
<td>1.03</td>
<td>2,254.4</td>
<td>75.1</td>
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</table>

### Charging schedule

<table>
<thead>
<tr>
<th>Start Time</th>
<th>End Time</th>
<th>Energy(kWh)</th>
<th>Duration (H:M:S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-08-03 09:50:46</td>
<td>2021-08-03 10:45:50</td>
<td>127.6</td>
<td>00h 55m 04s</td>
</tr>
<tr>
<td>2021-08-05 09:35:41</td>
<td>2021-08-05 10:13:19</td>
<td>83.2</td>
<td>00h 37m 38s</td>
</tr>
<tr>
<td>2021-08-05 19:49:39</td>
<td>2021-08-05 20:25:42</td>
<td>47.0</td>
<td>00h 36m 03s</td>
</tr>
</tbody>
</table>
Volvo LIGHTS Update

- Volvo Class 8 eVNR trucks certified by CARB, EPA
- Eligible for sale in California
- Delivering parts full-time at TEC Fontana
- Online and/or socially distanced BET classes
- Approved baseline testing plans, UCR installed data loggers at DHE, collecting PEMS data
- CALSTART collecting charging data from fleets
Project Partners

• OEM
• Government
• Utilities
• Fleets
• Education/Training
• Ports
• Dealership
• Outreach
• Charging Infrastructure
Microgrid - On-Site Solar + Storage

- BEV fleet owners to maximize their investment while reducing their energy costs.
- As grid-independent energy resources, solar + storage systems enhance resiliency
- Pairing an energy storage device, such as a second-life battery, with a solar system enables a fleet to access carbon-free power.
Next phase of Volvo LIGHTS: EPA Switch-On

- CARB certified commercial trucks
- Largest single commercial truck deployment
- Additional performance data in drayage/freight applications
- U.S. EPA Targeted Airshed grant
- Volvo and fleets provide in-kind and cash cost share
- Deploy 70 Class 8 battery electric trucks
Next phase of Volvo LIGHTS: CARB-CEC Pilot

- CARB and CEC awarded South Coast AQMD $16M and $11M respectively to deploy up to 100 Daimler and Volvo Class 8 BETs and infrastructure at two fleets in DACs

- Daimler and Volvo will manufacture trucks certified by U.S. EPA and CARB

<table>
<thead>
<tr>
<th>Daimler</th>
<th>Volvo</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 – 250-mile electric range</td>
<td>195 – 220-mile electric range</td>
</tr>
<tr>
<td>475 kWh lithium-ion battery pack</td>
<td>564 kWh lithium-ion battery pack</td>
</tr>
<tr>
<td>CCS1 connector for fast charging</td>
<td>CCS1 connector for fast charging</td>
</tr>
</tbody>
</table>

- Data Collection
  - Ricardo—data collection/analysis on BETs
  - CALSTART—charger pricing analysis, fleet case studies
  - EPRI—charger performance analysis, fleet reliability uptime dashboard
Daimler/Freightliner
Battery Electric Transport
Demonstration to Deployment

Clean Fuels Technical Advisory Meeting

South Coast AQMD

September 15, 2021

Phil Barroca, Program Supervisor,
Technology Demonstration
Technology Advancement Office
Pre-commercial Class 8 (eCascadia) and Class 6 (eM2) DC Fast Charging distributed in Air Basin Energy Storage System (Time-of-Usage study) Penske Truck Leasing and Logistics and NFI Logistics

Q4-2018 Vehicles & EVSE Q2-2022

Expanded demonstration of pre-commercial EVs DC Fast Charging using portable DCFC from ChargePoint CPE250 2-9 months of “hands-on” with 10 major fleet operators

Q3-2020 Q4-2022

Commercial ready eCascadia and eM2 Customer installed/paid DCFC US Foods; JB Hunt; Ryder Truck; Schneider

Q2-2019 EVSE Vehicles Q2-2025
Objectives –

- Develop and demonstrate on-road heavy-duty battery-electric trucks
- Meet performance objectives
- Meet or exceed all safety standards, EPA and CARB certifications
- Install DC Fast Charge Infrastructure
- High visibility, well-positioned demonstration partners

Project Cost: $31 MM

- DTNA, SCAQMD ($12.5 MM)
- POLA, POLB, EPA ($1MM ea)
Innovation Fleet – Vehicle Specs

**Class 8**
- 23,500 lbs. (curb weight)
- 80,000-lb GVWR
- 670 peak h.p.
- 1430 lb-ft. torque
- 400 kWh battery (useable)
- 160 mile full load range
- <3 hours full recharge @150kW

**Class 6**
- 17,500 lbs. (curb weight)
- 26,000-lb GVWR
- 333 peak h.p.
- 737 lb-ft. torque
- 220 kWh battery (190 kW useable)
- 150 mile full load range
- 2 hours full recharge @150kW

Anti-lock Braking System (ABS)
Electronic Stability Control (ESC)
Traction Control System (TCS or ASR)
Advanced Driver Assist System (ADAS)
Adaptive Cruise Control (ACC)
Automatic Emergency Braking (ABA)
Data Collection

• Shift duration
• Miles driven per day
• Location of operation
• Total energy consumed per day
• Charge duration per day
• Driving efficiency per day
• Vehicle regenerative energy per day
• Auxiliary load and energy per day
• Driver behavior
• Thermal system performance
• Battery & cell temperature; battery health
Innovation Fleet - Metrics to Date

• Total miles accrued all vehicles: > 525,000 miles thru August 2021
• eCascadia: 470,000+ miles; 2.03 kWh/mile (avg)
  • NFI: (avg/max)
    • Miles: 150 / 246
    • Hours per day: 7.5 hrs / 11.6
    • Loads (lbs): 24,000 / 53,000
  • Penske Logistics: (avg/max)
    • Miles: 102 miles / 196
    • Hours: 5.5 hrs / 11.1
    • Loads (lbs): 40,000 / 60,000
  • Charging hours: 3 - 4
• eM2: 55,000+ miles; 1.35 kWh/mile (avg)
  • Penske Logistics: (avg/max)
    • Miles: 86 miles / 135
    • Hours: 1.42 / 12.5
    • Loads (lbs): 2,500 / 6,000
  • Charging hours: 2-3
Miles and Efficiencies

Total Electric Vehicle Miles Traveled

Calendar Weeks (2019-2021)

Average kWh/mile

Calendar Weeks (2019-2021)
ESS Profile

Innovation Fleet

Vehicle Charging

ESS Charging
Innovation Fleet – Problems/Resolutions

- **Concerns**
  - Turning radius is larger
  - Back-of-Cab radiator obstructs view of fifth wheel
  - Accelerated tire wear

- **Problems:**
  - High Voltage Batteries
  - eAxle Bearing failures
  - Software
  - AC Compressor issue
  - COVID delays
Vehicles & EVSE first deployed in Q3 2020
Demonstration through Q4 2022

"Customer Experience"

Objectives –
- Expand vehicle demonstration to multiple fleets / outreach
- Provide introduction to DCFC
- 2 – 9 months of demonstration
- Stimulate consumer interest and education
- Gain additional insights on fleet operations and challenges

Demonstration Partners

Project Cost: $ 6.742 MM
- DTNA, SCAQMD ($1 MM), BAAQMD, SCE
Data Collection

• Data loggers captures include:
  • Driver behavior (vehicle controls)
  • Location of operation
  • Recuperation demand
  • Thermal system performance
  • Battery & cell temperature; battery health
  • Charging rate; state of charge and kWh used
  • Power/torque
  • Auxiliary load demand
  • Issues
CX Fleet - Metrics to Date

• Total miles accrued all vehicles: ~ 71,000 miles thru August 2021

• eCascadias : (10 fleets)
  • 64,000 miles
  • 2 kWh/mile (avg.)
  • 5.3 hours / day (avg.)

• eM2’s (2 Fleets)
  • 7,000 miles
  • 1.34 kWh/mile (avg.)
  • 5.7 hours / day (avg.)
CX Fleet – Problems / Resolutions

• Comparable Issue to Innovation Fleet
• Pre-emptive Steps taken on Main Issues
  • eAxle Bearings replaced with ceramic bearings
  • HV Batteries - circuit board isolation issues addressed

• DMV Registration issues
  • CARB certified / not experimental
  • Sales tax on each transfer
  • IRP taxed out of state
### Vehicle Performance

<table>
<thead>
<tr>
<th>Feature</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use and maneuverability</td>
<td>75%</td>
</tr>
<tr>
<td>Range</td>
<td>75%</td>
</tr>
<tr>
<td>Acceleration</td>
<td>95%</td>
</tr>
<tr>
<td>Torque Availability</td>
<td>100%</td>
</tr>
<tr>
<td>Power</td>
<td>90%</td>
</tr>
<tr>
<td>Regenerative braking - performance</td>
<td>90%</td>
</tr>
<tr>
<td>Regenerative braking - ease of use</td>
<td>95%</td>
</tr>
<tr>
<td>Uptime</td>
<td>95%</td>
</tr>
<tr>
<td>Instrument Cluster &amp; HMI</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Charging

<table>
<thead>
<tr>
<th>Feature</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall ease of use</td>
<td>100%</td>
</tr>
<tr>
<td>Functionality</td>
<td>90%</td>
</tr>
<tr>
<td>Uptime</td>
<td>100%</td>
</tr>
<tr>
<td>Vehicle Integration</td>
<td>85%</td>
</tr>
<tr>
<td>Network Services</td>
<td>65%</td>
</tr>
</tbody>
</table>

### Overall Scoring

<table>
<thead>
<tr>
<th>Area</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>91%</td>
</tr>
<tr>
<td>Charging</td>
<td>88%</td>
</tr>
<tr>
<td>Total</td>
<td>90%</td>
</tr>
</tbody>
</table>
Objectives -
Commercial Roll-out of eCascadia and eM2
Four Fleets ; 20 eCascadia’s ; 15 eM2’s
Infrastructure install assistance / SCE funds
Project Cost: $12.5 million

- DTNA ( $3.3 MM), EPA TAG ($4.2 MM)
- HVIP/SCE/DTNA ($5.3 MM)
eCascadia
Functional Product Requirements

Range capability: 250 miles per day
  - Achieve 2.0 kWh/mile
  - Redesign 500-550 kWh battery back system
  - Ultra-efficient integrated e-axles
  - Reduce curb weight to ~20,000 lbs
  - Lighter battery packaging

Enhance motor design, software, telematics, weatherization and diagnostic systems custom designed for electric trucks

Provide a life-cycle cost-effective and zero-emission freight movement solution for more than 70% of use cases
## Prototype to Commercial Changes
### Drivetrain and Batteries

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>E/E Platform</th>
<th>Battery</th>
<th>eAxle</th>
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</thead>
<tbody>
<tr>
<td>eCascadia</td>
<td>Current Cascadia</td>
<td>Agility</td>
<td>ZF</td>
</tr>
<tr>
<td>Current M2</td>
<td></td>
<td>ROMEO POWER</td>
<td></td>
</tr>
<tr>
<td>Series Production</td>
<td></td>
<td>XALT</td>
<td>RE440</td>
</tr>
<tr>
<td>eCascadia</td>
<td>CEEA+</td>
<td>DAIMLER</td>
<td>DAIMLER</td>
</tr>
<tr>
<td>Current M2</td>
<td></td>
<td>EVA2/ CB401</td>
<td>EVA2/ CB400</td>
</tr>
<tr>
<td>Series Production</td>
<td></td>
<td>DAIMLER</td>
<td>DAIMLER</td>
</tr>
<tr>
<td>eM2</td>
<td></td>
<td>RE440L</td>
<td></td>
</tr>
<tr>
<td>Series Production</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
eCascadia Infrastructure

US Foods (La Mirada)
- Site preparations underway
- Trenching options being explored
- EVSE three-part Phase-in through 2024:
  - three power modules;
  - 50 charging dispensers
  - 3.6-4.5 MW
- First vehicles expected in Q2 2022

Daimlers’ “Electric Island” in Portland, OR

"The site is built to immediately provide charging for EVs of all shapes and sizes, and will serve as an innovation center, allowing both PGE and DTNA to study energy management, charger use and performance, and, in the case of DTNA, its own vehicles' charging performance."
Thank You
Disadvantaged Communities Disproportionately Exposed to Unhealthy Air

Zero Emission Truck Pilot Project

Patricia Kwon
Program Supervisor

Clean Fuels Retreat
September 15, 2021
South Coast AQMD awarded $27M from CARB and CEC to deploy 100 commercial Class 8 BETs and EVSE

- 50 trucks per fleet (Ontario, South El Monte)
- Fleets heavily utilize I-710 freight corridor
- Located and operate in DACs
  - Drayage & regional short haul
  - Leverage past & on-going demonstrations
  - ZEV workforce plan & training courses
  - Community and stakeholder outreach
  - Data collection, analysis, fleet tools

<table>
<thead>
<tr>
<th></th>
<th>NFI</th>
<th>Schneider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty Cycle</td>
<td>Drayage</td>
<td>Drayage &amp; Regional Haul</td>
</tr>
<tr>
<td>Number of Trucks</td>
<td>50*</td>
<td>50*</td>
</tr>
<tr>
<td>Number of Chargers</td>
<td>34</td>
<td>16</td>
</tr>
<tr>
<td>Solar</td>
<td>1 MW</td>
<td></td>
</tr>
<tr>
<td>Battery Storage</td>
<td>5 MWh</td>
<td></td>
</tr>
<tr>
<td>Truck Deployment</td>
<td>10 BETs Q2 22 40 BETs Q1 23</td>
<td>10 BETs Q4 22 40 BETs Q2 23</td>
</tr>
<tr>
<td>Fleet Location</td>
<td>Ontario</td>
<td>South El Monte</td>
</tr>
</tbody>
</table>

*Volvo and Daimler Class 8 battery electric trucks are CARB and EPA certified*
Project Goals

CEC/CARB project goals
- Advance Class 8 BET technology
- Assess feasibility of 50 trucks each at fleets
- Support economies of scale for OEMs
- Achieve criteria and GHG emission reductions
- Compliance with CARB regulations
- Address concerns of residents in DACs

South Coast AQMD and partner project goals
- NOx reductions towards attainment
- Compliance with ISR regulations
- Transition to zero emission at Ports and fleets
- Analyze infrastructure and grid impacts

<table>
<thead>
<tr>
<th>Project Benefits</th>
<th>NFI</th>
<th>Schneider</th>
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</thead>
<tbody>
<tr>
<td>NOx, ROG, PM10 Weighted Reductions (tpy)</td>
<td>2.45</td>
<td>2.55</td>
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<tr>
<td>CO2 reductions (MT/year)</td>
<td>3,823</td>
<td>3,984</td>
</tr>
<tr>
<td>Jobs Created/Retained</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Solar CO2 reductions (MT/year)</td>
<td>440</td>
<td>--</td>
</tr>
</tbody>
</table>

*Emission reductions based on current fleet truck age and VMT
Deployment at NFI

NFI will deploy in Ontario (drayage)

- 50 Daimler and Volvo BETs
- 34175 kW and 350 kW DC fast chargers
- 1 MW solar
- 5 MWh battery energy storage
Deployment at Schneider

Schneider will deploy in South El Monte (regional haul)
- 50 Daimler BETs
- 16 175 kW and 350 kW DC fast chargers
## Project Costs by Fleet

<table>
<thead>
<tr>
<th>Task</th>
<th>NFI</th>
<th>Schneider</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 8 battery electric trucks</td>
<td>$21.7M</td>
<td>$19.2M</td>
<td>$40.9M</td>
</tr>
<tr>
<td>Chargers</td>
<td>$6.9</td>
<td>$7.3</td>
<td>$14.2</td>
</tr>
<tr>
<td>Solar</td>
<td>$2.0</td>
<td>--</td>
<td>$2.0</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>$2.0</td>
<td>--</td>
<td>$2.0</td>
</tr>
<tr>
<td>Maintenance Facility</td>
<td>$2.0</td>
<td>--</td>
<td>$2.0</td>
</tr>
<tr>
<td><strong>Project Total</strong></td>
<td>$34.6M</td>
<td>$26.5M</td>
<td>$61.1M</td>
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</table>
## Project Funding

<table>
<thead>
<tr>
<th></th>
<th>Amount</th>
<th>Percent</th>
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<tbody>
<tr>
<td>CARB</td>
<td>$16.0M</td>
<td>24%</td>
</tr>
<tr>
<td>CEC</td>
<td>$11.0M</td>
<td>16%</td>
</tr>
<tr>
<td>NFI</td>
<td>$9.5M</td>
<td>14%</td>
</tr>
<tr>
<td>Schneider/DTNA</td>
<td>$8.7M</td>
<td>13%</td>
</tr>
<tr>
<td>MSRC</td>
<td>$8.0M</td>
<td>12%</td>
</tr>
<tr>
<td>South Coast AQMD</td>
<td>$5.4M</td>
<td>8%</td>
</tr>
<tr>
<td>SCE</td>
<td>$5.0M</td>
<td>7%</td>
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<tr>
<td>POLA</td>
<td>$1.5M</td>
<td>2%</td>
</tr>
<tr>
<td>POLB</td>
<td>$1.5M</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Project Total</strong></td>
<td><strong>$66.6M</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Other Project Partners

- Daimler/Volvo: BET OEMs
- Black & Veatch, Electrify Commercial, Power Electronics: EVSE partners
- Ricardo: data collection on trucks, fleet analysis
- CALSTART: charger pricing, fleet case studies
- EPRI: charger performance, fleet uptime dashboard
- UCR CE-CERT: BET eco-routing
- GNA: media/communications, ZEV workforce plan, EVSE support
- LACI: ZEV workforce plan, workforce performance metrics, stakeholder outreach
- CCA: DAC outreach
- Rio Hondo and San Bernardino Valley College: BET education and training partners
Timeline

2021  2022  2023  2024  2025

Media & Communications

Trucks

EVSE

DER

Data Collection

DAC Outreach

Stakeholder Outreach

Final Report

BET Eco-Routing
Charger Pricing
Charger Performance
Fleet Case Studies
Fleet Uptime Dashboard

ZEV Workforce Plan
Project Benefits

● Demonstrate feasibility of large BET deployments
● Better understand fleet needs
● Develop fleet tools for transition to BETs
● Drive technology improvements in electric range and fast charging
● Address equity and scale priorities in DACs near Ports and goods movement

5 Weighted Tons of criteria pollutants will be avoided each year by displacing diesel

8,200 Metric Tons of greenhouse gas emissions (GHGs) will be reduced each year

5.5 Million DGEs of diesel fuel will be displaced over the eight-year project

239 Long-Term Jobs sustained, including drivers and service technicians

$16.8+ Million in regional economic activity as result of site construction
Next Steps

- Kick-off meeting Sept 2021
- Execute remaining contracts
- Develop data collection plans on BETs, EVSE, specialized studies
- Refine infrastructure deployment at fleets
- Update BET deployment at fleets
- Work on stakeholder and DAC outreach plans
- Finetune workforce training between colleges, fleets, OEM partners
- Develop outline and metrics for ZEV workforce plan
Fuel Cell Heavy-duty Truck Demonstration and Beyond

Technology Advancement Office
Program Supervisor

Seungbum Ha
Zero Emission Fuel Cell Vehicle Project

Technology Readiness Level

- **4**: Technology Development
- **5**: Technology Development
- **6**: Technology Development
- **7**: Technology Development
- **8**: Technology Development
- **9**: Technology Development

<table>
<thead>
<tr>
<th>Year</th>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2009</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2010</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2011</td>
<td>Early Demo</td>
<td>Honda FCX</td>
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<tr>
<td>2012</td>
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<td>Honda FCX</td>
</tr>
<tr>
<td>2013</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2014</td>
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<td>Honda FCX</td>
</tr>
<tr>
<td>2015</td>
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<td>Honda FCX</td>
</tr>
<tr>
<td>2016</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2017</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2018</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2019</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2020</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
<tr>
<td>2021</td>
<td>Early Demo</td>
<td>Honda FCX</td>
</tr>
</tbody>
</table>

- **200mi**
  - **150mi**
    - **100mi**
      - **2008**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2010**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2012**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2014**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2016**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2018**: Data analysis: Toyota Highlander, Hyundai Tucson
      - **2020**: Data analysis: Toyota Highlander, Hyundai Tucson

- **2017**: ZECT II Fuel Cell Bus/CNG Hybrid, $20M/$2.5M
- **2018**: ZANZEFF - Toyota-KW Fuel Cell Truck
- **2019**: CEC ARF VTP - Cummins Fuel Cell Truck, $5M/$0.6M

* $ Total Project Cost (SCAQMD Cost-share)
# US DOE ZECT II

## ZECT II Fuel Cell trucks

<table>
<thead>
<tr>
<th>Developer</th>
<th>BAE/Kenworth</th>
<th>Cummins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>1</td>
<td>Freightliner</td>
</tr>
<tr>
<td>Fuel Cell Power</td>
<td>85kW</td>
<td>60kW</td>
</tr>
<tr>
<td>Fuel Cell stack</td>
<td>Ballard</td>
<td>Hydrogenics</td>
</tr>
<tr>
<td>Battery Capacity</td>
<td>100 kWh</td>
<td>100kWh</td>
</tr>
<tr>
<td>Range (per fueling)</td>
<td>120 miles</td>
<td>150 miles</td>
</tr>
<tr>
<td>Fuel Cap.: H2 (kg)</td>
<td>30 kg @350 bar</td>
<td>30 kg @350 bar</td>
</tr>
</tbody>
</table>

- Up to 250 miles range
- 700 bar H2 tank

**ZANZEFF**
Toyota-KW
Fuel cell Truck

**CEC ARFVTP**
Cummins
Fuel cell Truck
System Design

- Two electric motors with 270 kW combined power output - comparable to a current Class 8 truck engine’s power output.
- 100 kWh Li-ion batteries,
- 85 kW (net) fuel cell system
- Hydrogen storage capacity is 30 kg (25 kg usable)

Target Performance

<table>
<thead>
<tr>
<th>Performance Parameters</th>
<th>Expected Performance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Economy</td>
<td>4.5 to 6.0 mi/kg</td>
</tr>
<tr>
<td>Hydrogen Storage</td>
<td>30 kg storage and 25 kg usable</td>
</tr>
<tr>
<td>Range</td>
<td>112 miles</td>
</tr>
<tr>
<td>Gradeability and Start-ability</td>
<td>6.5% grade at 35 mph</td>
</tr>
<tr>
<td></td>
<td>5.0% grade at 40 mph</td>
</tr>
<tr>
<td></td>
<td>15 second start-ability at 30% grade</td>
</tr>
<tr>
<td>Top Speed</td>
<td>70 mph</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-4 F (-20 C) to 115 F (46 C)</td>
</tr>
</tbody>
</table>

* Note: All performance parameters tested with a vehicle GVW of 65,000 lbs.
Vehicle In-service Operation

- Over a 24-month demonstration on regularly scheduled routes, I-710 freeway in the ports and I-10/CA-60 corridor in Los Angeles
- NREL - Detecting overall trends and spotting days of service, more specific to the operator, TTSI
US DOE ZECT II

- Fuel cell truck performed a higher efficiency compared to the baseline vehicles

<table>
<thead>
<tr>
<th>Metric</th>
<th>Units</th>
<th>Baseline* Conventional</th>
<th>Kenworth ZECT</th>
<th>Date range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date range</td>
<td></td>
<td>2014–2015</td>
<td>6/13/2019 – 1/15/2021</td>
<td></td>
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<tr>
<td>Number of total days recorded</td>
<td>#</td>
<td>557</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>In-service days with &gt;5 miles</td>
<td>#</td>
<td>—</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Max daily distance</td>
<td>mi</td>
<td>—</td>
<td>245.2</td>
<td></td>
</tr>
<tr>
<td>Avg daily distance</td>
<td>mi</td>
<td>127.9</td>
<td>53.9</td>
<td></td>
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<tr>
<td>Avg operating time (key-on)</td>
<td>hr</td>
<td>10.1</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Avg driving time</td>
<td>hr</td>
<td>4.5</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Avg speed</td>
<td>mph</td>
<td>14</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>Avg driving speed (speed&gt;0)</td>
<td>mph</td>
<td>26.5</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Kinetic intensity</td>
<td>1/mi</td>
<td>0.64</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Avg stops/day</td>
<td>#/day</td>
<td>124.9</td>
<td>176.1</td>
<td></td>
</tr>
<tr>
<td>Avg stops/mi</td>
<td>#/mile</td>
<td>1.38</td>
<td>4.7</td>
<td></td>
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<tr>
<td>Median stop duration</td>
<td>sec</td>
<td>40.8</td>
<td>7.4</td>
<td></td>
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<tr>
<td>Avg daily fuel use (H₂)</td>
<td>kg</td>
<td>—</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>Avg daily fuel use (diesel equiv.)</td>
<td>gal</td>
<td>23.7</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Avg fuel economy (diesel equiv.)</td>
<td>mi/gal</td>
<td>5.7</td>
<td>6.5</td>
<td></td>
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<tr>
<td>Avg fuel cell efficiency</td>
<td>%</td>
<td>—</td>
<td>52.1%</td>
<td></td>
</tr>
</tbody>
</table>

*ZECT II milestone report: Baseline Vehicle Data Collection and Analysis Report – Part Drayage

More Stop-n-Go
Higher fuel economy
The largest strides in Technology Readiness Level (TRL) on the overall vehicle design and architecture.

Improvements to packaging and vehicle control strategies to increase efficiency

Challenges
- Lack of standardization in componentry
- Improving reliability across the system
- Deploying a larger numbers of vehicles
- Reliable H2 fuel supply
In 2019, Cummins acquired EDI and Hydrogenics

4 Fuel Cell Class 8 drayage trucks (200+ mile ZE range)

Complete and deliver vehicles in 2021 with 12 month demonstration
Hyundai Fuel Cell Drayage Truck

- Fuel-cell technology is an attractive solution for regional and long-haul services

- The trucks will be demonstrated for 12 months in regional and long-haul routes to fully utilize up to 500-mile range

- South Coast AQMD has been awarded $500,000 from U.S. EPA FY21 Clean Air Technology Initiative Program
### Comparison of Technologies

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **Diesel**           | • The most common fuel type for decades, so capital costs are low and fueling locations are common  
|                      | • Range only limited by driver’s 10 hour driving limit             | • Biggest polluter of particulate matter and greenhouse gases  
|                      |                                                                      | • Loud and odorous operation                                         |
|                      |                                                                      | • Relatively high maintenance costs                                  |
|                      |                                                                      | • Being phased out by California and port regulations                |
| **CNG**              | • Less emissions than diesel                                        | • Not zero-emission                                                  |
|                      | • Quick refill like diesel                                          | • Although highly commercialized now, gained a reputation for not being reliable when first entering the market |
|                      | • ~ 300 mile range                                                  | • Emits about 75% as much CO₂ and 10% as much NOₓ as diesel trucks  |
|                      | • Fueling infrastructure relatively common                          |                                                                      |
|                      | • Fuel slightly less expensive than diesel                          |                                                                      |
|                      | • Quieter operations                                                 |                                                                      |
| **Hydrogen Fuel Cell** | • Zero tailpipe emissions                                          | • Least commercialized option with fewest vehicles on the road      |
|                      | • Quick refueling (10 minutes)                                      | • High MSRP                                                          |
|                      | • Expected 300+ mile range                                          | • High fuel cost                                                     |
|                      | • Quiet operations                                                   | • Fueling infrastructure not commonly available                      |
|                      | • Reduced maintenance costs                                         |                                                                      |
|                      | • Possibility for extended range with 700 bar fueling               |                                                                      |
|                      | • Torque / acceleration                                              |                                                                      |

- Hydrogen infrastructure
  - Assessment of feasible pathway for hydrogen fueling in near and long term
  - Renewable hydrogen station
- TCO analysis and commercialization roadmap
Clean Fuels Advisory Group Meeting
September 15, 2021

Hydrogen Infrastructure for Heavy-Duty Vehicles

Lisa Mirisola
Program Supervisor
Science and Technology Advancement
South Coast AQMD
CA Heavy Duty Hydrogen Stations

HD Truck Infrastructure CaFCP 2030 Vision

A.C. Transit
CEC NOPA 20-606 NorCal Pilot
CTE – First Element, Hyundai
700 bar, 3000 kg/day
2 dispensers, 30 Hyundai CL8 FCT

POLA ZANZEFF
Equilon (Ontario: August 2021 –
Wilmington: September 2021 -)
350 & 700 Bar, 1000 kg/day
10 Kenworth Class 8 FC Trucks

US EPA – SCAQMD
2 Hyundai Cl8 FCT

CEC NOPA 17-603
Equilon, Toyota @ POLB
July 2021 -
350 & 700 bar, 1000 kg/day

POLA

CEC NIPA 20-604 H2RAM
GTI – Equilon, FCT &
Sierra Northern H2 Locomotive

SBCTA Rail (Redlands Arrow route) MSRC\$ 2024+

SunLine Transit*
Nel H2 – Proton
2020 + (est 2002)
350 bar, 900 kg/day
2 dispensers

UC Irvine
Upgrade to LH2 delivery
2022+ (est. 2005)
800 kg/day, 700 bar LD,
350 bar FC Bus (at night)

OCTA
Trillium, APCI LH2 delivery
February 2020 -
350 bar, 1600 kg/day
10 New Flyer, 36 kg/bus

CEC ARFVTP
Cummins
Fuel Cell truck

US DOE ZECT1, ZECT 2,
(Video: Toyota Red=Alpha & Blue = Beta)
A Vision for Freight Movement in California – and Beyond

Figure 6: Envisioned station network to support 70,000 hydrogen fuel cell electric trucks.
H2Freight Project at POLB

- CEC GFO-17-603 - Advanced Freight Vehicle and Infrastructure Deployment:
- CONTRACTOR: Equilon (dba Shell) Station at POLB (property leased to Toyota)
- 1,000 kg/day truck refueling with multiple fueling positions at 700 bar
- SCAQMD cost-share to refuel heavy-duty vehicles at 350 bar for demonstration by multiple operators
- **Commissioned & Open July 2021**
- Evaluate fueling protocols, dispenser design, station throughput/reliability, etc.
Zero Emissions Freight “Shore to Store”

- Contractor: POLA
- Total $82.5M ZANZEFF
- Develop and demonstrate ten fuel cell trucks (Class 8 Kenworth T680 with Toyota fuel cells)
- H2 stations in Ontario & Wilmington (Shell Equilon)
- All 10 FCET in revenue service (August 2021)
  United Parcel Services (3),
  Total Transportation Services Inc (2),
  Southern Counties Express (1),
  Toyota Logistics Services (4)
UC Irvine Hydrogen Station Expansion

- Expansion to 800 kg/day with liquid delivery, increased storage, and four fueling positions
- Public access will continue 24/7, with bus refueling at night
- Co-funding approved & contracts executed
  - MSRC for up to $1M (PON 2018-02)
  - CEC $400k (ARFVTP)
  - SCAQMD $400k (Clean Fuels)
- Equipment will be moved to new location on UCI property (at UCI expense), then upgraded
California HD Hydrogen Infrastructure Research

- U.S. DOE H2@Scale program with national labs, CA GO-Biz, CEC, CARB and SCAQMD
- Joint agreement led by NREL to continue hydrogen infrastructure research efforts 2021 – 2022
- Priorities
  - H2 Contaminant Detector
  - Heavy duty reference station design
  - Heavy duty station test device design
  - Heavy duty station capacity
California High Flow Bus Fueling Protocol

- U.S. DOE H2@Scale program with national labs and project partners to apply MC fueling protocol developed for light-duty vehicles to heavy duty vehicles (H35HF)

- Frontier Energy agreement led by NREL

- Project tasks (2021 – 2022)
  - Bus Fueling Protocol Modeling & Simulation
  - Protocol Test & Validation @ NREL
  - In-use demonstration @ Sunline Transit
Hydrogen Systems Analysis

• UC Davis

• Co-Sponsors including, but not limited to Aramco, CEC, GM, Honda, Hyundai, Leighty Foundation, Shell, So Cal Gas and Toyota.

• Project tasks (2021 – 2022)
  – Analyze and model hydrogen’s role in a carbon-neutral system of transportation, industry and energy storage through 2050 in California and beyond;
  – Assess existing policies to identify gaps over the next 5-10 years; and
  – Study the role of hydrogen and other storage including vehicle-to-grid (V2G) and power-to-gas (P2G) in grid serving both fuel cell and battery electric vehicles.
San Bernardino County agency orders its first zero-emission train for Redlands rail service

BY STEVE SCAUZILLO
November 15, 2019 at 4:07 pm

• Michigan State University (MSU) feasibility study
• Approved the hydrogen fuel cell-battery hybrid alternative propulsion technology for implementation as part of the future Arrow Service
• Potential site of joint use hydrogen station, west of 215 fwy, between 10 & 210 fwys
• 2024 Zero Emission in-service goal
• MSRC awarded $1,662,000 co-funding under PON 2018-02 (June 2021)

https://www.gosbcta.com/project/redlands-passenger-rail-project-arrow/
Hydrogen Shot Summit

Goal: 80% Cost Reduction of Clean Hydrogen
($1 per kg in 1 decade)

DOE Hydrogen Shot Summit 2021 Topics
• Electrolysis
• Thermal Conversion with Carbon Capture and Storage
• Advanced Pathways
• Deployment and Financing

https://www.energy.gov/eere/fuelcells/hydrogen-shot-summit
Infrastructure Challenges & Opportunities

- Policy & funding predictability
  Coordination across all gov levels
- Supply Chain: H2 Production, distribution, parts, materials,
  Need multiple suppliers & scale
- Skilled labor, workforce training
- Focus on safety always; codes & standards
- CEQA/Permits
- Site specific development & operational issues
- Increasing capacity stations are starting to reduce dispensed cost; working on refined HD fueling protocols to become “Recommended Practice”
- Address short-term H2 network fragility
- Increase renewable H2 production dedicated to transportation
Heavy-Duty Engine
Development and Beyond
NOx Target ≤ 0.02 g/bhp-hr

Joseph Lopat
September 15, 2021
Achates Opposed Piston Engine

- Increased TRL diesel engine development
- 0.02 NOx results with less complicated aftertreatment
- Integrated into Peterbilt chassis.
Achates Demonstration

- Beginning Demonstration
- Walmart revenue service
- In-use emissions testing
## Low NOx Diesel Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Expected end date</th>
<th>Expected Results</th>
<th>Funding agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low NOx conventional diesel</td>
<td>2022</td>
<td>0.02 NOx</td>
<td>South Coast AQMD, CARB, US EPA, MECA</td>
</tr>
<tr>
<td>Final Aftertreatment Selection</td>
<td>2021</td>
<td>800,000 miles aged at near 0.02 NOx</td>
<td>CARB, US EPA</td>
</tr>
<tr>
<td>Low NOx hardware studies</td>
<td>2022</td>
<td>Supporting low NOx</td>
<td>CARB, US EPA</td>
</tr>
<tr>
<td>Final assessment and testing</td>
<td>2022</td>
<td>Determination of new standards for emissions</td>
<td>CARB, US EPA</td>
</tr>
<tr>
<td>Demonstration of near-zero NOx engine in class 8 truck</td>
<td>2022-2023</td>
<td>In-use testing at 0.02 Nox</td>
<td>Potentially South Coast AQMD, CARB, MECA, Peterbilt?</td>
</tr>
</tbody>
</table>
Continuous Development Toward Lowering NOx (2021-2022)

- Cummins Cylinder Deactivation 15L ISX
  - 0.02 NOx results
  - Final selected aftertreatment configuration
  - Aftertreatment durability
    Tested to maintain near 0.02 NOx at 800,000 miles useful life
Low NOx Hardware Studies (2021-2022)

Target is any engine and/or exhaust after treatment development that has the potential to attain a NOx emissions of 0.02 g/bhp-hr or lower.

- Exhaust Gas recirculation
- Turbo and supercharger advancement
- Cold ambient air and wind speed testing
- Expectation in-use 2021-2035 0.04 NOx
Low NOx Engine
Demonstration in class 8 truck (2022)

- Final data collection in September 2022
- Down selected hardware and engine for chassis integration
- Demonstrate low NOx diesel technology
- Renewable Diesel
- 0.05 NOx capable diesel technology for market 2027
- 0.02 NOx capable diesel technology for market 2030
Potential Natural Gas Future Projects

- Certified 0.02 NOx
- 12-liter class 8 drayage trucks
- 9-liter for refuse haulers and buses
- On-going class 6-7 projects Ford 7.3
- 15-liter development
- RNG
- Infrastructure
Market Acceleration Program

- Launched in July 2020
- Port trucks only
- 40 class 8 CNG powered trucks ordered
- Award amount $100,000/truck
- 40 2014 and older diesel trucks scrapped
- Streamlined process
- $4 million funding available
- 2021-2022 truck delivery
Trade Down Pilot Program

- Launched in Fall of 2020
- 50 CNG replacements expected - Port trucks only
- Fleet 1 - EMY 2014 or newer diesel traded in
- Fleet 1 - Award amount $100,000 + $25k for trade-in to purchase low NOx truck
- Fleet 2 – EMY 2009 or older for scrapping
- Fleet 2 – Purchases the trade-in for $30k
- Dealership matches fleets/packages application
- $5 million funding available from EPA and MSCRC
Questions
200 Vehicle In-Use Emissions Testing Program Update

Clean Fuels Advisory Group | Sam Cao - Air Quality Specialist | September 2021
Objectives

Identify technology benefits/shortfalls, feed information into future R&D opportunities, future regulation development and improve emissions inventory estimates.

Total Vehicles Recruited

219
22 Vehicle OEMs, 9 Engine OEMs, 200 PAMS, 100 PEMS, 60 Chassis, 10 On-Road Trailer

Vocations Covered

5
25 Fleet Participants: Delivery (44), Goods Movement (95), Transit Bus (21), School Bus (27) and Refuse (32)

Technologies Covered

9
Propane (4), Propane 0.02 (2), CNG 0.02 (34), CNG 0.2 (84), Non SCR Diesel (7), Diesel 0.2 (70), Diesel-Hybrid (6), BEV (10), FCEV (1), HDPI (4), RD (12)
## Testing Phase Update

<table>
<thead>
<tr>
<th>Testing Phase</th>
<th>Assigned</th>
<th>Recruited</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable Activity Monitoring System (PAMS)</td>
<td>200</td>
<td>219</td>
<td>206</td>
</tr>
<tr>
<td>Portable Emissions Measurement System (PEMS)</td>
<td>100</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>Chassis Dynamometer</td>
<td>60</td>
<td>62</td>
<td>60</td>
</tr>
<tr>
<td>Real-World In-Use Trailer</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

- Analysis & reporting in progress
- Target testing completion - 3Q2021
- Target report completion - early 2022
Testing Elements of This Study

New Chassis Test Cycle

- **PAMS**
  - Activity, Average Speed, VMT, Idle, Starts

- **PEMS**
  - Real-World Data, NTE/WBW, Start/Running Emissions

- **Chassis**
  - Lab Grade Data, Real-Word Cycles
  - Start/Running Emissions

- **On-Road**
  - Real-World Lab Grade Data, NTE/WBW
  - Start/Running Emissions

Route Information

Emission Inventory

This Update
On-Road Testing Matrix

- Test cycle generated from on-road telemetry data (PAMS) w/actual segments and statically representative cycle similar to chassis cycles (Markov method)
- 10 vehicles, equally shared between WVU and UCR
- On-road tests: repeatable duty-cycle, lab-grade equipment but limited to class 7/8 tractors only, GVWR 65,000 – 68,000 lbs

<table>
<thead>
<tr>
<th>Technology</th>
<th>Grocery</th>
<th>Drayage</th>
<th>Parcel</th>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SCR Diesel (2)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>0.2 Diesel (4)</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>0.2 CNG (1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>0.02 CNG (3*)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Overall Preliminary Findings

- 8 trucks, NOx emission averaged over the entire route, each route 4-9 hours long
- Is comparing to the standard best way to assess emissions?
Technology Comparison Show Lower NOx for CNGs

- CNGs significantly lower NOx compare to 0.2 diesel baseline
- 0.2 CNG very low NOx (<0.1 g/bhp-hr)
- 0.02 CNG higher NOx on parcel & CR&R route, data still being verified
- 2 additional 0.02 CNGs to be tested
- Segmented analysis later

*Preliminary findings, data still being analyzed and finalized
Grocery Delivery Truck Route ("Ralphs" Route)

- Representing typical operation of grocery from IE warehouse to LA supermarkets, using telemetry data from 23 trucks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>[hrs]</td>
<td>9.35</td>
</tr>
<tr>
<td>Distance</td>
<td>[miles]</td>
<td>185.6</td>
</tr>
<tr>
<td>Idle</td>
<td>[%]</td>
<td>37.4</td>
</tr>
<tr>
<td>Urban (≤31mph)</td>
<td>[%]</td>
<td>30.9</td>
</tr>
<tr>
<td>Rural (&gt;31 &amp; ≤46.6mph)</td>
<td>[%]</td>
<td>10.8</td>
</tr>
<tr>
<td>Highway (&gt;46.6mph)</td>
<td>[%]</td>
<td>20.9</td>
</tr>
</tbody>
</table>
Grocery Delivery Truck Route ("Ralphs" Route)

- Route has 4 stops (5 segments/"legs") at stores to unload goods, engine off events of about 30min duration
Segmented Emissions – Grocery Route

- One truck from each technology
- Averaged NOx emissions over each segment/leg (e.g. Grocery Route “Leg 1” = IE to Stop 1 in DTLA)
- The duty cycle vary drastically from one segment to next (so as segmented averaged NOx emissions)

### Averaged NOx Emissions g/bhp-hr

<table>
<thead>
<tr>
<th>Segment</th>
<th>Diesel No SCR</th>
<th>0.2 Diesel</th>
<th>0.02 CNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Time-based vehicle speed distribution

- **Idle** Vehicle Speed <= 1 mph
- **Urban** 31 mph > Vehicle Speed > 1 mph
- **Rural** 46.6 mph > Vehicle Speed > 31 mph
- **Highway** Vehicle Speed > 46.6 mph

![Diagram showing vehicle speed distribution](chart.png)
Parcel & Waste Hauling Routes

- Modified versions of “CARB Southern” Route
- Goods movement route with ~ 4,200 ft of elevation change (“UPS” route ~ 115 miles)
- Highway goods movement route (“CR&R” route ~ 179 miles)

“CR&R” Route
Segmented Emissions - Parcel

- Elevation change ~ 4,200 ft
- 0.2 diesel drastically different segmented NOx emissions between leg 1 (traffic or cool-off?) and leg 2
- 0.02 CNG + NO SCR Diesel did not show segmented dependency on NOx emissions
- Traffic conditions impacts NOx emissions even on same route
Segmented Emissions – Waste Hauling

- Unlike Parcel route, waste hauling route does not show different NOX emissions between segments,
- High percentage of highway operation (> 50%)
- 0.02 CNG showed higher levels of NOx on Grocery route, data to be checked and verified
- Two additional 0.02 CNG trucks planned
Drayage Truck Route ("TTSI" Route)

- Representing typical operation of drayage trucks between ports and regional IE warehouses, using telemetry data from 49 trucks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>[hrs]</td>
<td>6.03</td>
</tr>
<tr>
<td>Distance</td>
<td>[miles]</td>
<td>161.5</td>
</tr>
<tr>
<td>Idle</td>
<td>[%]</td>
<td>23.3</td>
</tr>
<tr>
<td>Urban (≤31mph)</td>
<td>[%]</td>
<td>31.6</td>
</tr>
<tr>
<td>Rural (&gt;31 &amp; ≤46.6mph)</td>
<td>[%]</td>
<td>15.6</td>
</tr>
<tr>
<td>Highway (&gt;46.6mph)</td>
<td>[%]</td>
<td>29.6</td>
</tr>
</tbody>
</table>
Drayage Truck Route

- Leg 1: Transfer of load from IE warehouse to port
- Leg 2: 1hr long creep/idle operation in port to unload/load
- Leg 3: Transfer of load to IE warehouse
Segmented Emissions - Drayage

- Leg 2 (Neardock) cycle to simulate creep operation, < 90% idling
- Very little cycle work (~ 3.3 bhp-hr vs ~300 bhp-hr for leg 3)
- High brake-specific/distance-specific emissions due to duty-cycle and “math”
- 0.02 CNG showed lowest NOx emissions, as expected
Metric are Important Considerations for Idle/Low-Load Conditions

- g/bhp-hr vs g/mile vs g/hr will affect the NOx emissions comparison
- Idle should use grams/hr for characterizing emissions (subsequent slides idle all in g/hr)
- Lower load duty-cycles emissions should also be treated differently
- Should consider for “where” and “when” the emissions are emitted
Better Way to Look at Emissions: Speed Binning

- Compare only two trucks for simplicity (0.2 diesel and 0.02 CNG)
- Idle in gram/hr (chart not to scale)
- Bin: 1 sec mini windows binned by vehicle speed
- Average NOx emission for all windows within each bin

<table>
<thead>
<tr>
<th>Speed Bin</th>
<th>Vehicle Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle Bin</td>
<td>Vehicle Speed &lt;= 1 mph</td>
</tr>
<tr>
<td>Urban Bin</td>
<td>31 mph &gt; Vehicle Speed &gt; 1 mph</td>
</tr>
<tr>
<td>Rural Bin</td>
<td>46.6 mph &gt; Vehicle Speed &gt; 31 mph</td>
</tr>
<tr>
<td>Highway Bin</td>
<td>Vehicle Speed &gt; 46.6 mph</td>
</tr>
</tbody>
</table>

0.2 Diesel

0.02 CNG

Legend:
- Leg 1
- Leg 2 (Neardock)
- Leg 3
Future Regulations Will Account for Duty Cycle

- Omnibus and EPA CTI will dramatically change how emissions are regulated
- Different limit/metric for different duty cycles
- Conformity Factor (CF) added to account for measurement system variability under in-use conditions
- Future combustion technology are expected to be more robust emissions under various operating conditions

<table>
<thead>
<tr>
<th>Bin</th>
<th>Duty-Cycle</th>
<th>2024 NOx Standard (CA Only)</th>
<th>2027 NOx Standard</th>
<th>CF</th>
<th>2024 In-Use Std W/ CF</th>
<th>2027 In-Use Std W/CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>&lt; 6%</td>
<td>10 g/hr</td>
<td>5 g/hr</td>
<td>2.0</td>
<td>20 g/hr</td>
<td>10 g/hr</td>
</tr>
<tr>
<td>Low Load (LLC)</td>
<td>6% - 20%</td>
<td>0.20 g/bhp-hr</td>
<td>0.05 g/bhp-hr</td>
<td>2.0</td>
<td>0.40 g/bhp-hr</td>
<td>0.10 g/bhp-hr</td>
</tr>
<tr>
<td>Mid-High Load</td>
<td>&gt; 20%</td>
<td>0.05 g/bhp-hr</td>
<td>0.02 g/bhp-hr</td>
<td>2.0</td>
<td>0.10 g/bhp-hr</td>
<td>0.04 g/bhp-hr</td>
</tr>
</tbody>
</table>

Source: CARB Omnibus Final Rule
3B-MAW Results

- Each window is 300 secs (MAW)
- As expected, 0.2 diesel performed well on Mid/High bin (similar to cert cycle) but poorly on Low-Load/Idle bin
- 0.02 CNG NOx level close to CARB 2027 standard

<table>
<thead>
<tr>
<th>Bin</th>
<th>2024 In-Use Std W/CF</th>
<th>2027 In-Use Std W/CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle &lt; 6%</td>
<td>20 g/hr</td>
<td>10 g/hr</td>
</tr>
<tr>
<td>Low Load (LLC) 6-20%</td>
<td>0.40 g/bhp-hr</td>
<td>0.10 g/bhp-hr</td>
</tr>
<tr>
<td>Mid-High Load (FTP/RMC) 20%</td>
<td>0.10 g/bhp-hr</td>
<td>0.04 g/bhp-hr</td>
</tr>
</tbody>
</table>
Team

Contractors: WVU, UCR/CE-CERT

Funding Partners: CEC, CARB, SoCalGas and South Coast AQMD
Thank you.