CLEAN FUELS PROGRAM ADVISORY GROUP AGENDA
SEPTEMBER 17, 2020, 9:00 AM – 3:30 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 participate during public comment periods.

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.
INSTRUCTIONS FOR ELECTRONIC PARTICIPATION AT BOTTOM OF 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 – 10:00 AM	
(a)	Welcome & Introductions	Matt Miyasato/Naveen Berry, Deputy/Assistant Deputy Executive Officer
(b)	Emission Reductions and Air Quality Impacts from the COVID-19 Pandemic Response	Scott Epstein, Program Supervisor, Health Effects – Planning and Rules
(c)	Goals for the day	Joseph Impullitti, Manager, Technology Demonstration Group
(d)	Feedback and Discussion	All
1.	**Areas of South Coast AQMD Focus Commercialization of Zero and Near-zero Heavy & Medium-Duty Trucks & Infrastructure 10:00 AM – 12:00 PM**	
(a)	Near-zero Engine Technologies	Joseph Lopat, Program Supervisor
(b)	Heavy-Duty Trucks - Hybrid Electric Pathways	Sam Cao, PhD, Air Quality Specialist
(c)	Battery Electric Trucks - Volvo	Patricia Kwon, Program Supervisor
(d)	Battery Electric Trucks - Daimler	Phil Barroca, Program Supervisor
(e)	Feedback and Discussion	All
	Lunch 12:00 PM – 1:30 PM	
2.	**Commercialization of Zero and Near-zero Heavy & Medium-Duty Trucks & Infrastructure (con't) 1:30 PM – 3:00 PM**	
(a)	Fuel Cell Trucks – Kenworth & Cummins	Seungbum Ha, PhD, Program Supervisor
(b)	Transit Buses - Status	Maryam Hajbabaei, PhD, Air Quality Specialist
(c)	Hydrogen Infrastructure - Heavy Duty Vehicles	Lisa Mirisola, Program Supervisor

3.	Wrap-up – 3:00 PM – 3:30 PM	
(a)	2021 CF Proposed Plan Update Discussion & Wrap-up	Joseph Impullitti
(b)	Advisor and Expert Comments	All

Other Business
Any member of the committee, 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. (Government 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 Committee'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 prior to the meeting for public review at the South Coast Air Quality Management District Public Information Center, 21865 Copley Drive, Diamond Bar, CA 91765.

Americans with Disabilities Act
The agenda and documents in the agenda packet will be made available, upon request, in appropriate alternative formats to assist persons with a disability. Disability-related accommodations will also be made available to allow participation in the meeting. Any accommodations must be requested as soon as practicable. Requests will be accommodated to the extent feasible. 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.

South Coast AQMD

Emission Reductions and Air Quality Impacts from the COVID-19 Pandemic Response

September 17, 2020

The Question Everyone is Asking

How has the COVID-19 pandemic response affected air quality?

THE WALL STREET JOURNAL.

English Edition | May 11, 2020 | Print Edition | Video

Coronavirus got rid of smog: can electric cars do so permanently?

The Washington Post

The silver lining to coronavirus lockdowns: air quality is improving

Los Angeles MAGAZINE

As many stay home, L.A.'s air quality is better than it's been in decades

The New York Times

Traffic and pollution plummet as U.S. cities shut down for coronavirus

CNN

Los Angeles has notoriously polluted air. But right now it has some of the cleanest of any major city

CAL MATTERS

As Californians stay at home, air quality improves – for now.

THE SACRAMENTO BEE

Fires and climate change polluted California's air. Has coronavirus shutdown helped?

capradio

The 'unprecedented natural experiment:' Stay-at-home order reduces air pollution, offers clues in climate change fight

2 KCAL 9 CBS Los Angeles

LA Has The Cleanest Air In The World, Report Says

South Coast AQMD

South Coast
Air Quality Management District

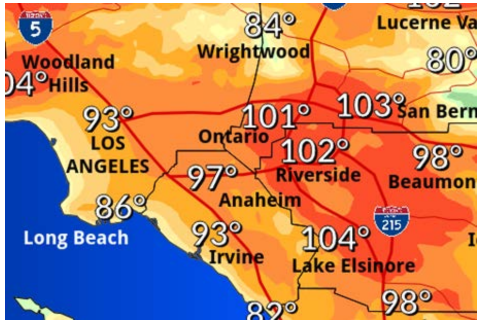
How do Emissions Influence Air Quality?

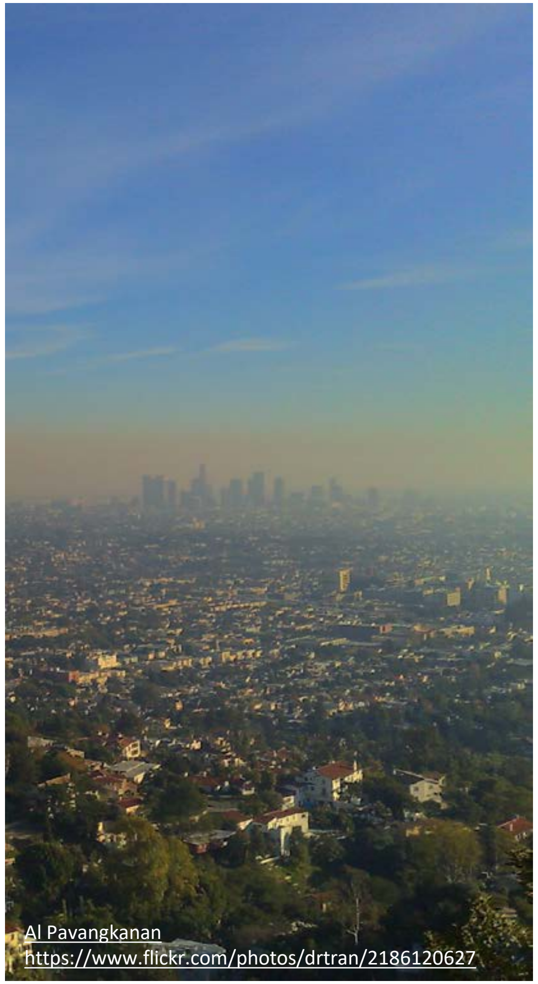
Emissions + **Meteorology and Chemistry** → **Air Quality**








Al Pavangkanan
https://www.flickr.com/photos/drtran/2186120627

South Coast
Air Quality Management District

How do Emissions Influence Air Quality?

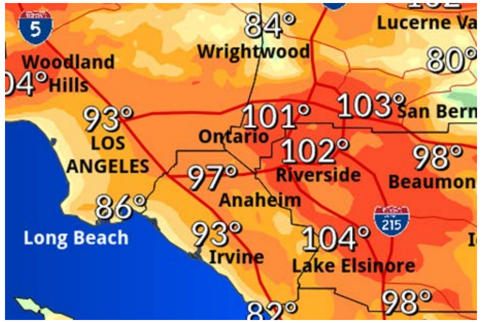
Emissions + Meteorology and Chemistry → Air Quality

- Emissions are usually not measured directly
- Emissions are estimated based on activity data that is not available in real-time
- An **Emissions Inventory** combines these estimates and measurements to track past emissions and predict future emissions

How do Emissions Influence Air Quality?

Emissions + **Meteorology and Chemistry** → Air Quality

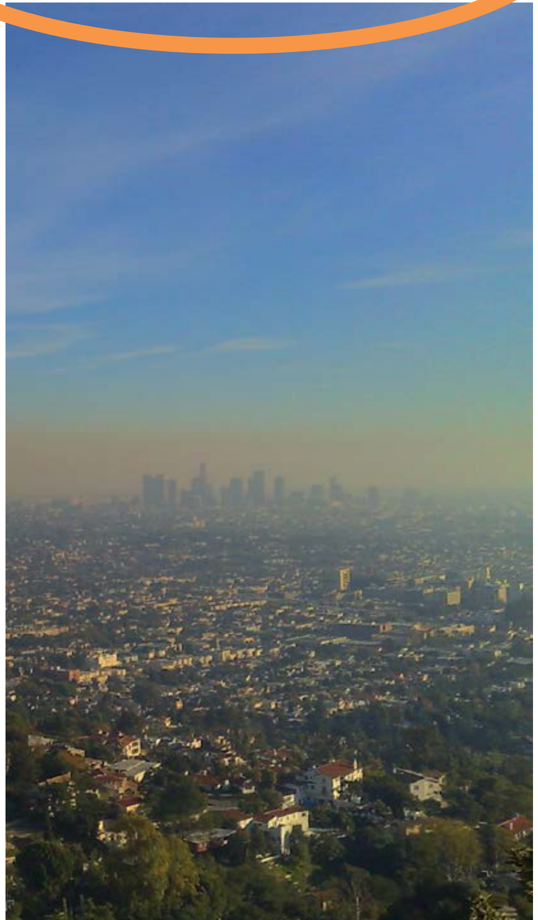
- Meteorology is measured at our monitoring stations and by other agencies
- We also use scientific models to predict:
  - Meteorology
  - Chemical transport
  - Chemistry



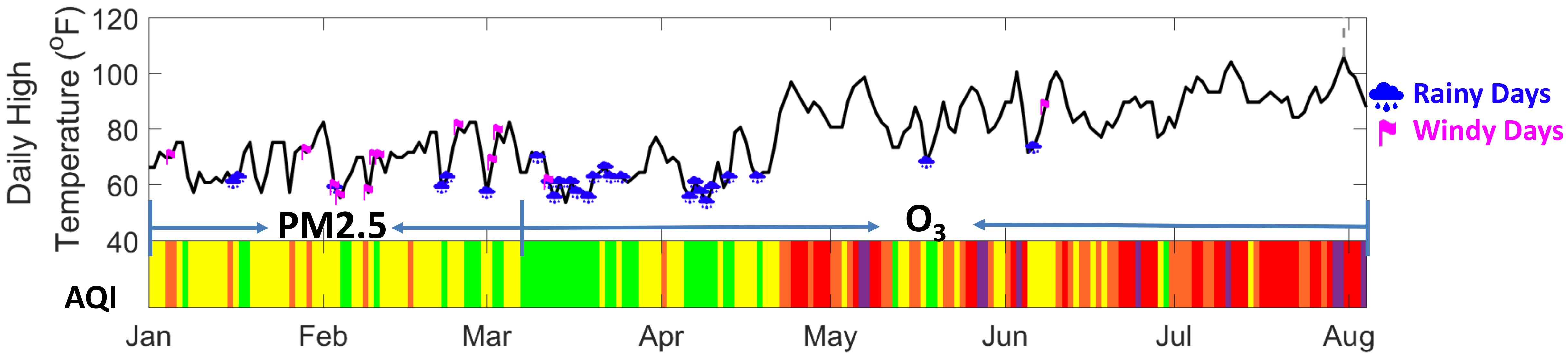
How do Emissions Influence Air Quality?

Emissions + Meteorology and Chemistry → **Air Quality**

- Air pollution concentrations are measured in real-time for many pollutants at 42 stations in the South Coast AQMD jurisdiction
- Satellites also measure air pollution from space (but this may not reflect ground-level concentrations that people breathe)


Al Pavangkanan
https://www.flickr.com/photos/drtran/2186120627

Meteorology and Air Quality Timeline

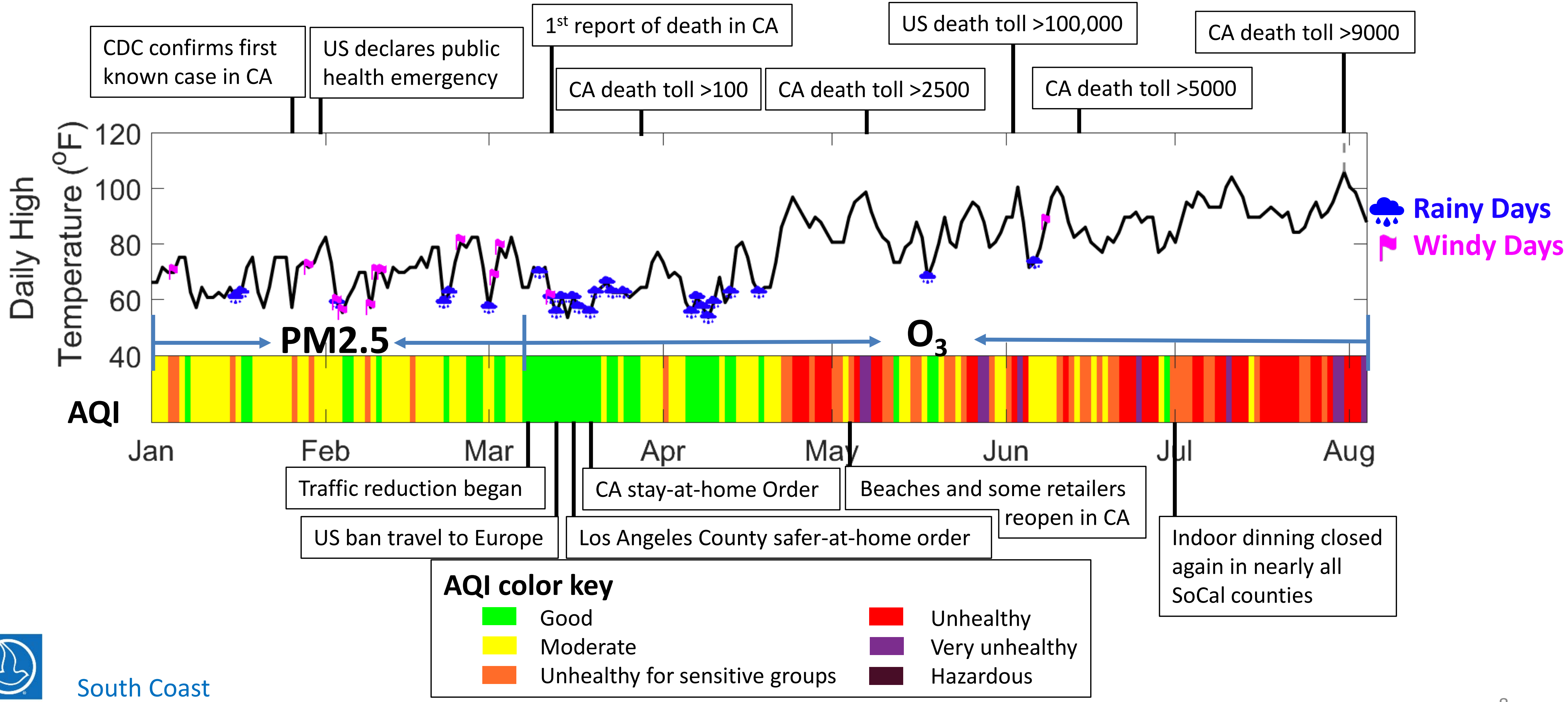


AQI color key

Good	Unhealthy
Moderate	Very unhealthy
Unhealthy for sensitive groups	Hazardous

South Coast AQMD

Meteorology and Air Quality Timeline



Three Key Ongoing Analyses

Emissions **+** **Meteorology and Chemistry** **→** **Air Quality**

1. Emissions: Evaluating changes in mobile source emissions from activity data
2. Air Quality: Concentration measurements during the COVID-19 period
3. Meteorology and Chemistry: Using statistical and modeling analysis to account for the influence of meteorology and chemistry

Changes in Mobile Source Emissions

Cargo at Ports of LA & Long Beach[1]

↓~12%

April – June

Flights at Major Airports in Jurisdiction[2]

↓~50%

April – June

Vehicle Activity on Freeways in Jurisdiction

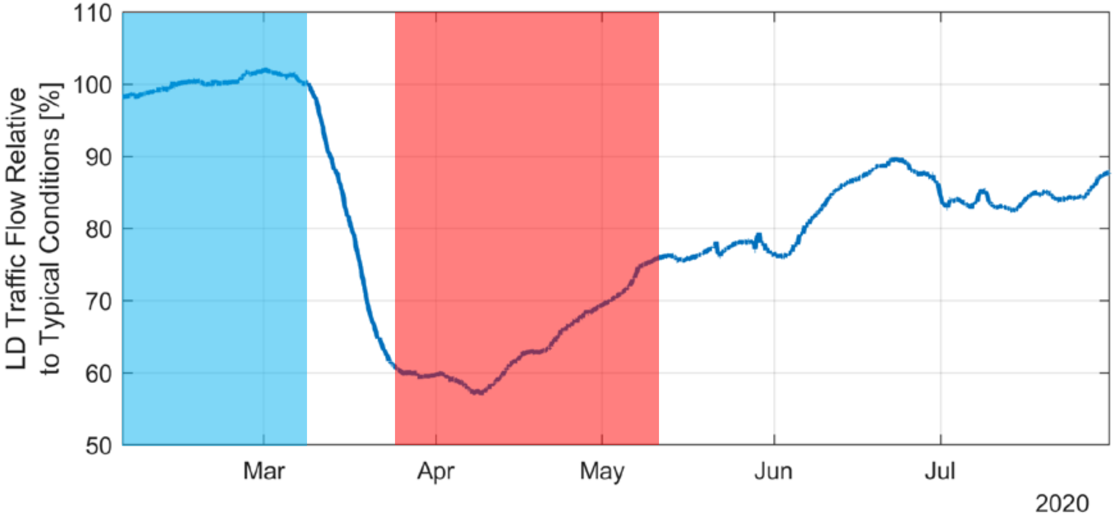
Cars ↓~43% at peak

Trucks ↓~26% at peak

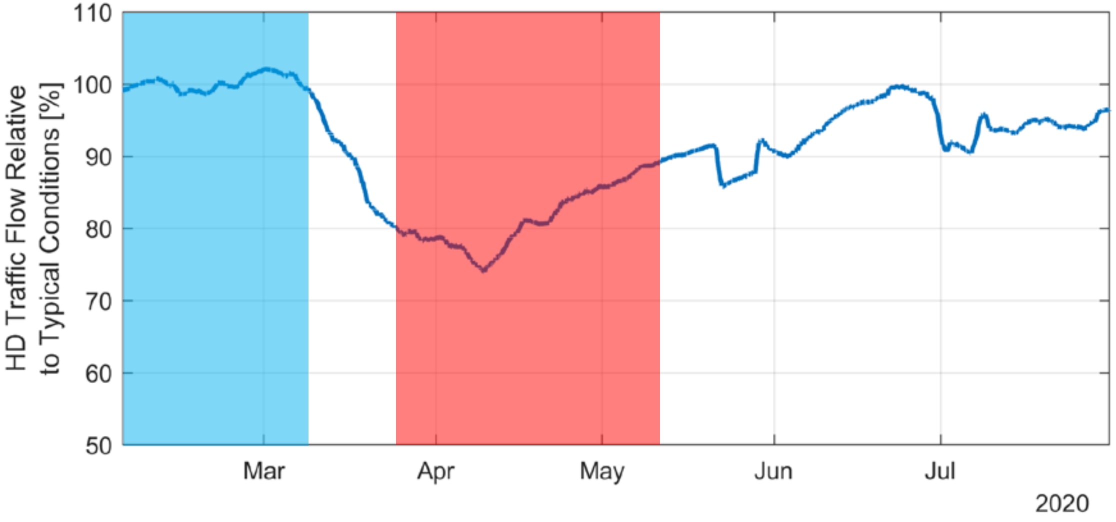
1) Approximate change in TEUs (Twenty foot equivalent units) comparing April—June 2020 to April—June 2019
2) Approximate change in aircraft operations at LAX, LGB, SNA, BUR, PSP, ONT from April—June 2020 to April—June 2019 from FAA Operations Network (OPSNET)
3) Approximate maximum reduction in car and truck flow from pre-COVID orders (Feb 1 – Mar 7) to post-COVID orders (Apr 9 to Aug 6) calculated from CalTrans PeMS data.

Changes in Traffic in the South Coast AQMD

Car Flow Reductions



Truck Flow Reductions

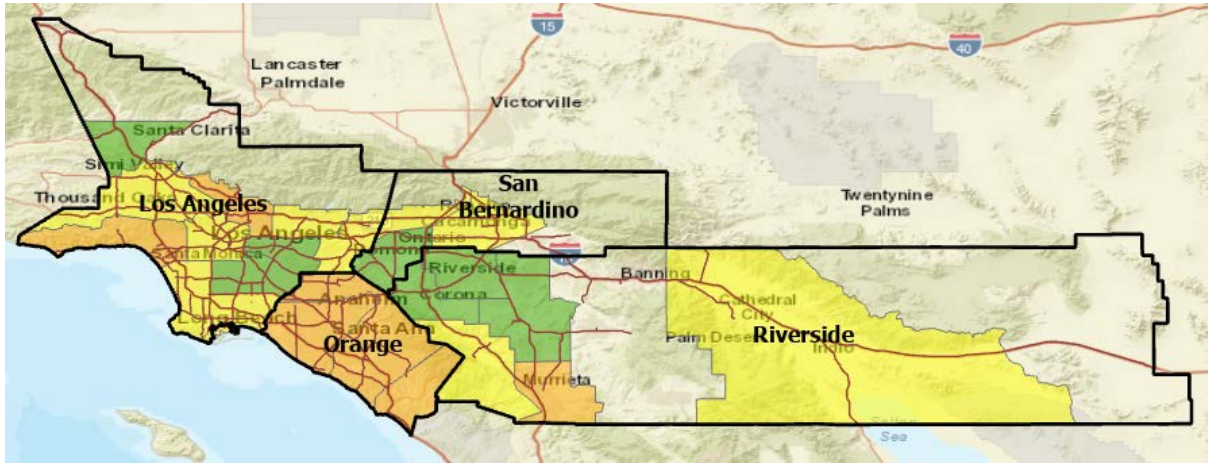


- **On-Road trucks** are responsible for **35%** of NOx emissions in the SCAB (Cars responsible for 5%)
- Car and truck flow data based on CalTrans sensors on freeways. Traffic trends on local roads will differ.
- Results are generally consistent with other independent analyses (at different spatial and temporal scales):
  - Apple Maps: 20 to 60% decrease in routing requests from February baseline in the City of Los Angeles[1]
  - CalTrans: 34% decrease in car VMT and 33% decrease in truck VMT on freeways in LA County[2]
  - Inrix: 46 to 57% decrease in miles driven in City of Los Angeles[3]

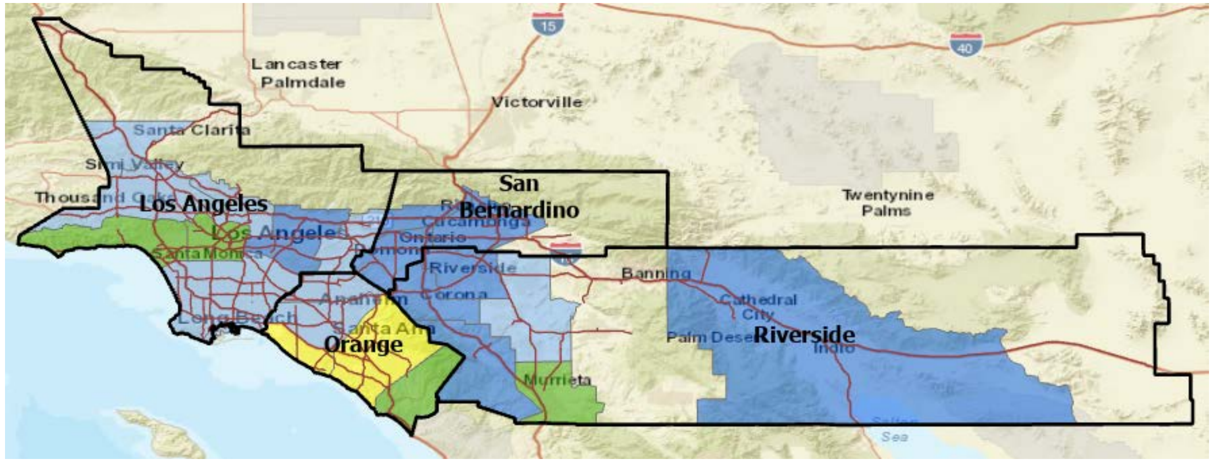
1 https://www.apple.com/covid19/mobility
2 https://laist.com/2020/04/13/coronavirus-los-angeles-freeways-caltrans.php
3 https://www.latimes.com/california/story/2020-05-08/coronavirus-traffic-uptick-los-angeles-freeways-congestion-busier-heavier

Spatial Changes in Traffic in the South Coast AQMD

Car Traffic Reduction



Truck Traffic Reduction



Color key

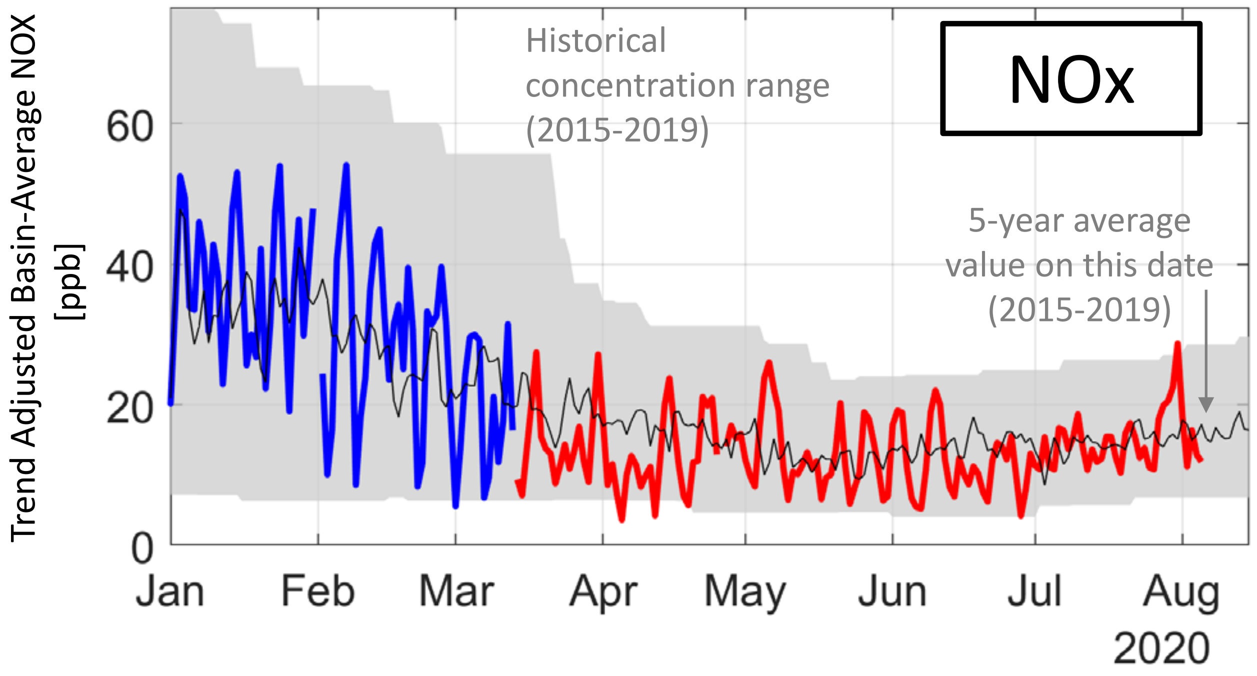
- <8% reduction
- 8% - 16% reduction
- 16% - 24% reduction
- 24% - 32% reduction
- 32% - 40% reduction
- 40% - 50% reduction

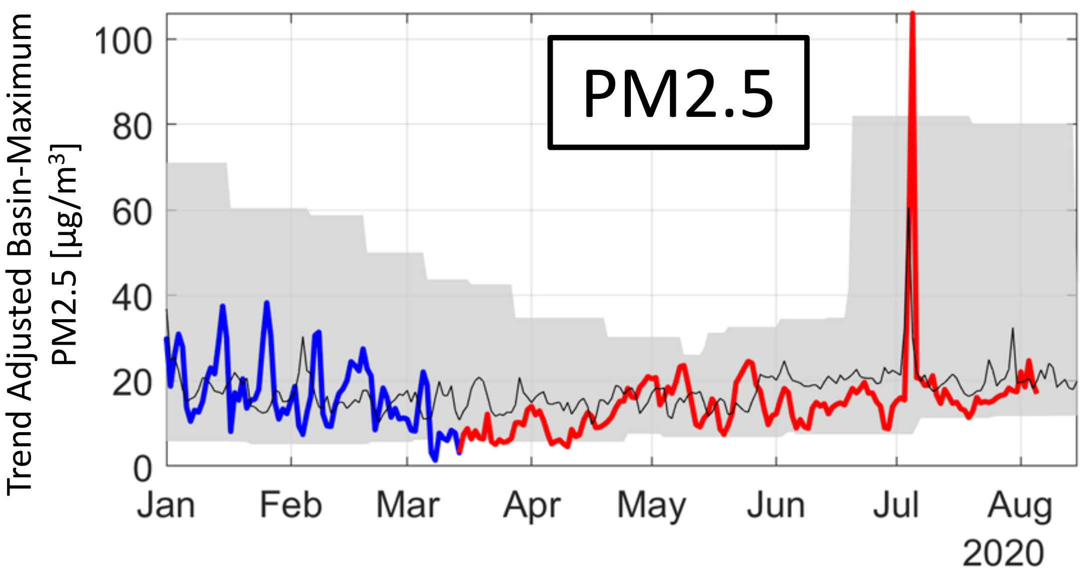
- Coastal areas had biggest reductions in car and truck activity
- Inland Empire did not see as much reduction in truck flow

Business-as-usual defined as Feb 1st to March 7th, COVID period defined as March 23rd to May 11th for mapping purposes

Source receptor areas with less than 25 sensors are not shown

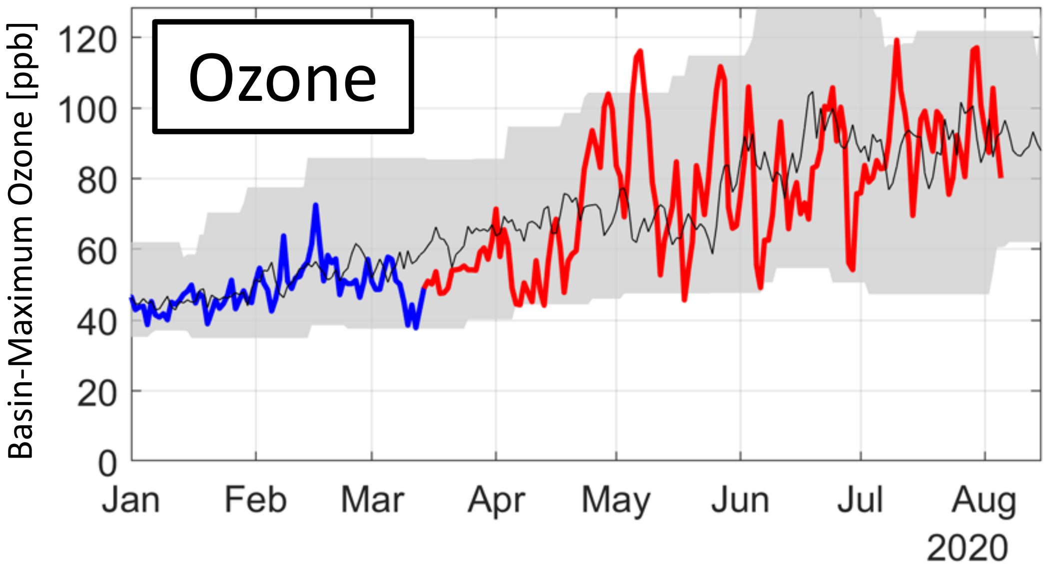
Air Quality Measurements During COVID-19





Business as usual

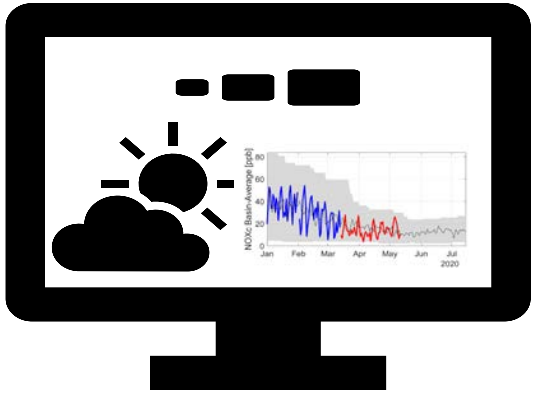
COVID period



South Coast
Air Quality Management District

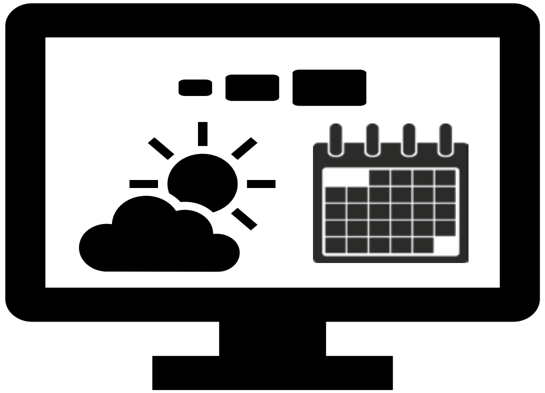
How Much did NOx Emissions Decrease Due to COVID-19 Response?

To estimate emissions from concentration measurements, must remove influence of meteorology using models



Measured NOx concentrations from COVID-19 time period

compare



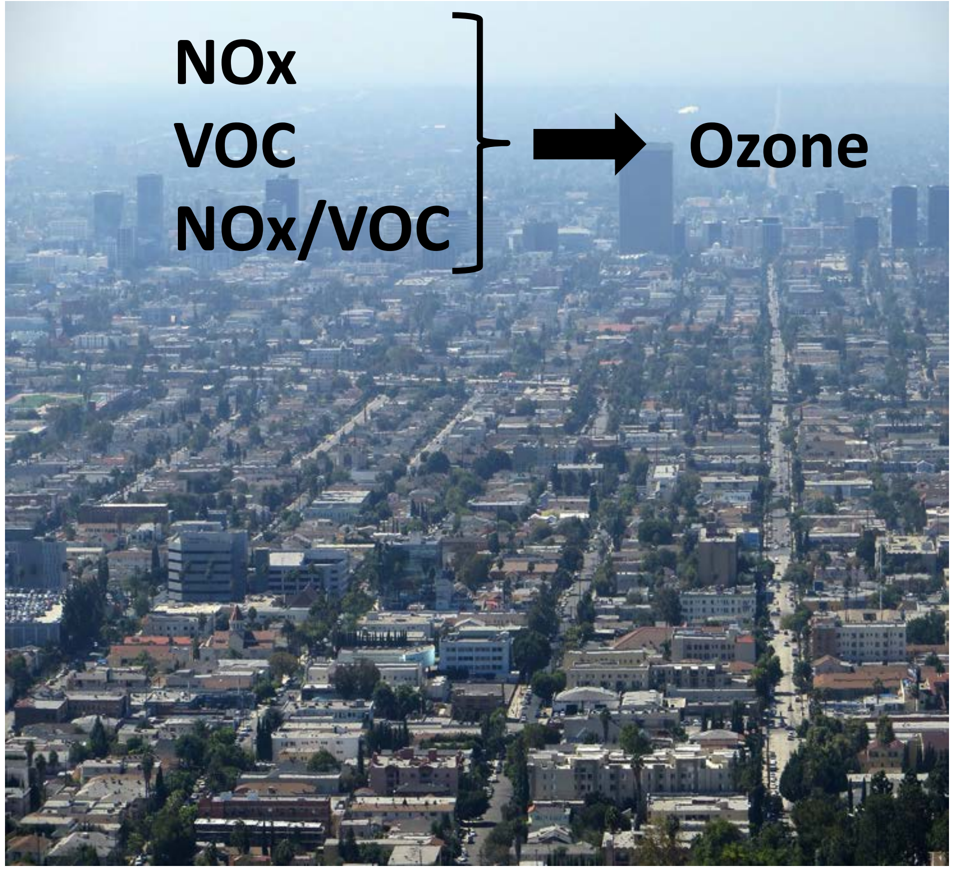
Measured NOx concentrations from previous years with similar:

- meteorology
- time-of-year
- time-of-day

Preliminary estimates indicate that NOx emissions have decreased by about 17% (March 14th to August 5th)

Ongoing Work

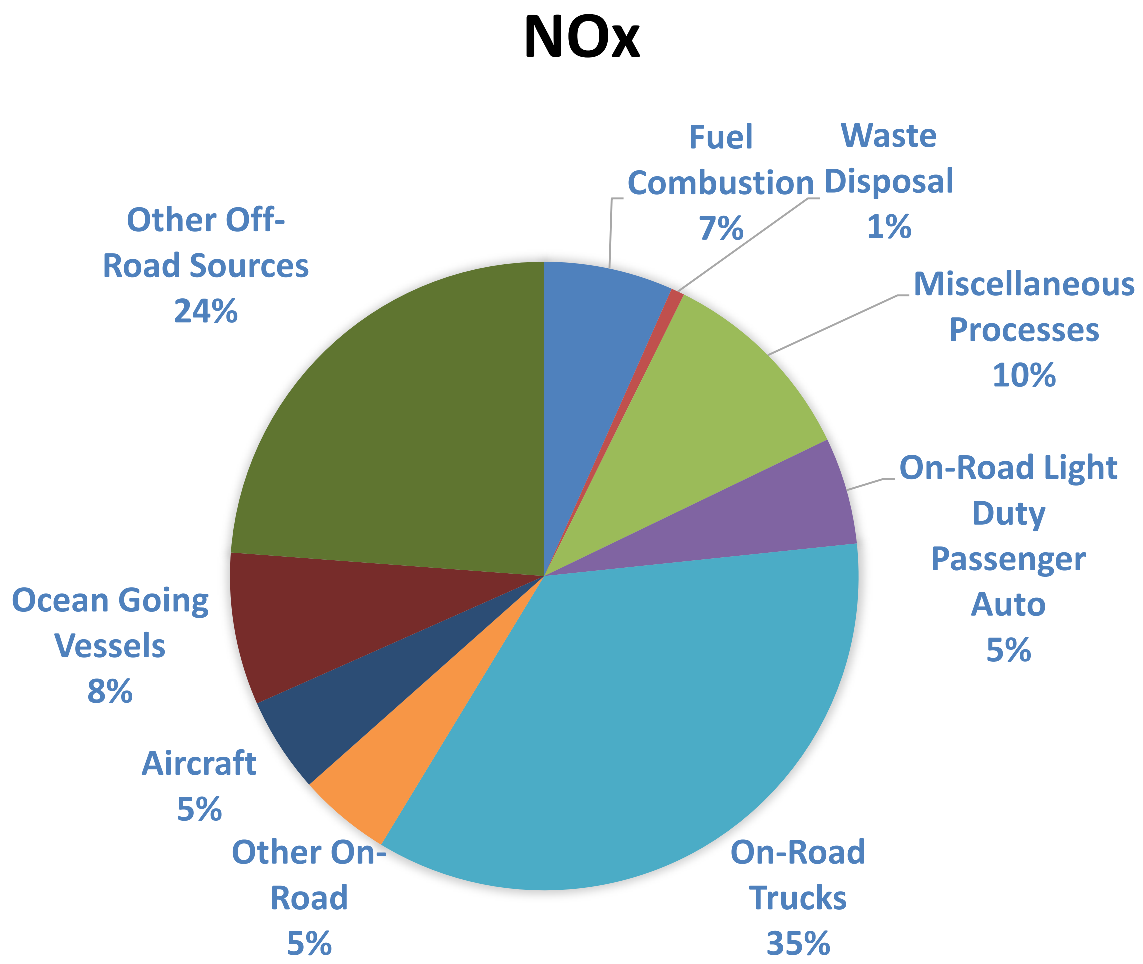
- Evaluating high ozone concentrations in late April/early May, considering:
  - Relative impact of COVID on NOx and VOC emissions (NOx to VOC ratio)
  - Meteorology
  - Satellite measurements working with researchers at Columbia University

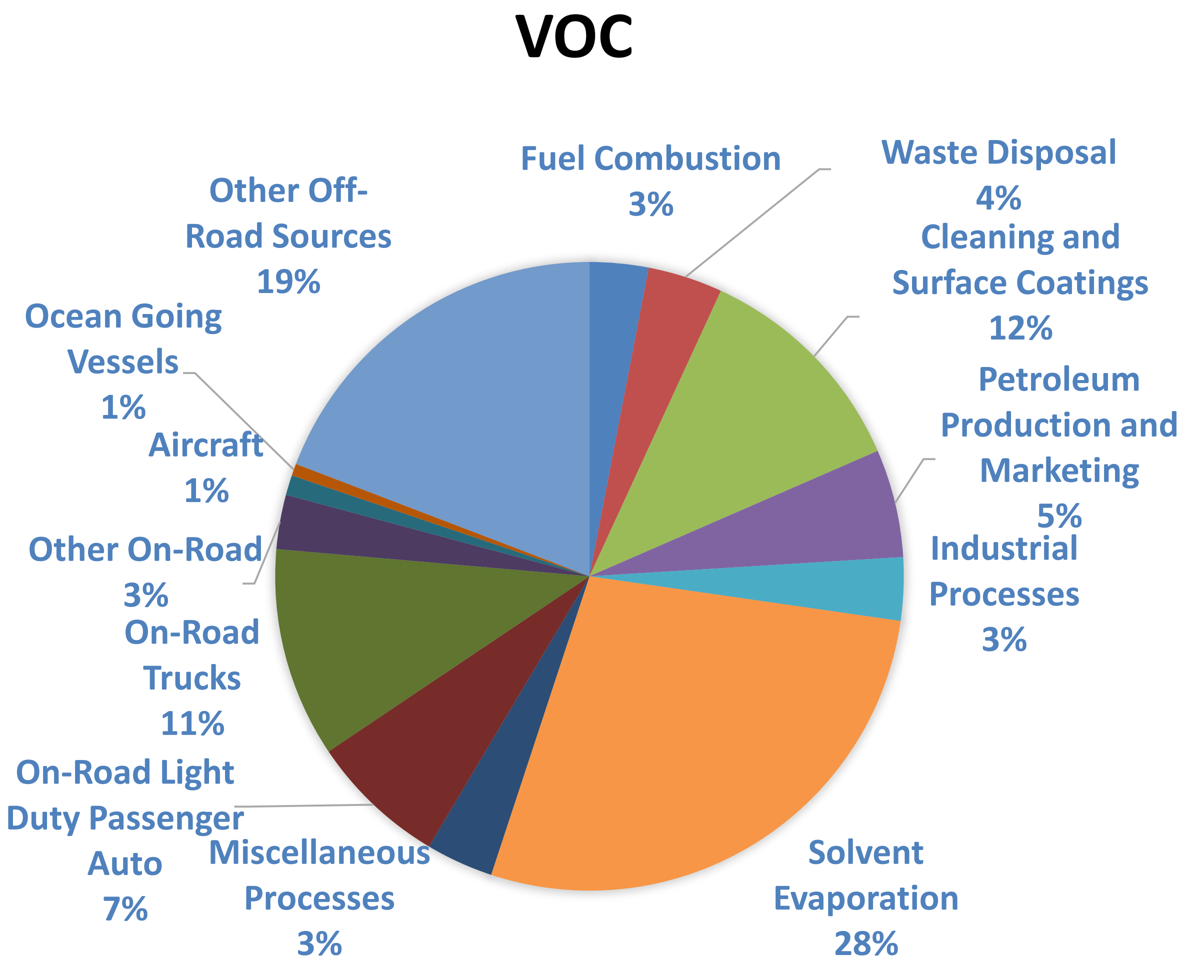


Supplemental Slides

2020 Annual Emission Inventory By Source Category

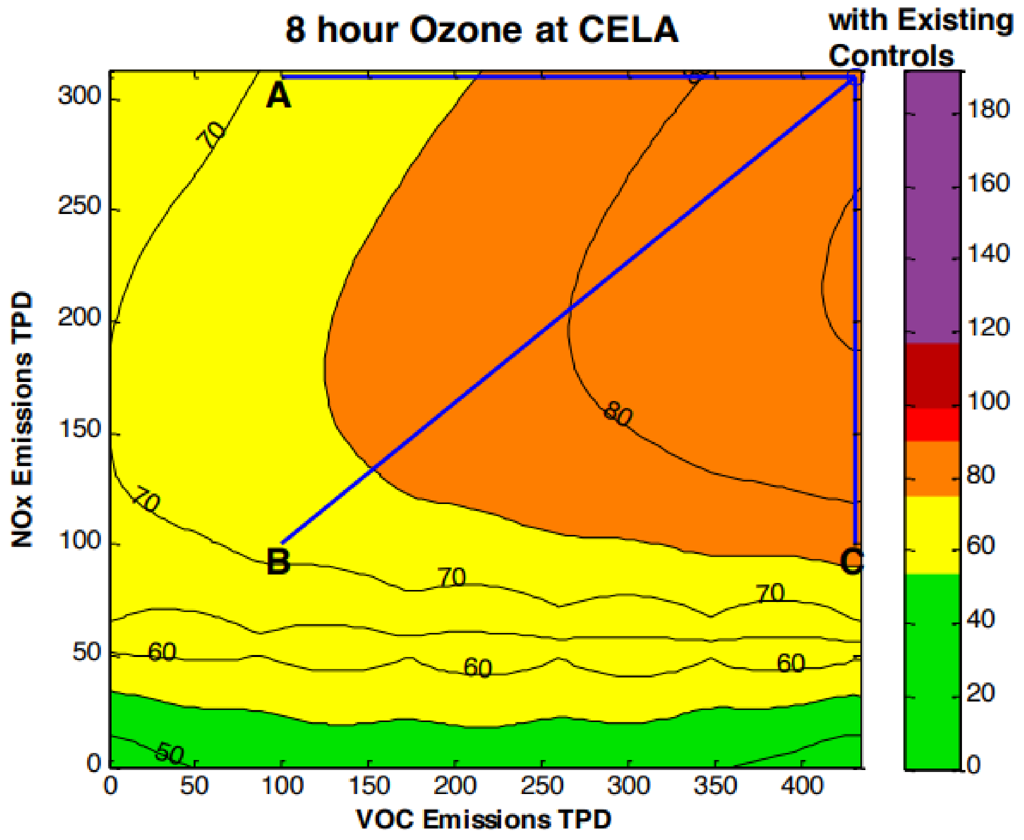
(Assuming Business as Usual)

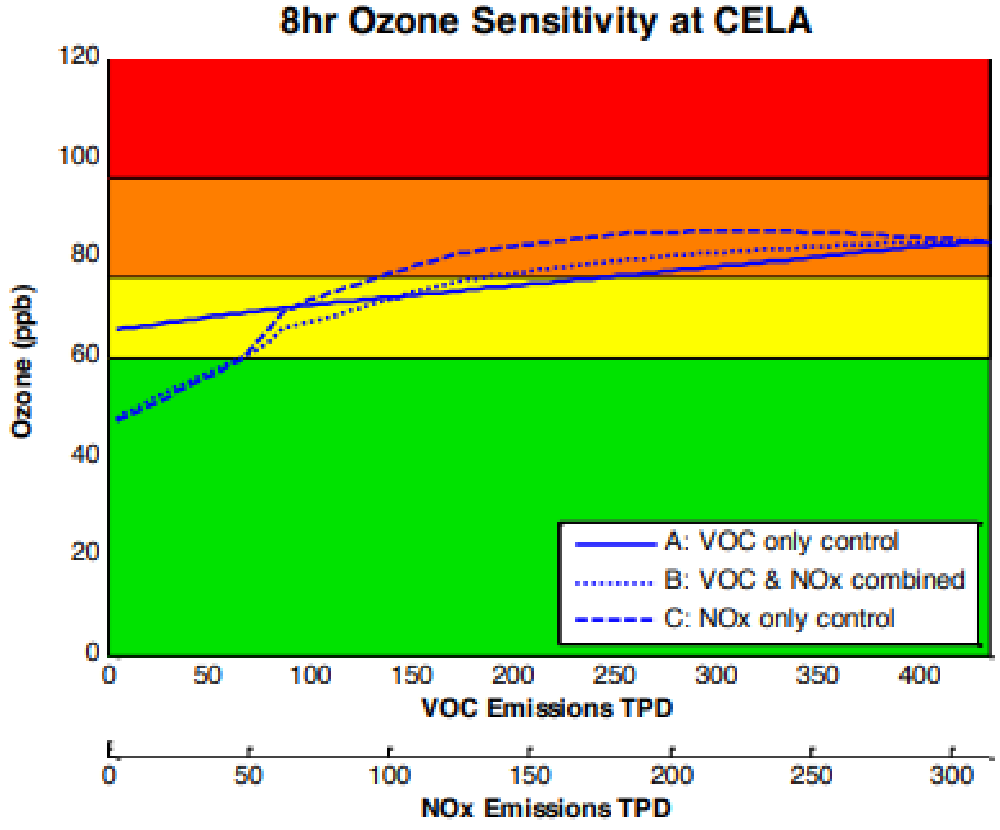




Source: 2016 AQMP Appendix III
(http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/appendix-iii.pdf)

Changes in Ozone Concentrations with Changes in NOx and VOC Emissions



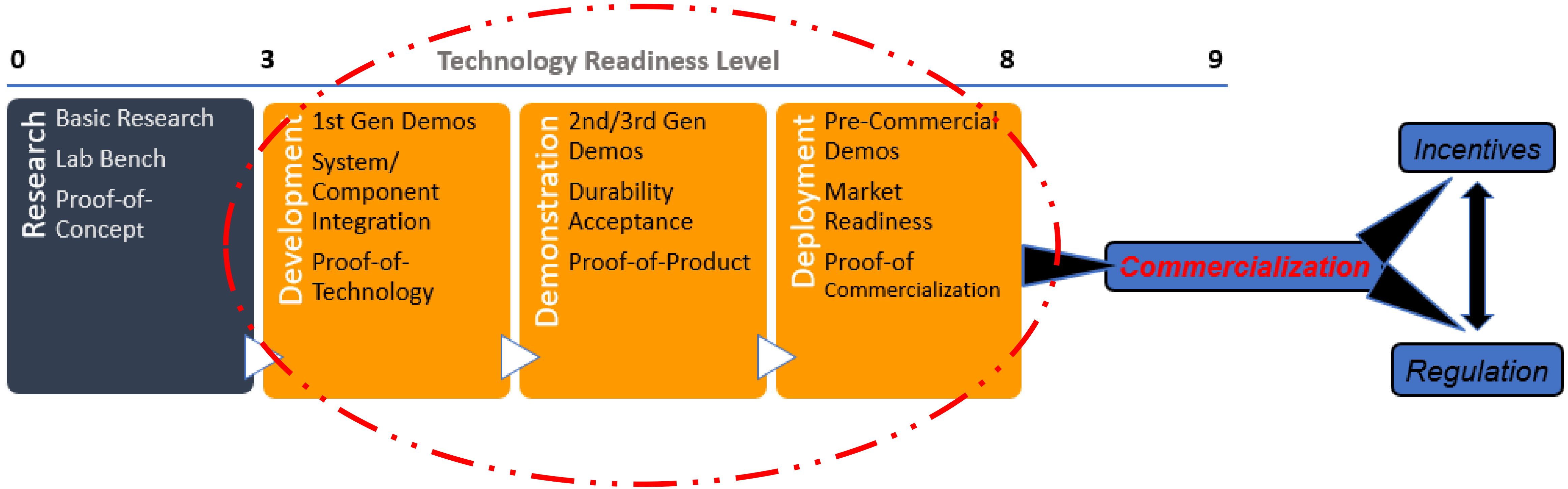


Source: VOC Controls Whitepaper (2015)

Clean Fuels Program Advisory Group Meeting

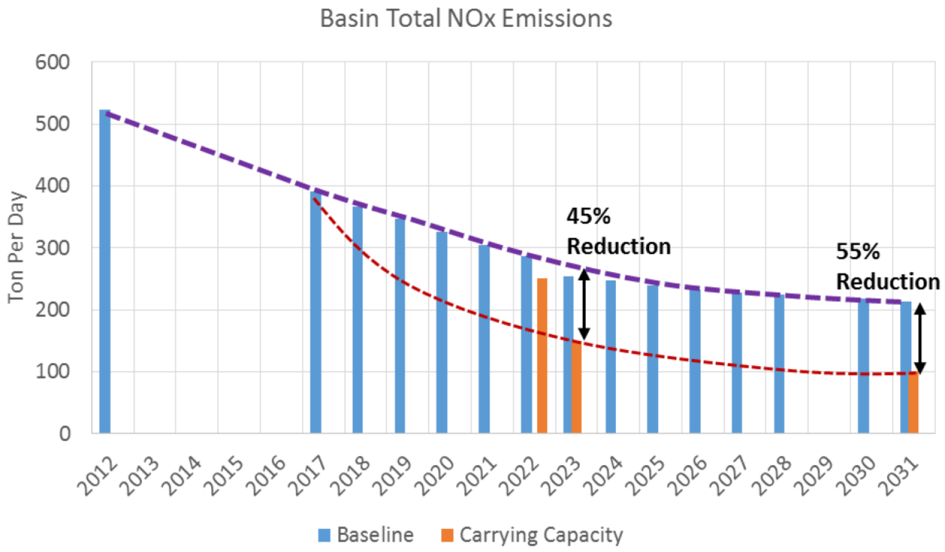
September 17, 2020

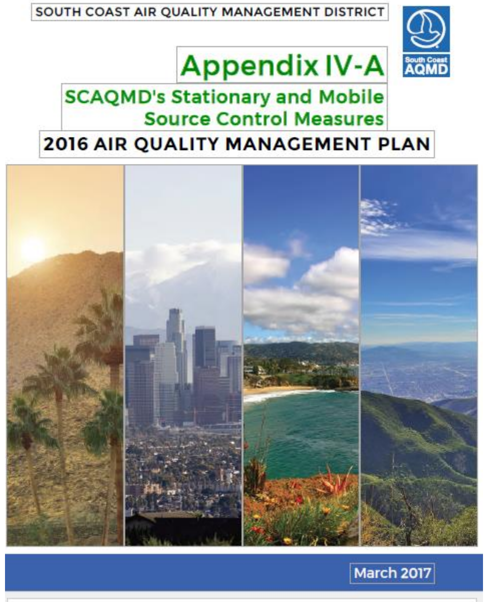
Clean Fuels Fund Program



South Coast AQMD Plans & Policies

- 2016 AQMP – NAAQS



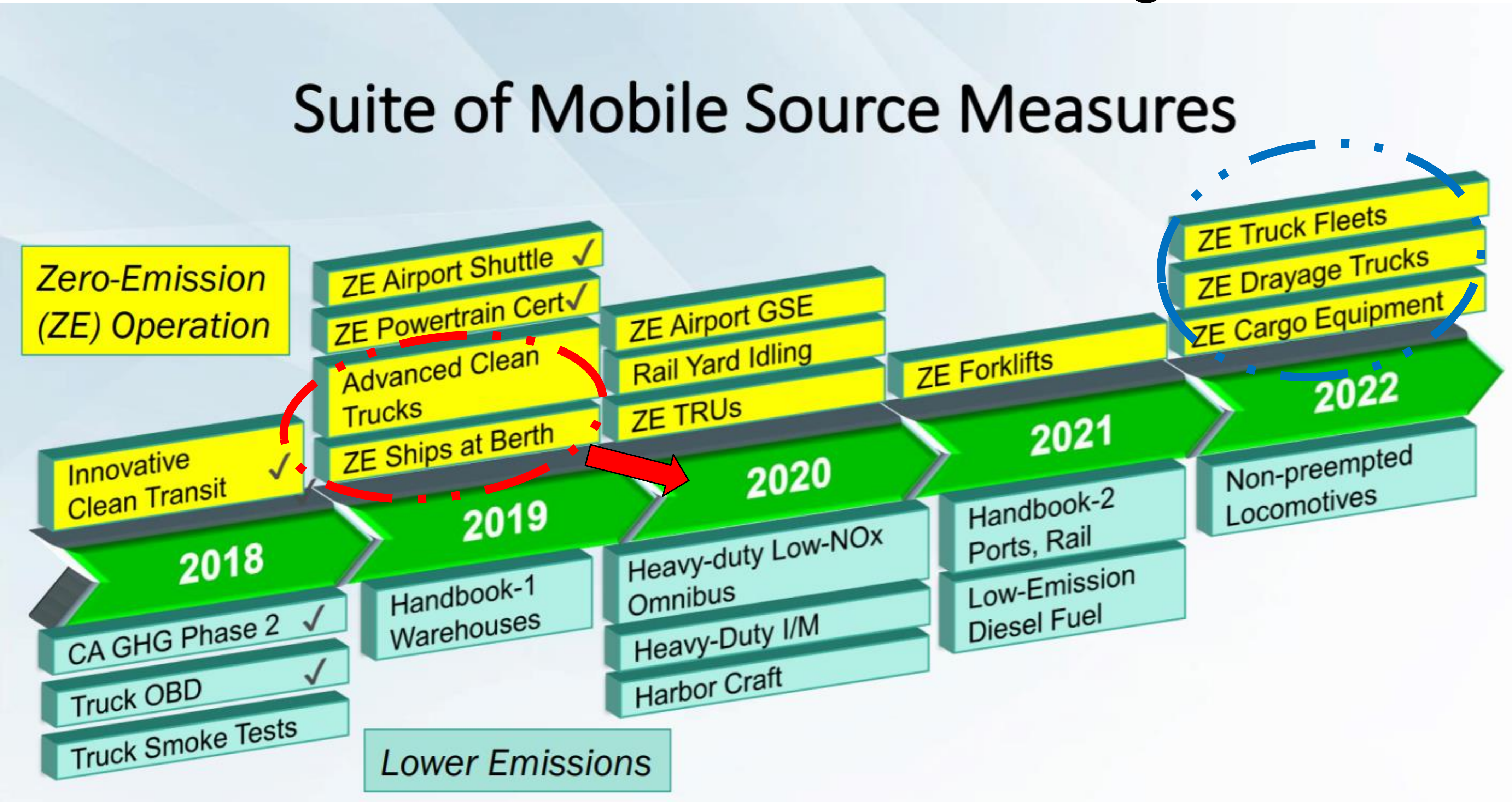


Sector	Board Direction
Commercial Marine Ports	Develop MOU with ports to implement Clean Air Action Plan (CAAP)
Railyard and Intermodal Yards	Pursue Indirect Source Regulation (ISR)
Warehouse Distribution Centers	Pursue ISR
Commercial Airports	Develop MOU with airports to create and implement Air Quality Improvement Plans (AQIPs)
New/Redevelopment Projects	Further study on potential ISR or other approaches

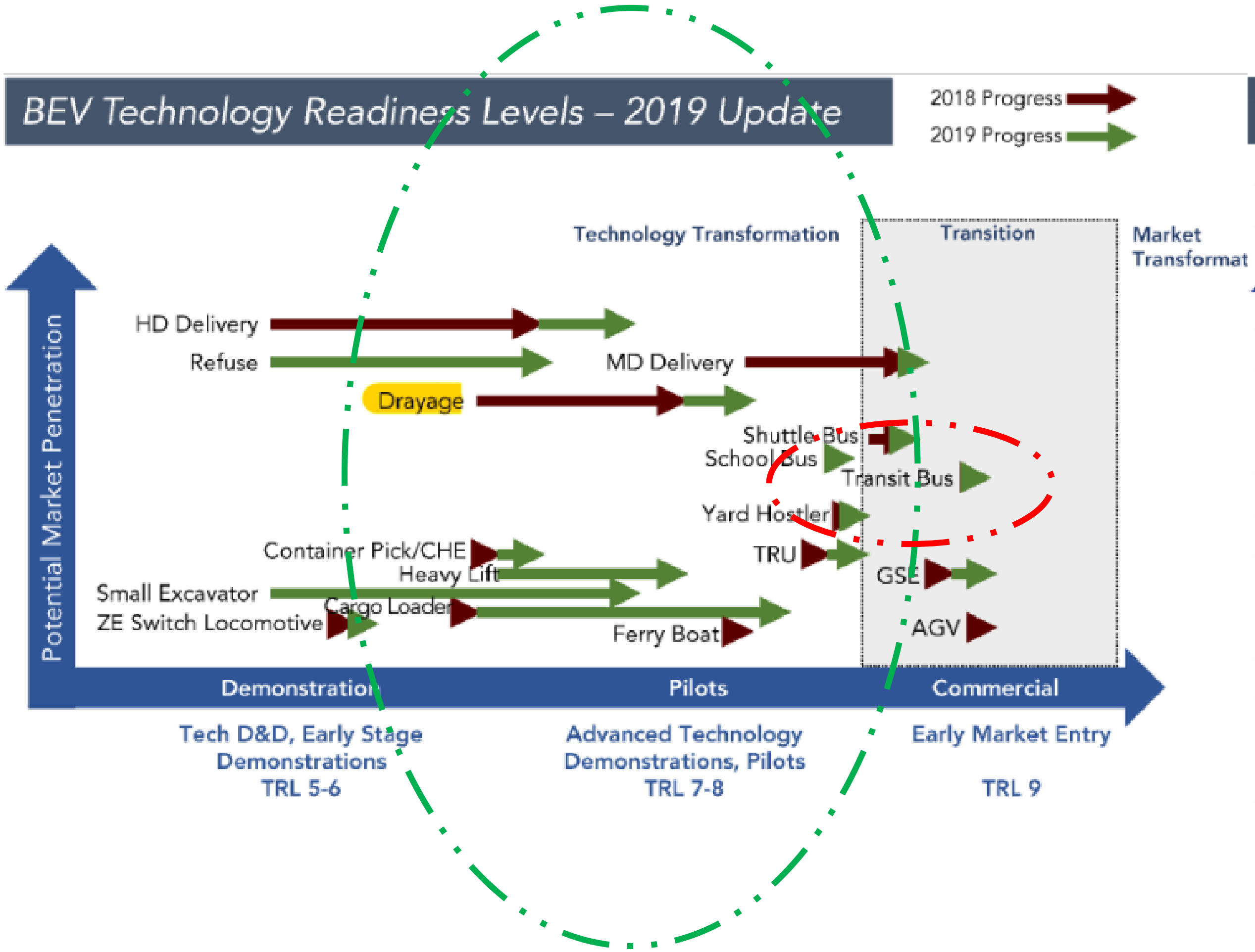
Federal/State Actions

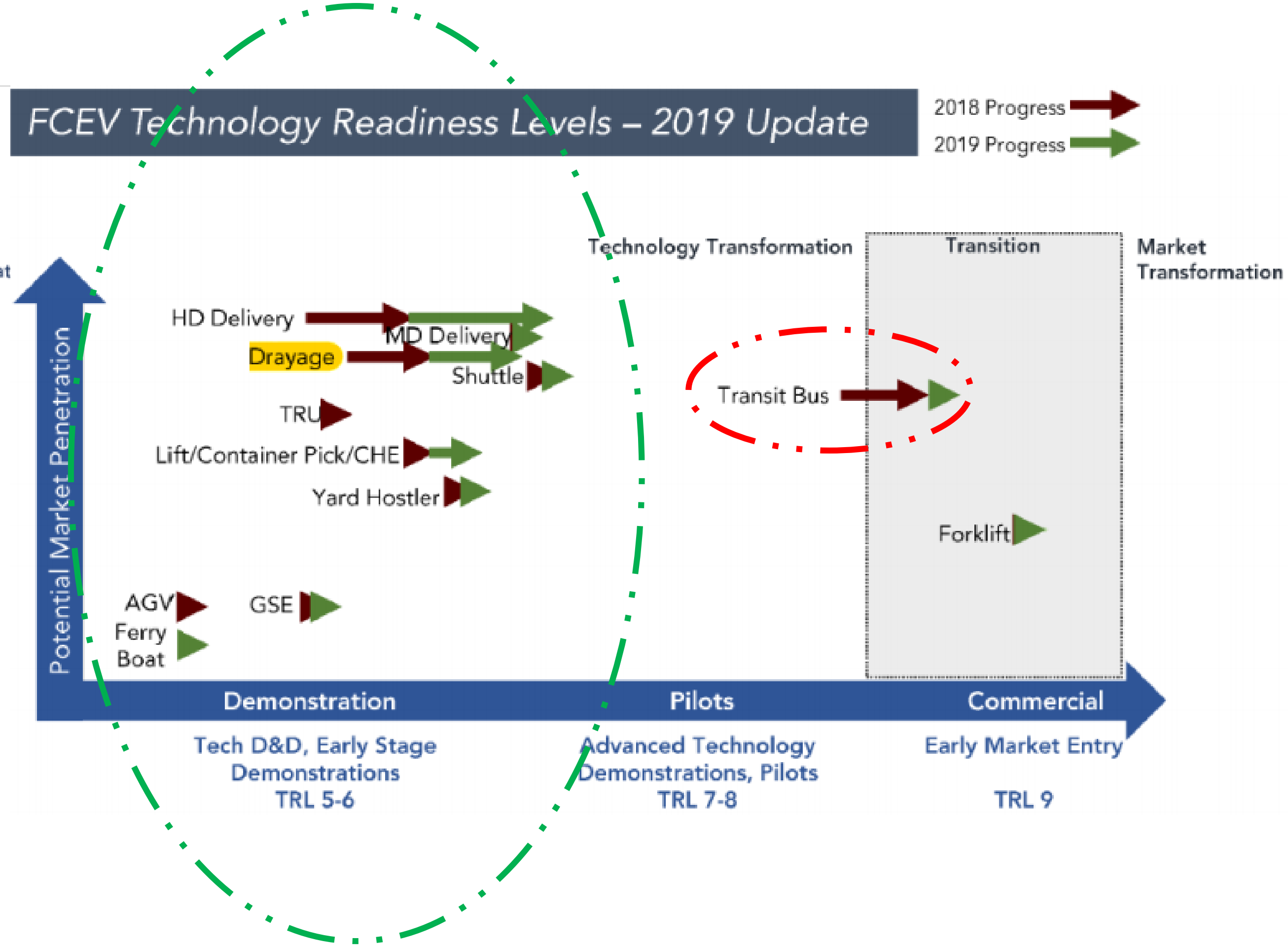
- Feds – FY 2021 Interior, Environment and Related Agencies funding bill
- USEPA – Cleaner Trucks Initiative
- CEC – Low Carbon Fuel Production Program (LCFPP)
- CARB Regulations
  - Heavy-Duty On-Road "Omnibus" Low NOx Regulation
  - Advanced Clean Truck Regulation (ACT)
  - Truck and Bus Regulation (Compliance begins 2020)
  - Innovative Clean Transit (ICT) Regulation

CARB Efforts - Zero Emission Regulations



Battery Electric vs. Fuel Cell Readiness Levels





Source: Proposed Fiscal Year 2019-20 Funding Plan for Clean Transportation Incentives For Low Carbon Transportation Investments and the Air Quality Improvement Program; Appendix D: Heavy-Duty Investment Strategy" (CARB, 2019b).

2021 Plan
Key Proposed Projects

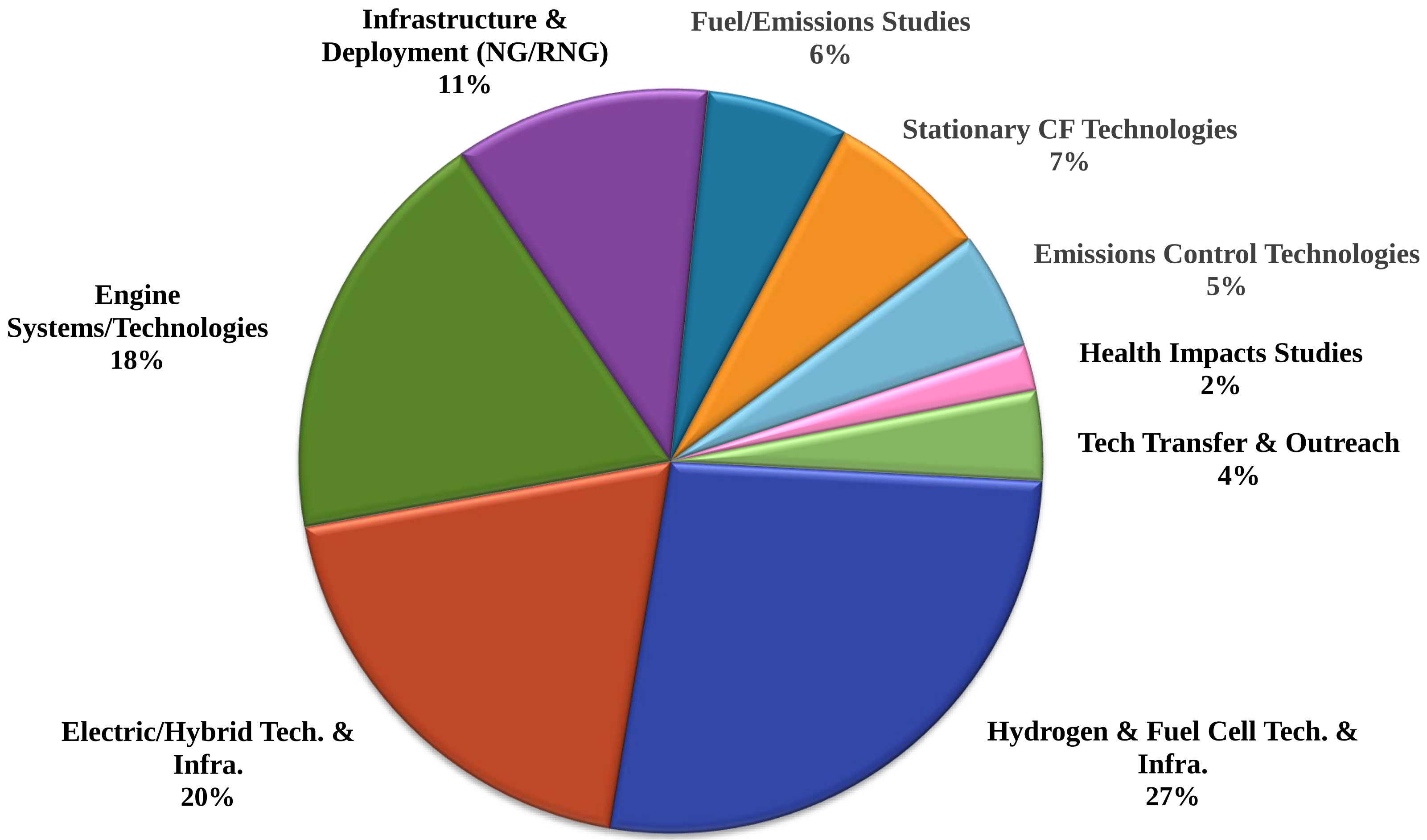
- Heavy-duty zero emission battery electric and fuel cell trucks and infrastructure
- Onboard sensor development for emissions monitoring and improved efficiency
- Microgrid demonstrations to support zero emission infrastructure
- Battery, fuel cell electric transit and school buses charging/fueling infrastructure
- Heavy-duty diesel truck replacements with near-zero emissions natural gas trucks
- Fuel and emissions studies:
  - measurements and analysis of NOx emissions
  - emissions impacts of hydrogen-natural gas fuel blends on near-zero natural gas engines

Projects not funded in 2021 may be considered for funding in future years

Draft 2021 Plan Update
(Key Technical Areas)

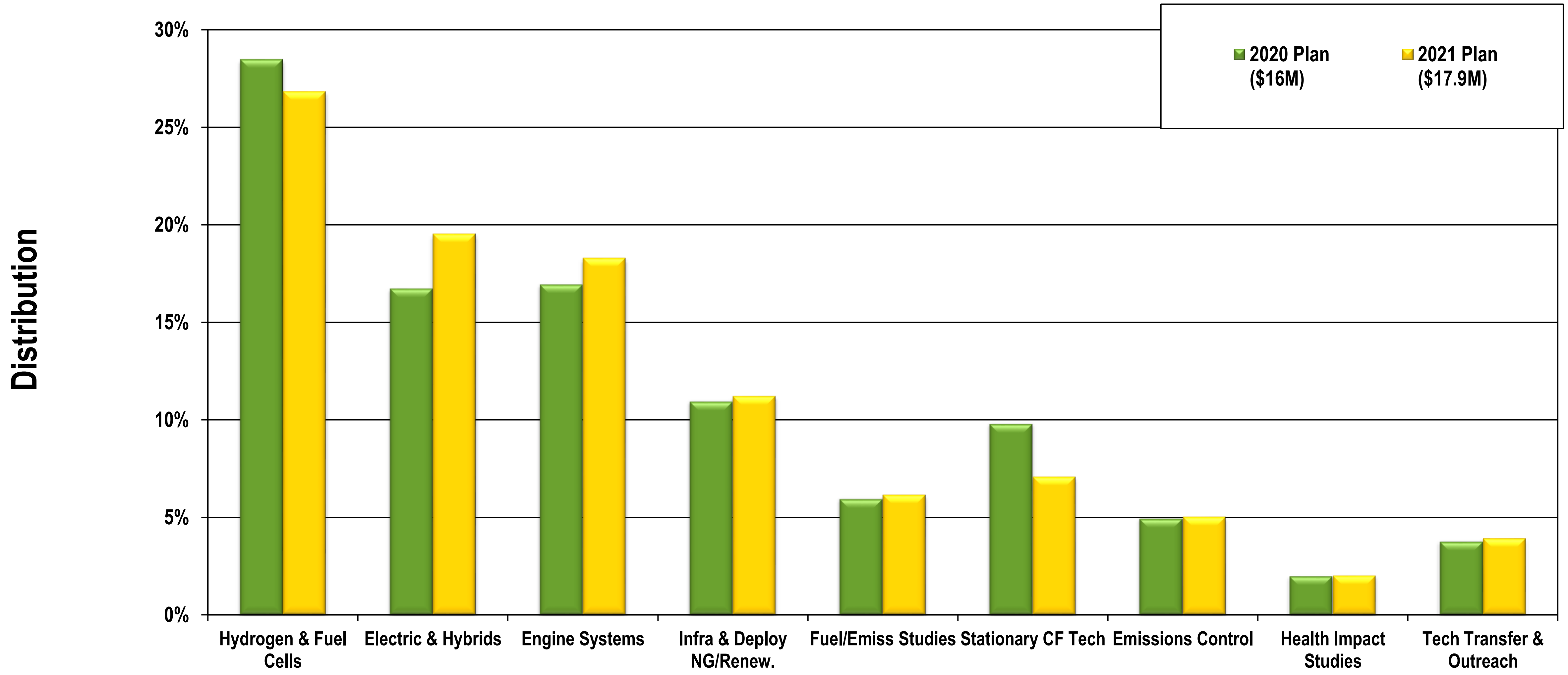
- Focus priorities on large demonstrations of zero emissions drayage trucks to test and validate OEM readiness and infrastructure viability
- Defining technology pathways via special projects - the Ultra-Low Emissions Engine Program
- Near-zero emission (gaseous and liquid fuel) engine systems, especially high HP uses
- Expand focus on local biogas production and use
- Leverage OEM partnerships to focus on continued deployment of hybrid, plug-in, electric-drive technologies and infrastructure
- Onsite hydrogen production and dispensing and mobile refueling
- Maintain other areas of emphasis

Proposed 2021 Plan Distribution



$17.9M

Plan Update Comparison



Proposed Distribution

	2020 Plan	Draft 2021 Plan
Hydrogen & Fuel Cell Tech. & Infra.	28%	↓ 27%
Engine Systems/Technologies	17%	↑ 18%
Electric/Hybrid Tech. & Infra.	17%	↑ 20%
Infrastructure & Deployment (NG/RNG)	11%	11%
Stationary CF Technologies	10%	↓ 7%
Fuel/Emissions Studies	6%	6%
Emissions Control Technologies	5%	5%
Tech Transfer & Outreach	4%	4%
Health Impacts Studies	2%	2%
	100%	100%

Feedback

Email
Naveen Berry
nberry@aqmd.gov
or
Joseph Impullitti
jimpullitti@aqmd.gov

Heavy-duty Engine Technology Update

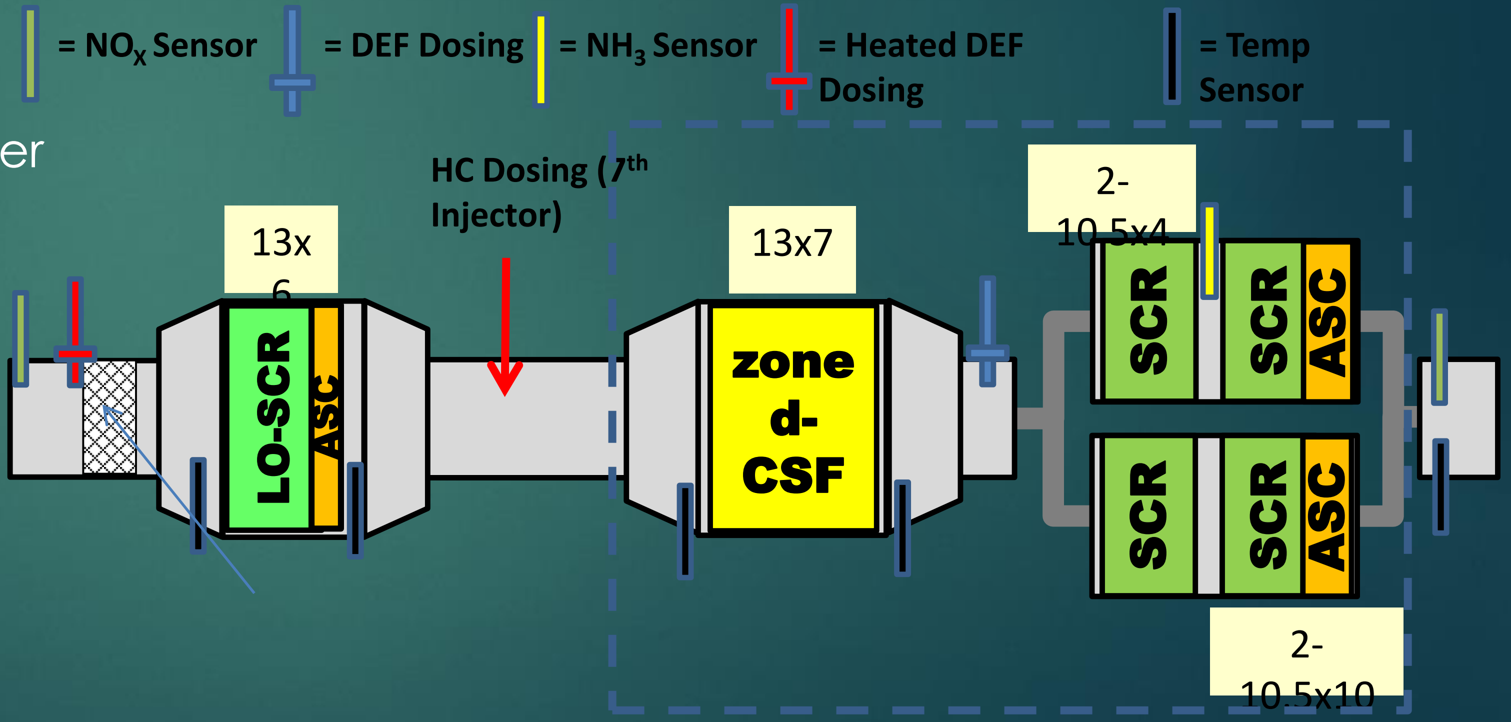
JOSEPH LOPAT

South Coast AQMD

Heavy-duty Diesel Engine Development

- Southwest Research, CARB, SCAQMD, MECA, and the US EPA project recently completed to develop a 0.02 g/bhp-hr 15-Liter diesel engine
- technologies have been proven to lower NOx by maintaining Aftertreatment temperature throughout useful life
- Emphasis on low-load cycles and real world driving conditions
- Requires engine and aftertreatment modifications
- Testing with Renewable Diesel

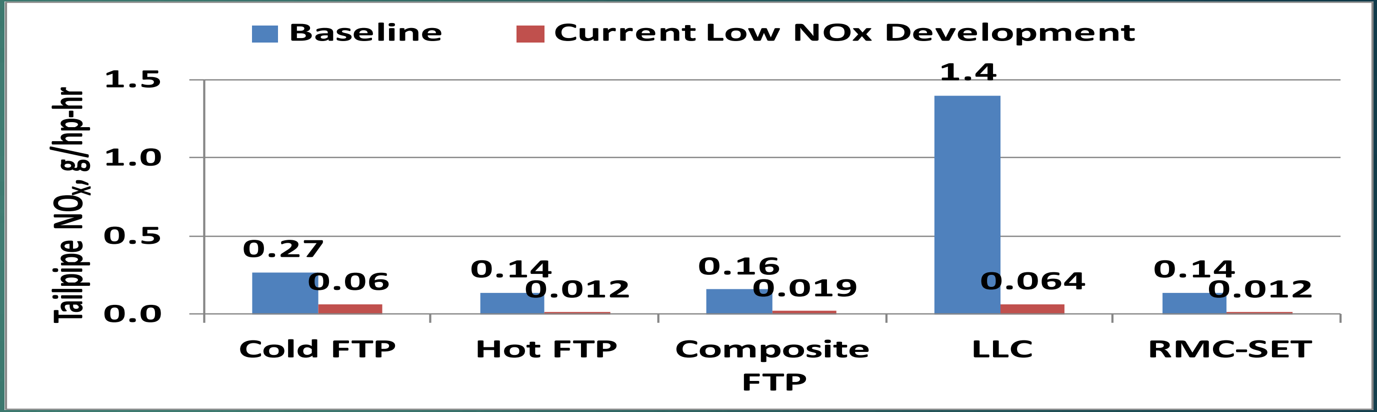
- Support for CARB Omnibus ruling

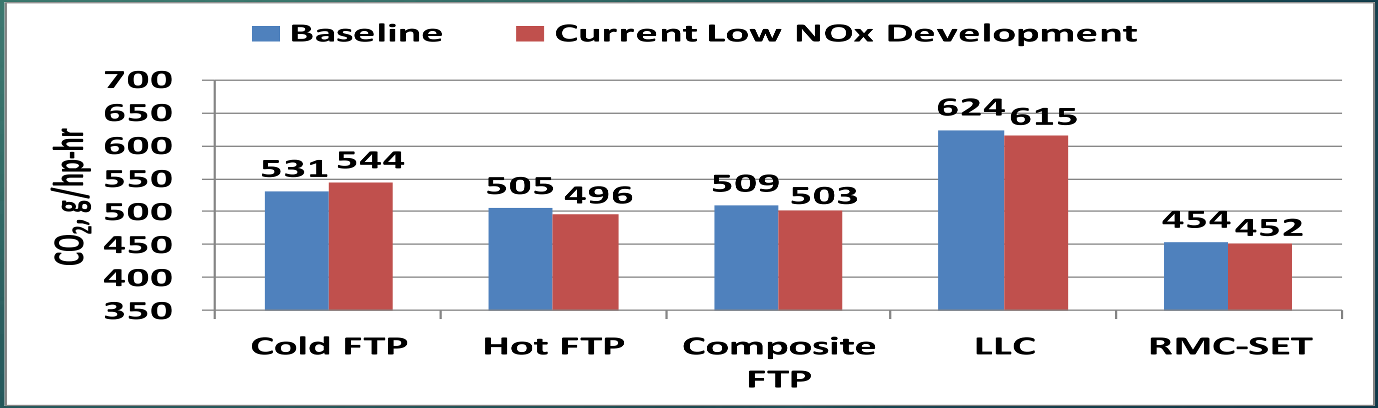


Heavy-duty Diesel Engine development Results

- Several technologies have been proven to lower NOx by maintaining Aftertreatment temperature
- Cylinder deactivation
  - Close coupled catalyst
  - Heated dosing, dual dosing
- Testing results reducing emissions by 99% with no CO2 penalty
- 1,000 hr testing .026 g/bhp-hr NOx

- Support for CARB Omnibus ruling





Heavy-duty Diesel Engine Development Next Steps

- Integrate the proven technologies to lower NOx in a class 8 truck
- Demonstrate near-zero diesel Class 8 truck in real world driving conditions in SCAB
- Evaluate costs
- Emissions tests on dyno and using PEMS
- Engage in fleet participation and possible further trucks

2020 Peterbilt Long Haul

Opposed piston Engine technology

- CARB funded - $16.7M Project - started in January 2018
- Liquid fueled – including renewable diesel
- 3 engines completed and tested
- Integration into truck currently in-use testing


FIRE LANE
PARKING

Opposed Piston Engine Technology Update and Future Plan

- Emissions testing on-going
- Parts failures being addressed and redesigned
- Future aftertreatment development and cost savings
- Alternative fuels options
  - CNG
  - Ethanol

Continuing Near-Zero CNG Engine Technology

- Ford authorized CNG conversion company Landi Renzo developing near-zero NOx 7.3-liter engine $4.5M for class 6-7 Heavy-duty trucks
- Engines expected to be certified at 0.02 g/bhp-hr NOx in 2021'
- 430 HP/475 ft-lb Torque engine
- 0.02 g/bhp-hr NOx LPG version



Future Technology

- Demonstration of the successful near-zero heavy-duty diesel engine system in a class 8 truck
- Further advancement of the heavy-duty near zero NOx technology involving 48 volt heated catalysts and variable valve timing
- Continued near-zero NOx CNG and LPG project advancements, including cylinder head design and combustion research
- Further Hybrid technologies and range extenders
- Development and certification of alternative fuel near zero emissions engines - goal of the recently adopted 0.01 g/bhp-hr Optional Low NOx Standard

Heavy-Duty Hybrid Technology

Clean Fuels Program Advisory Group | Sam Cao - Air Quality Specialist | September 17, 2020

SCAQMD Supports Heavy-Duty Hybrid Pathway

2012 DOE ZECT 1

U.S. Hybrid CNG Plug-in Parallel Hybrid

TransPower CNG Plug-in Series Hybrid

2014 DOE ZECT 2

Kenworth CNG NZE Plug-in Series Hybrid

2017 CARB GGRF

Kenworth CNG NZE Plug-in Series Hybrid

Volvo Low NOx Diesel Plug-in

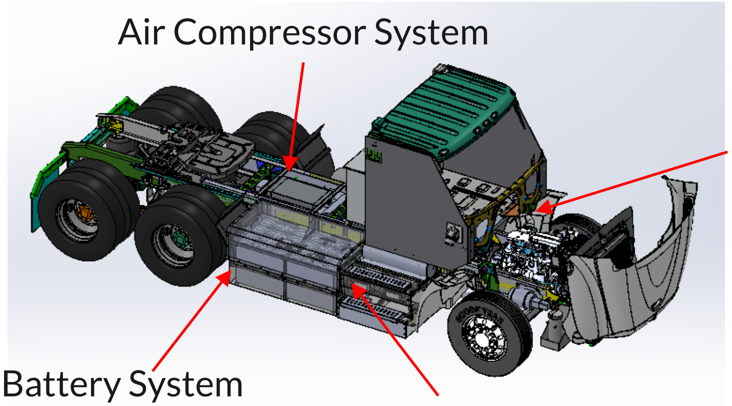
2018 NREL NGV Consortium

U.S. Hybrid NZE CNG Plug-in Parallel Hybrid

SwRI/Isuzu NZE Class 6 CNG Plug-in Parallel Hybrid

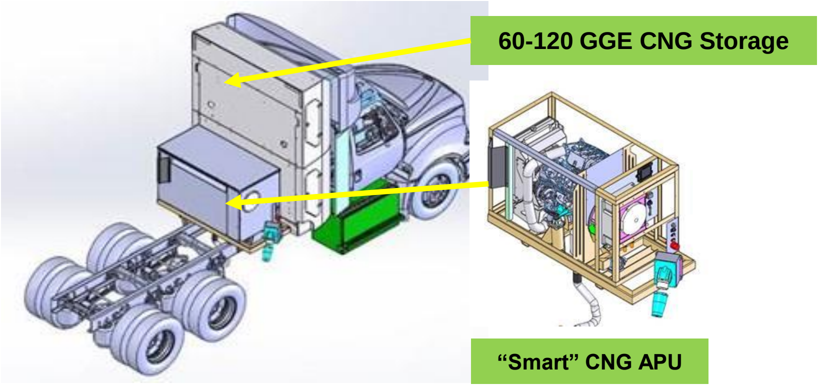
U.S. Hybrid LNG/CNG PHET

- 2012 ZECT 1
  - 3 trucks, parallel hybrid architecture
  - 8.9L Cummins ISLG (0.2 g/bhp-hr NOx) 240 hp + 300 hp traction motor
  - 72 DGE LNG , 80 kWh battery
  - 250 miles range, 30 miles AER
  - Drivers "liked the power"
- 2018 DOE/NREL NGV Consortium
  - Three next gen PHETs with 0.02 g/bhp-hr Cummins L9N + 340 hp traction motor
  - 145 DGE CNG + 40 kWh battery
  - 500 miles range, 20 miles AER
  - GPS based Predictive-Geofencing (iGeo)



TransPower CNG PHET

- ZECT 1, two PHETs series hybrid architecture based on EDD drivetrain
- Behind Cab Mounted 3.7L Ford CNG (gasoline conversion) Engine 134hp auxiliary power source + 400 hp traction motor
- 60 DGE CNG, 138 kWh battery
- 250 miles range, 50 miles AER
- Lessons Learned
  - Stationary trim engine output is capped in firmware to 83 hp
  - Poor emissions unable to leverage engine calibration



South Coast AQMD

Kenworth CNG PHET

BAE SYSTEMS
INSPIRED WORK
KENWORTH
A PACCAR COMPANY

- One PHET under ZECT 2, four additional trucks under GGRF
- Kenworth T680 and Peterbilt 579 chasses
- Series hybrid , Cummins L9N 0.02 g/bhp-hr CNG genset as auxiliary power source + 560 hp traction motor
- 30 DGE CNG, 100 kWh battery
- 150 miles range, 20 miles AER (284 miles/26 miles actual)
- Under demonstration in POLA/POLB and Port of Oakland

South Coast AQMD

Volvo Diesel PHET

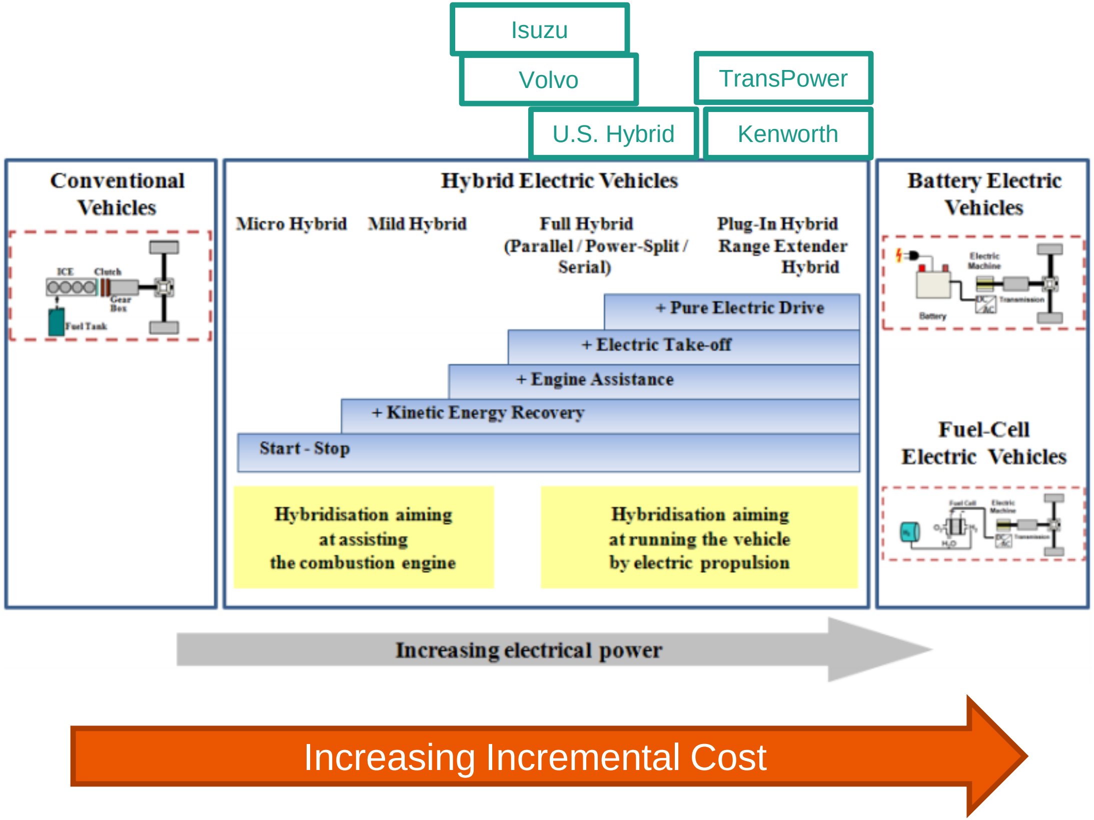
- Demonstrate two diesel parallel PHETs
- Building pervious DOE/SCAQMD/CEC effort
- 11 liter Volvo diesel engine + 200hp traction motor
- 75 DGE + 20 kWh battery
- 300 miles range + 10 miles AER
- Focus on efficiency and emission optimization
  - Engine calibration and aftertreatment innovations (miniburner)
- Integrate C-ITS solutions in partnership with LA Metro/UCR ECO-Drive
  - Freight Eco-Driving/Geofencing

Isuzu CNG PHET

- 2018 DOE/NREL Consortium, SwRI, Izusu, SoCalGas, SCAQMD
- Convert Isuzu 4HK gasoline engine to CNG with pent-roof cylinder head
- Higher efficiency and 0.02 g/bhp-hr NOx
- Perform vehicle and hybrid components selection study
- Integration and demonstration with Class 6 Isuzu F-series truck

Previous HD Hybrid Technologies Focused on CO_2 Reduction

- PHET barriers/lessons learned
  - Optimization of APU and traction motor
  - Weight penalty
  - Pervious hybrid certification procedure do not account for blended benefit of CO_2 and NOx
  - High incremental cost
- Past hybrid studies found higher NOx emissions from hybrids
  - Partially due to different conventional baseline
  - Vehicle based integration, fuel economy as primary objective, emissions secondary
  - CARB requires hybrids chassis/PEMS test to ensure no NOx increase
- Mild hybrids?



Source: ERTRAC (2011) European Roadmap Hybridization of Road Transport https://www.ertrac.org/uploads/documents_publications/Roadmap/Hybridisation%20of%20Road%20Transport.pdf

Mild Hybrids Can Enable New Cost-Effective NOx Reduction Pathway

- 48 volt mild hybrids emerging on heavy-duty (Supertruck II)
  - Lower cost, infrastructure independence, range maintain base architecture
  - CO_2 benefit from electrification of accessories (credit in GHG Phase 2)
  - Energy recovery using motor generator and battery
  - 48 volt mild hybrid critical enablers of HD low NOx technologies
  - Complementary to other low NOx technologies
  - Transferrable and scalable
- Barriers
  - Limited power (~30 kW), no AER, limitation on NOx reduction
  - Reliability, initial cost/payback period
  - Timing

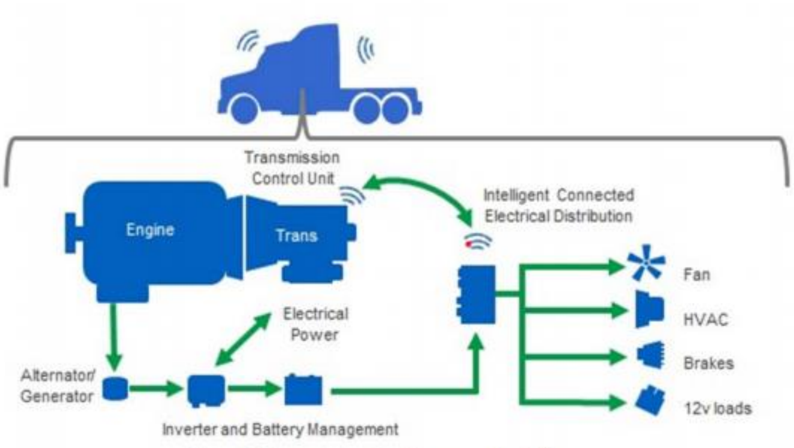
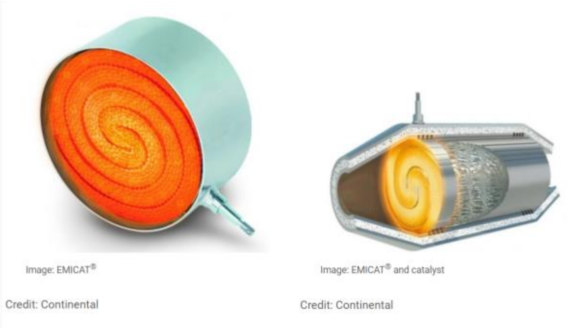


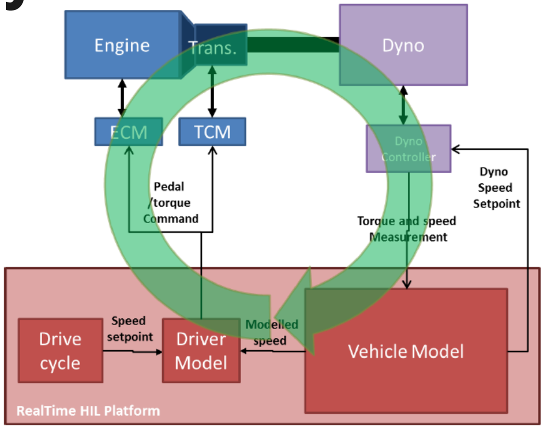
Figure 7. Schematic of a 48-volt commercial vehicle.



Source: MECA (2020) TECHNOLOGY FEASIBILITY FOR HEAVY-DUTY DIESEL TRUCKS IN ACHIEVING 90% LOWER NOX STANDARDS IN 2027, x-engineer.org, Continental EMICAT

CARB/EPA's New Test Procedure Enables Next Generation Highly Integrated Hybrids

- EPA GHG Phase 2 requires hybrids to run powertrain certification for fuel economy
- Real time simulation and controls with driver model & vehicle model
- Vehicle equivalent cycles (vFTP, vRMCSET and vLLC) and same engine g/bhp-hr emissions standards
- Maintain use of engine test cell enables traditional engine/powertrain based product development
- Optimized ICE and hybrid systems
- Procedure applicable for all hybrids



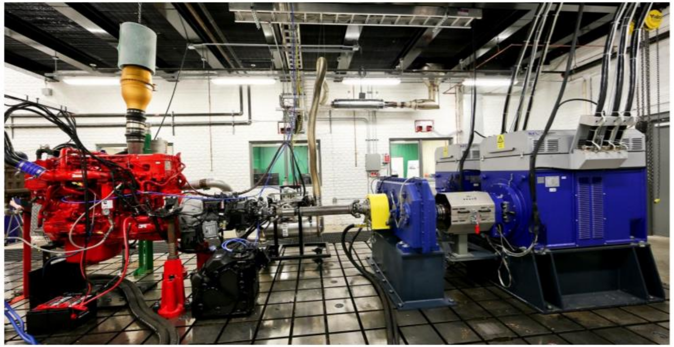
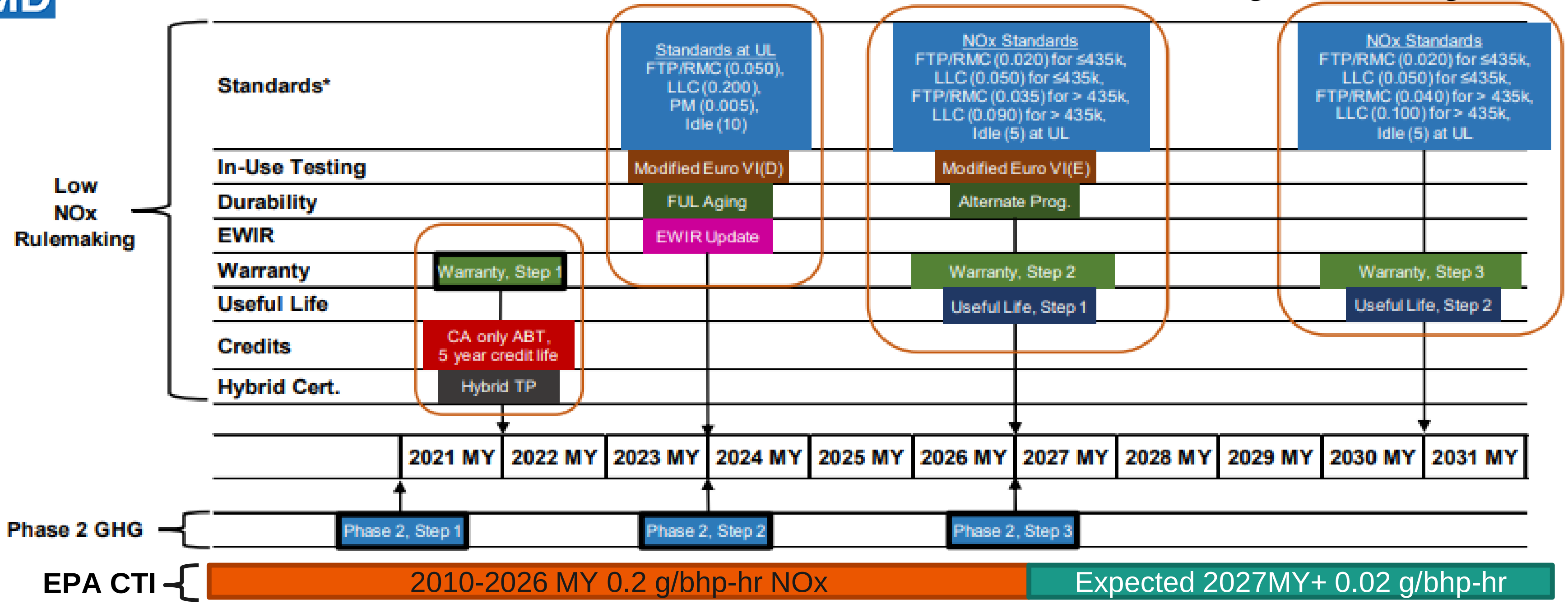


Figure 16. ISX450 engine and UltraShift Plus AMT under test in the Powertrain test cell of ORNL's VSI Laboratory.

Source: ORNL (2016) Powertrain Test Procedure Development for EPA GHG Certification of Medium and Heavy-Duty Engines and Vehicles

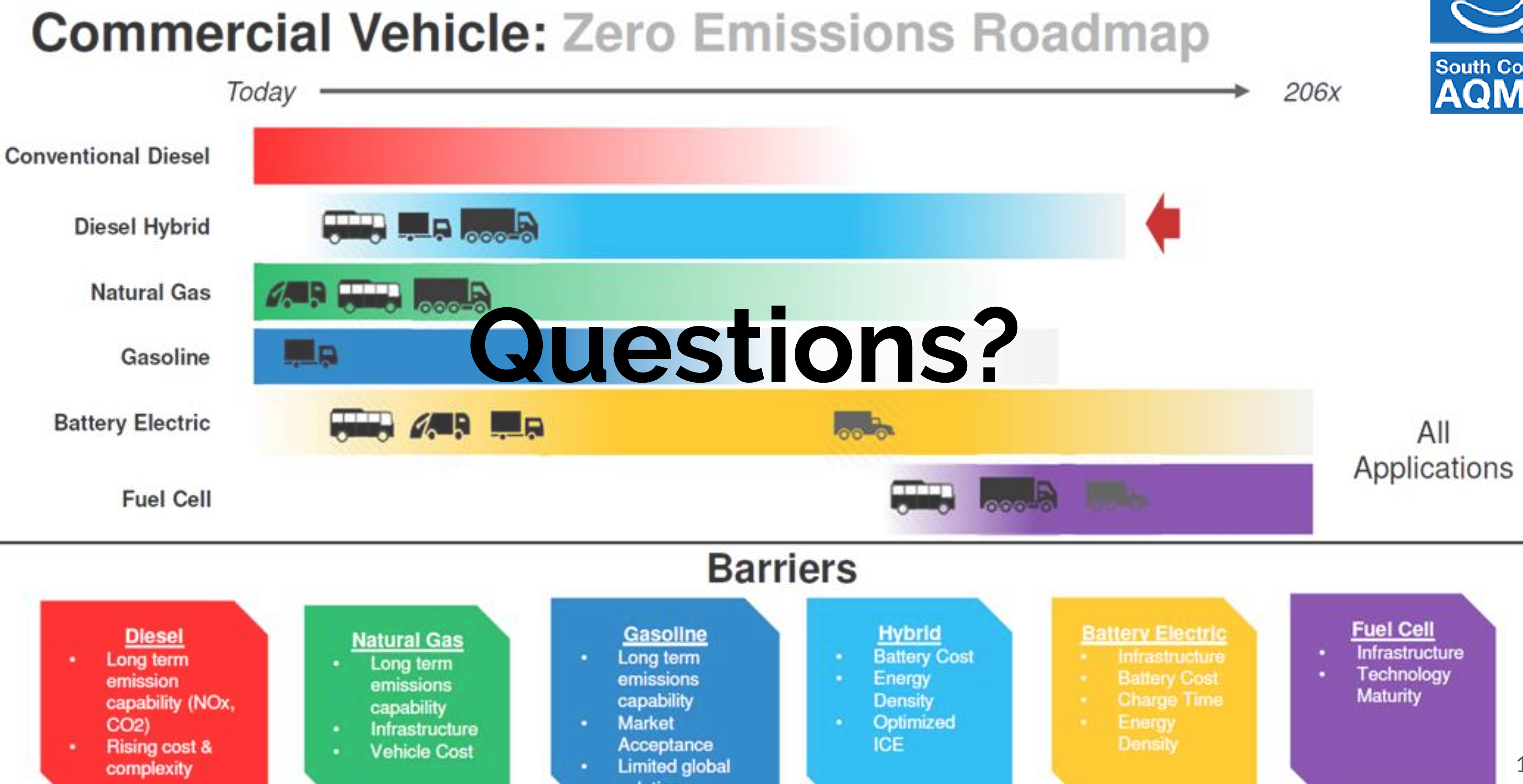
CARB 24 vs EPA 24 Provides Opportunity for Hybrids



Misalignment of CARB/EPA in 2024 likely favour non-engine based NOx reduction technology

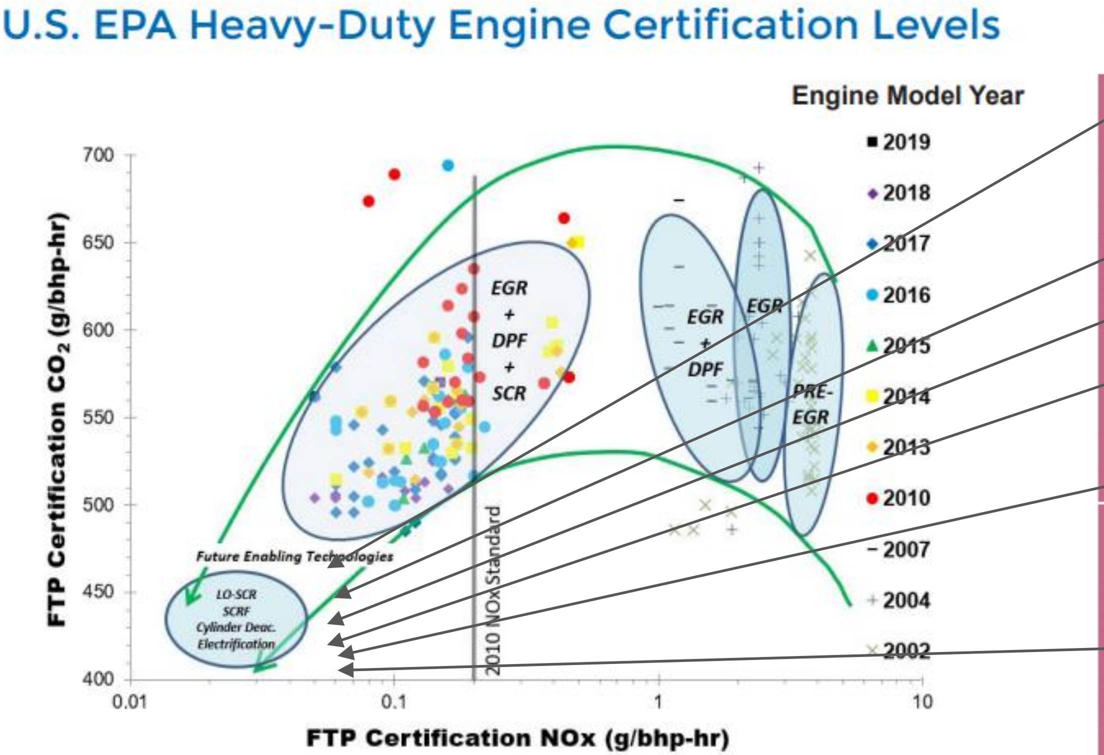
Source: CARB Omnibus ISOR (2020)

Questions?



Source: Stanton (2019) The Future of the Highly Efficient, Clean IC Engine to Meet Global Emissions Regulations, Presentation to the UW-Madison's 2019 Symposium Technologies to meet Ultra-Low NOx Standards

Future Powertrains Needs to Simultaneously Enable NOx and CO_2 Reductions



ICCT List of Low NOx Technologies

		Short description	Impact on CO_2 / GHG	Low NO_x into SCR	Fast warm-up	Stay warm	High conv. efficiency
Engine technologies	Air gap insulated manifold	Insulates the exhaust manifold and reduces heat losses before the SCR inlet during cold-start.	⇨		x		
Engine technologies	Cylinder deactivation	Deactivating cylinders at low loads increases exhaust temperatures of the firing cylinders.	⇩		x	x	
Engine technologies	Dual urea dosing	Improves NO_x conversion in high-load operation and enables the use of close-coupled SCRs.	⇨				x
Engine technologies	Ducted fuel injection	Eliminates trade-off between soot and NO_x, allowing higher EGR rates and less-frequent DPF regeneration.	⇨	x			
Engine technologies	EGR (backpressure)	Exhaust gases recirculation (EGR) reduces NO_x formation during combustion by diluting the intake air.	⇧	x			
Engine technologies	EGR pumps	Allow accurate control of EGR rates and eliminate the increase in backpressure to drive the EGR flow.	⇩	x			
Engine technologies	Coolers bypasses	Bypassing hardware with high thermal inertia reduces heat losses upstream of the SCR during cold-start	⇨		x		
Engine technologies	Electric boosting	Electric motors built into the turbo improve transient response, reducing NO_x peaks. 48V required.	⇩		x		
Engine technologies	Fast idle	Accelerates warm-up by increasing the flow of hot exhaust gases in cold-start.	⇧		x		
Engine technologies	Mild-hybrid (48 Volts)	Increases exhaust temperatures (higher engine load), improves transient NO_x and enables other measures.	⇩	x	x	x	
Engine technologies	Post / late injection	Increases the exhaust temperature and reduces engine-out NO_x at the cost of higher fuel consumption.	⇧	x	x	x	
Engine technologies	Stop/start	Prevents cooling of the SCR during idle by stopping the flow of cool exhaust gases. 48V required.	⇩			x	
Engine technologies	Variable valve actuation	Enables temperature management by early exhaust valve opening, intake valve closing modulation.	⇩		x	x	
Aftertreatment technologies	Burner	Burns additional fuel in the exhaust and increases exhaust temperature at the inlet of the SCR.	⇧		x	x	
Aftertreatment technologies	Close-coupled SCR	Positioning an SCR unit close to the engine makes possible significantly faster warm-up.	⇨		x		
Aftertreatment technologies	Electric catalyst heating	Accelerates warm-up and ensures operating temperature independent of engine load.	⇧		x	x	
Aftertreatment technologies	Heated urea dosing*	Enables urea dosing at lower temperatures without formation of deposits in the SCR inlet	⇨		x		x
Aftertreatment technologies	Improved SCR chemistries	Improved formulations increase the NO_x performance at low temperatures and reduce N_2O formation.	⇩		x		x
Aftertreatment technologies	Larger SCR volume	Larger SCR volumes can increase conversion efficiency but require more thermal management	⇨				x
Aftertreatment technologies	Passive NO_x adsorbers	Trap NO_x during cold-start and release it once the SCR is warm enough. Require periodic regeneration.	⇧	x			
Aftertreatment technologies	SCR on DPF (SCRF)	Integrating the SCR into the DPF substrate enables faster warm-up as it puts the SCRF closer to the engine.	⇨		x		
Aftertreatment technologies	Seventh injector	Injects fuel directly in the exhaust which is oxidized by the DOC increasing the exhaust temperature.	⇧		x	x	

* Heated urea dosers (HUDs) enable dosing at exhaust temperatures in the range of 130°C-150°C compared with a temperature limit of

Source: MECA Heavy-Duty Low NOx Fact Sheet (2019)
ICCT ESTIMATED COST OF DIESEL EMISSIONS-CONTROL TECHNOLOGY TO MEET FUTURE CALIFORNIA LOW NOX STANDARDS IN 2024 AND 2027 (2020)

Volvo Battery Electric Trucks

Patricia Kwon

Program Supervisor

Clean Fuels Retreat September 2020

Volvo LIGHTS

- 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
- Three tractors + 15 production trucks to be deployed in Oct – Dec 2020
- Battery electric forklifts, yard tractors at fleets

California Climate Investments
Cap and Trade Dollars at Work

South Coast AQMD

Volvo LIGHTS

- Chargers installed at fleets, awaiting tie-in by SCE
  - 7.2 kW, 15 kW for EVs, forklifts
  - 22 kW AC, 50 kW DCFC for yard tractors
  - 150 kW DCFC with CCS2 connectors for trucks
- First public heavy duty charging in Anaheim (CPUC Rule 18)
- TEC La Mirada installation underway
- Solar installed at DHE
- Three tractors, 15 production level trucks in late 2020

California Climate Investments — Cap and Trade Dollars at Work

South Coast AQMD

Volvo LIGHTS Showcase

- Volvo LIGHTS Showcase Fontana Speedway in Feb 2020
- Interactive knowledge sharing sessions on trucks, infrastructure, dealership service & support, technician training & workforce development, community/environmental benefits
- Fleet ride and drive experience at Fontana Speedway
- Media coverage on BETs quite favorable by trade publications
- https://youtu.be/j_sSQL2jF-c

Volvo LIGHTS Update

- Volvo Class 8 eVNR trucks certified by CARB, EPA
- Eligible for sale in California
- Trucks in operation at TEC Fontana and DHE
  - Delivering parts full-time at TEC Fontana
  - DHE received their trucks in late August
- 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

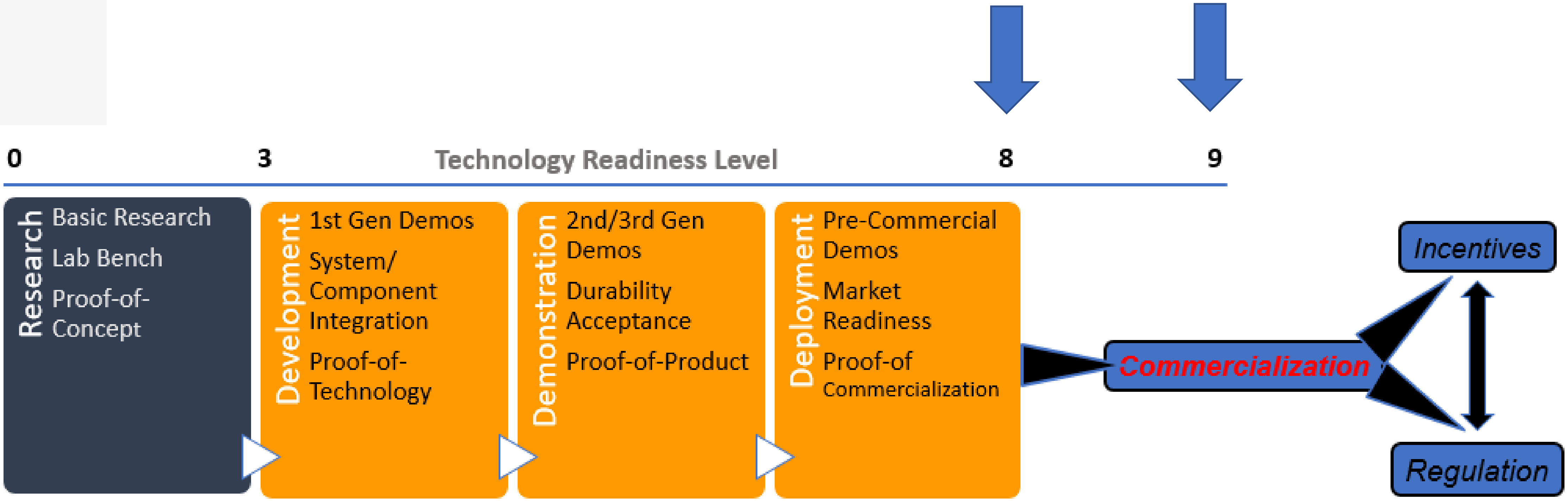
Preliminary Data

Slide deleted for the web version

Transition to commercialization

Develop, demonstrate Class 8 battery electric trucks
→ Volvo LIGHTS

Deploy Class 8 battery electric trucks
→ Switch-On



Switch-On Project

- Next phase of Volvo LIGHTS project
- 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

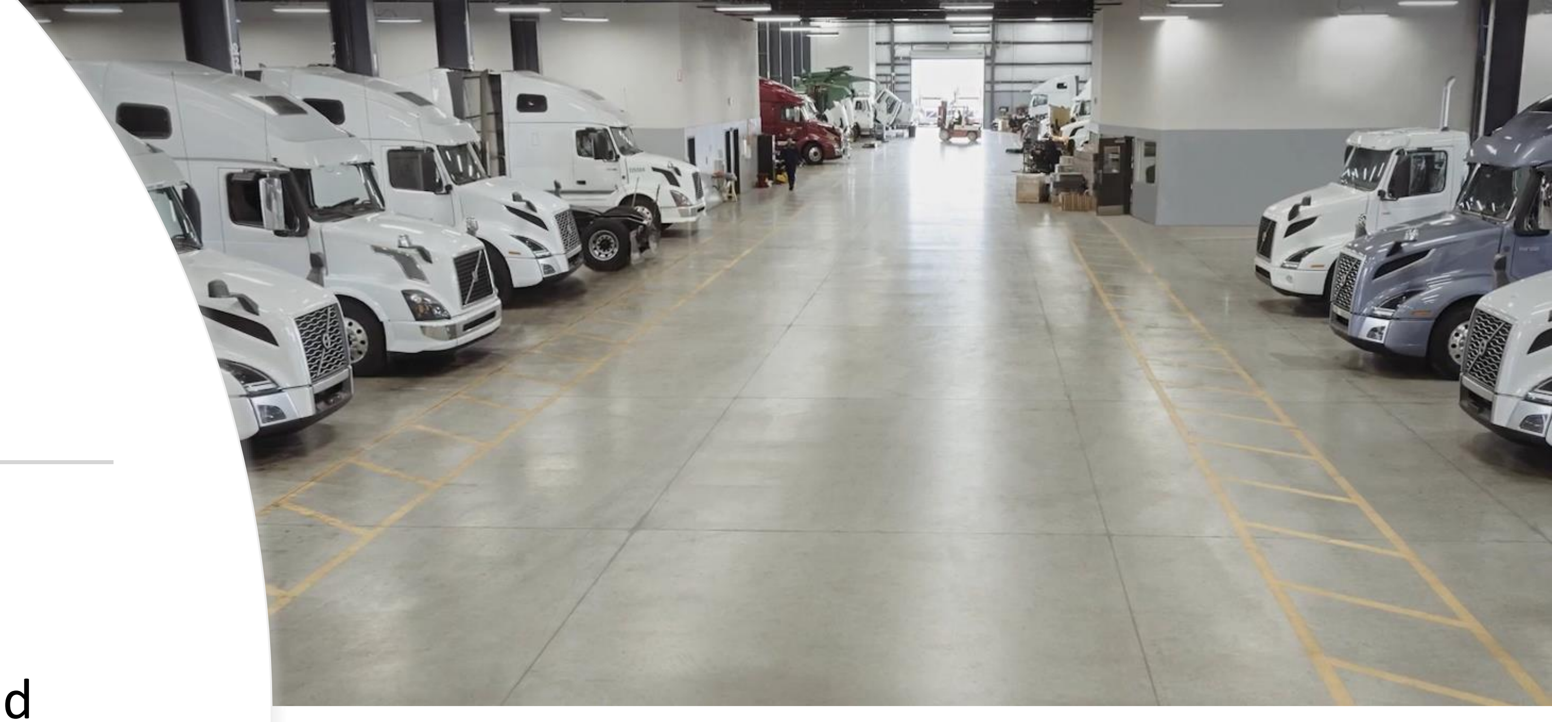
Switch-On Budget

- U.S. EPA funding – buy down on 70 trucks
- Volvo and Fleets contributing towards truck costs
- South Coast AQMD funding for infrastructure, data collection
- Administrative funds for South Coast AQMD staff time, administrative tasks

Source	Amount	Percent
U.S. EPA FY19 Targeted Airshed Grant	$19,460,000	61%
Volvo and Fleets (cash and in-kind match)	$10,080,000	31%
South Coast AQMD	$2,000,000	6%
Administrative Funds	$540,000	2%
TOTAL	$32,080,000	100%

Project Overview

- Deploy 70 Class 8 battery electric trucks in 2021 – 2022
- Up to five fleets in Inland Empire and San Fernando Valley
- Data collection up to two years
- Trucks owned by fleets and in commercial service
- 153 tons NOx reductions in 10 years anticipated
- Potential SCE Charge Ready, LADWP DCFC funding for infrastructure



Trucks

MULTIPLE TRUCK AND TRACTOR CONFIGURATIONS BASED ON FLEET NEEDS

STRAIGHT TRUCKS AND 66K AND 80K TRACTORS

264 KWH – 564 KWH LITHIUM-ION BATTERY PACK

ELECTRIC RANGE 200 – 250 MILES

Infrastructure

ABB 150 or 250 kW DC fast chargers

CCS1 or CCS2 connectors with UL certification

40 kW AC on-board charging with CCS2 connector

Fleets

- DHE and NFI demonstrated Volvo LIGHTS Class 8 battery electric trucks
- Anheuser Busch and Sysco would participate
- Three out of five fleets domiciled in DACs
- TEC dealerships in Fontana and La Mirada provide service and support

Deployment

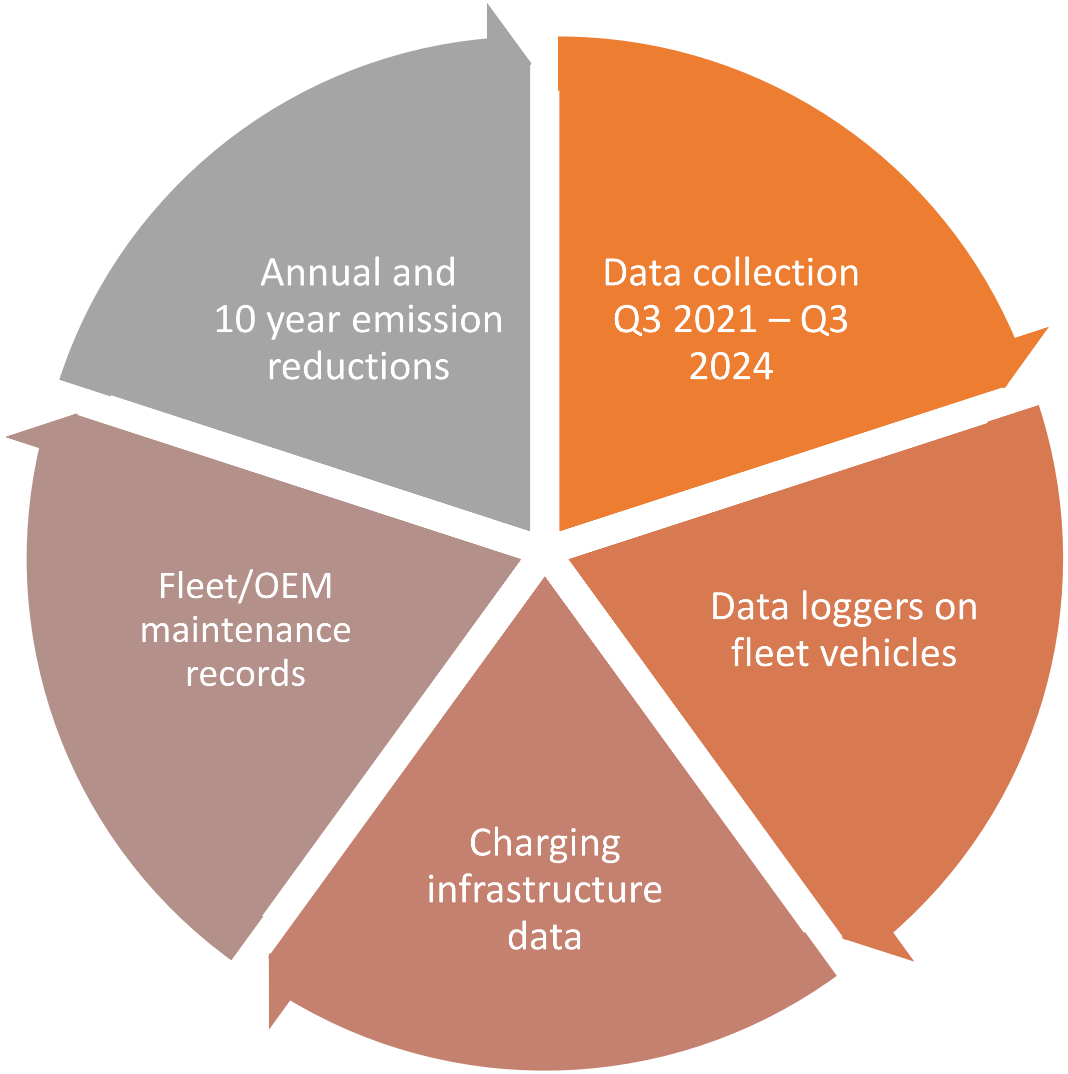
Deploy trucks starting late 2021

Phases of 5 or 10 trucks

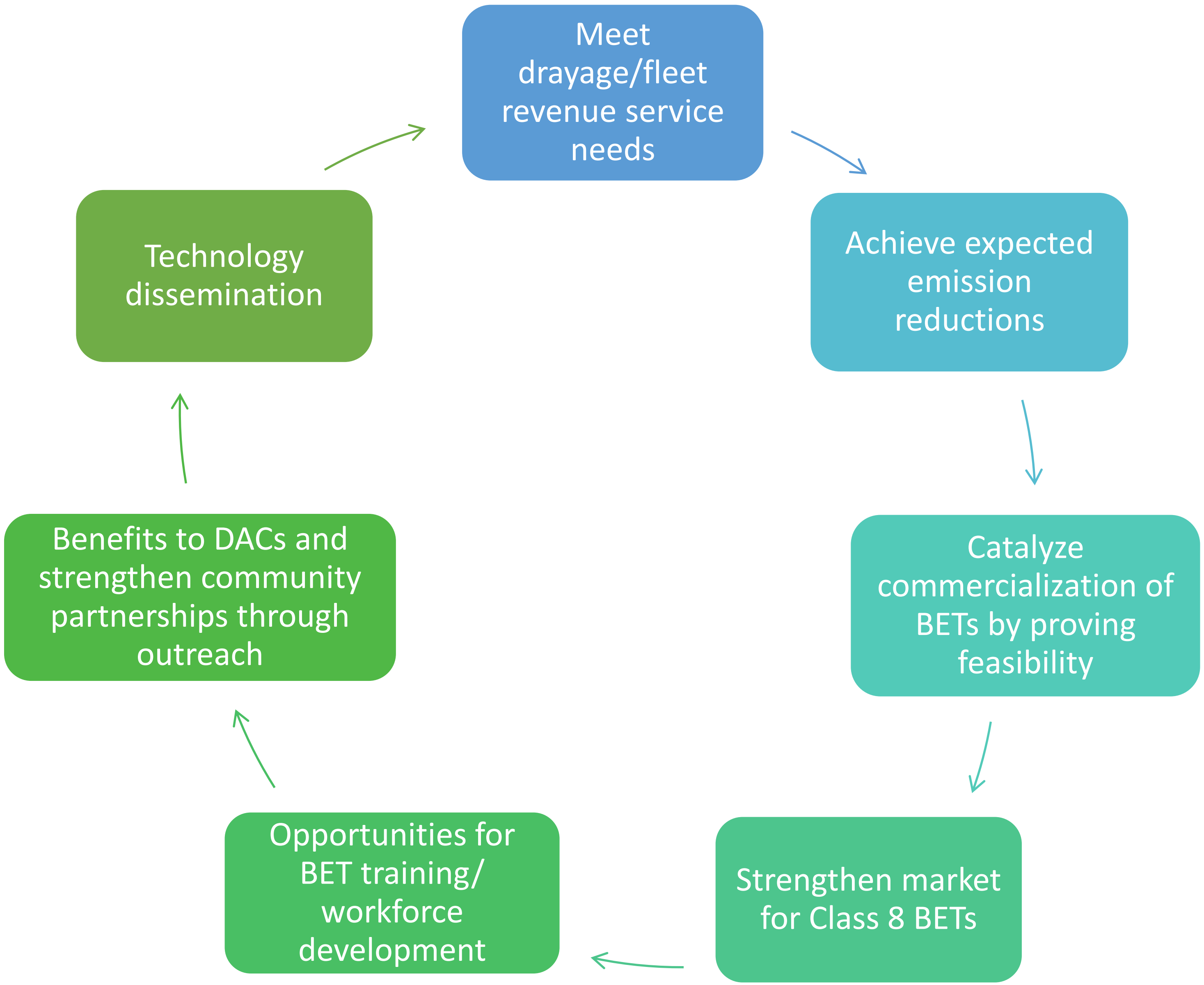
Infrastructure planning 2020 - 2021

Infrastructure installation 2021

Data Collection



Project Outcomes



Heavy-Duty Battery Electric Trucks & Infrastructure

Daimler/Freightliner

Clean Fuels
Advisory Meeting

South Coast AQMD

September 17, 2020

Phil Barroca, Program Supervisor
Technology Demonstration
Technology Advancement Office

Overview – Freightliner Innovation Fleet

South Coast AQMD

- 15 Class 8 - eCascadia DTNA (Portland, OR)
- 5 Class 6 - eM2 Agility/DTNA (Fontana, CA)
- Infrastructure
  - 2.5 MW, 11 DC Fast Charge Locations
  - 800 kWh Energy Storage System
- Demonstration/Outreach
  - Penske and NFI
- Cost Sharing: $31MM
  - DTNA, SCAQMD,POLA, POLB, EPA

DAIMLER

Agility® fuel solutions

South Coast AQMD

ZERO-EMISSION TRUCK

PROVIDED BY:

LA THE PORT OF LOS ANGELES

Port of LONG BEACH THE PORT OF CHOICE

eCascadias

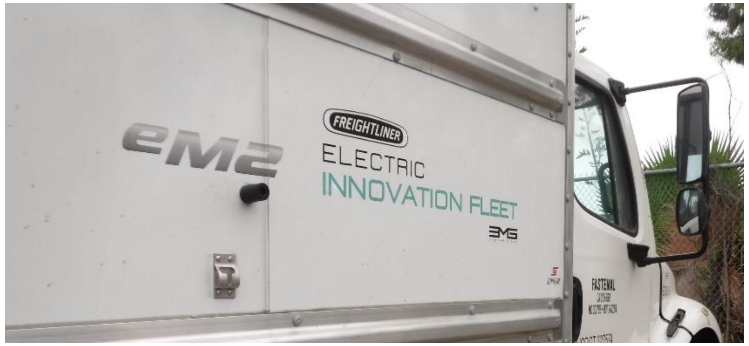
- All 15 tractors deployed (8/19 – 1/20)
- CARB and EPA certifications
- Distribution: 5:5:5 Penske Logistics, Leasing and NFI
- Penske Logistics moving goods for customers
- Penske Leasing:
  - UPS
  - Core-Mark
  - US Foods
  - KeHe Distributors
  - Black Horse Carriers
- NFI operating between Chino and San Pedro Bay Ports
- Drivers feedback:
  - **Pros**
    - Quiet, no torsional twist, easy to drive
    - Learning benefits of Regenerative braking
    - No reduction in performance
  - **Cons**
    - Larger turning radius
    - Back–of-Cab radiator obstructing view of fifth wheel
- Main issues: High Voltage Batteries and eAxle Bearing

eM2s

DAIMLER

South Coast AQMD

- All eM2 deployed (2/20 – 4/20)
- CARB and EPA certifications
- All eM2 deployed to Penske customers
  - Iron Mountain
  - Costco Wholesale
  - EnerSys
  - Fastenal
  - Mondelez
- Fleet's Operational Profiles –
  - generally local pick-up and delivery
  - combination of first/last mile services.
- Driver feedback
- Main Issues: Air compressor failure, Charging Issues

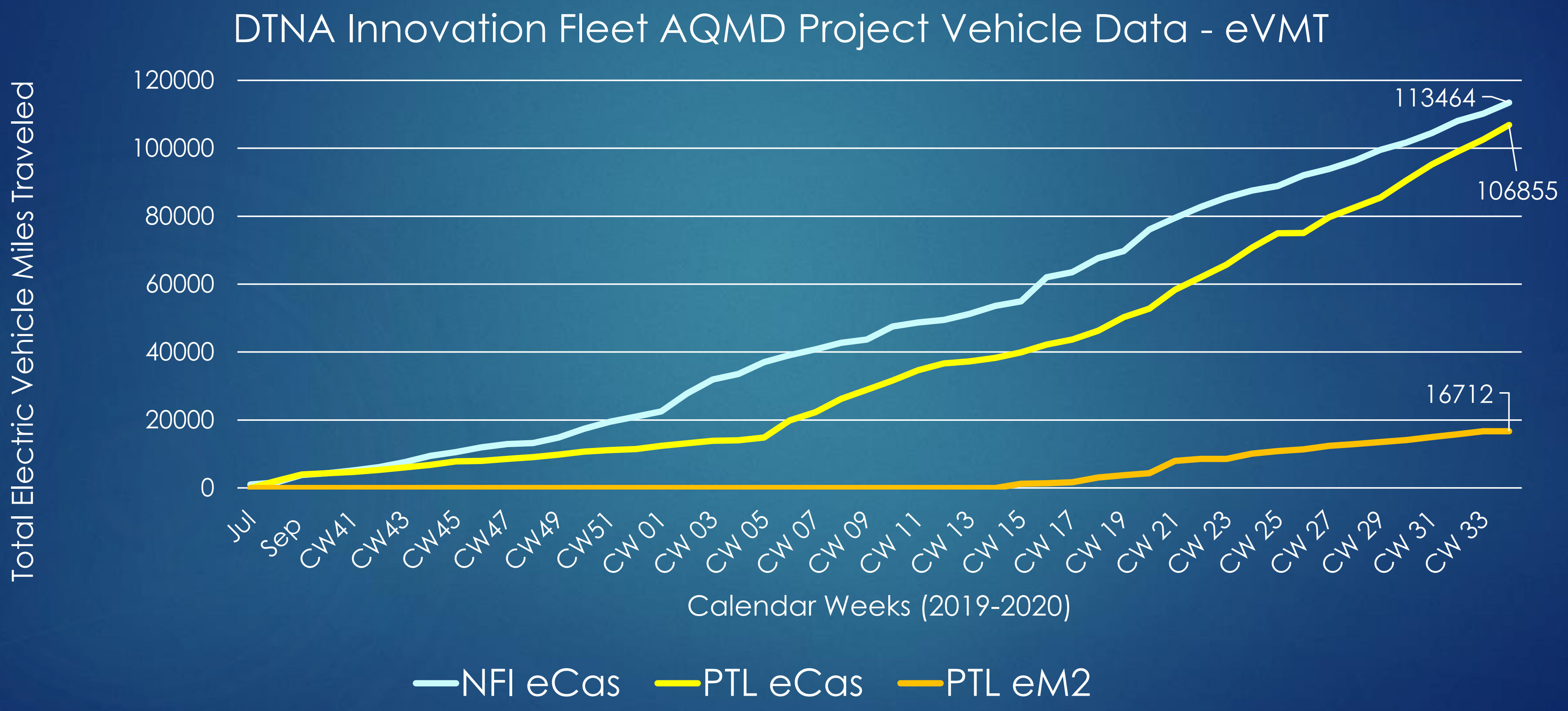


Agility® fuel solutions

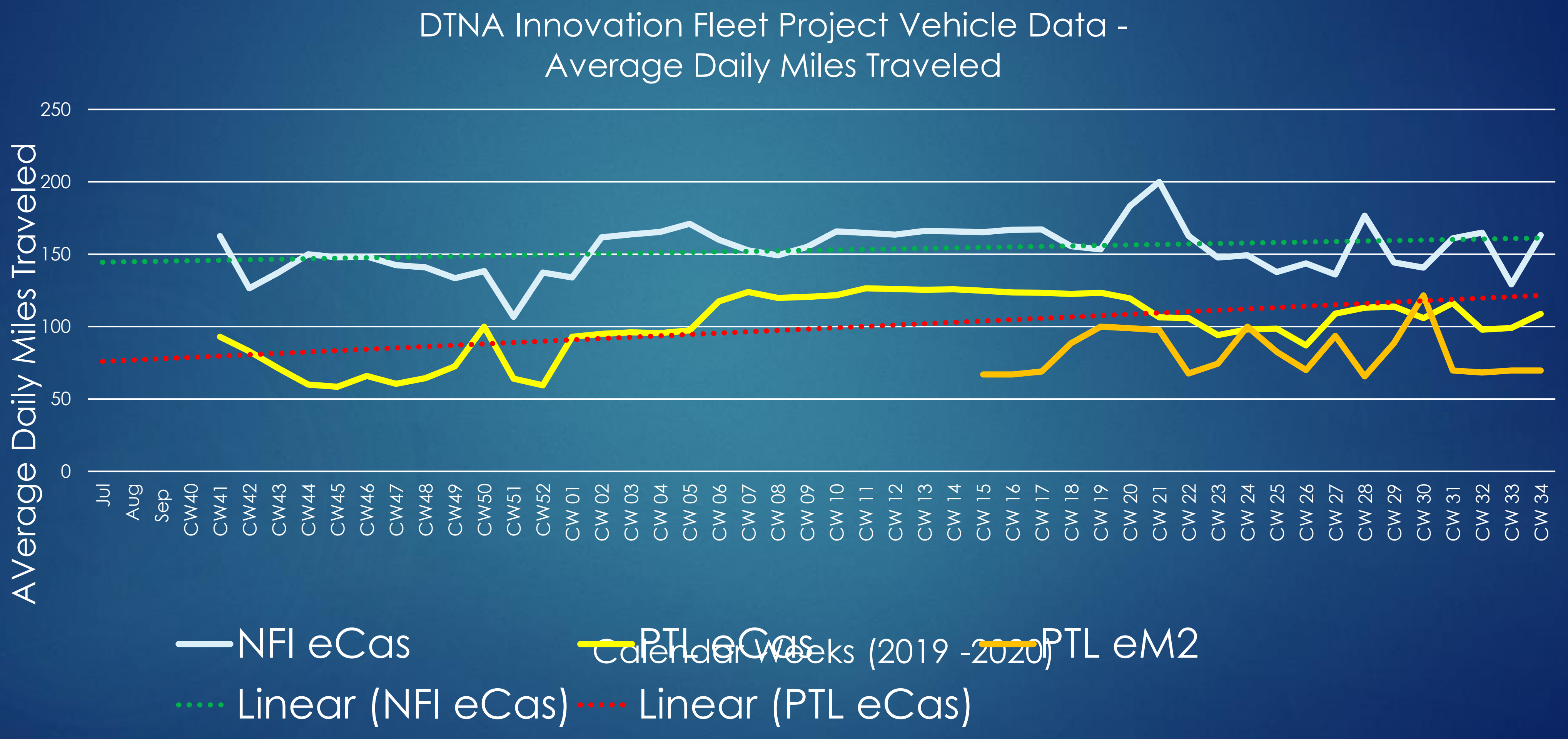
Metrics – eCascadia & eM2

- Total Miles Accrued all vehicles: ~ 300,000 miles thru August 2020
- eCascadia: 270,000 miles 2.08 kWh/mile 20-50,000-lbs payload
  - **Penske (averages):**
    - 25,000 miles/mo.; 110 miles/day/vehicle; 5.3 hrs/day operation
    - 48% SOC used per shift; 3.3 hrs/day charging
  - NFI (averages):
    - 15,000 miles/mo.; 160 miles/day/vehicle; 6.7 hrs/day operation
    - 57% SOC used per shift; 3.9 hrs/day charging
- eM2: 25,000 miles 1.35 kWh/mile 8-13,0000lbs payload
  - **Penske (averages):**
    - 5,000 miles/mo.; 80 miles/day/vehicle; 9.4 hrs/day operation
    - 67% SOC used per shift; 2.3 hrs/day charging

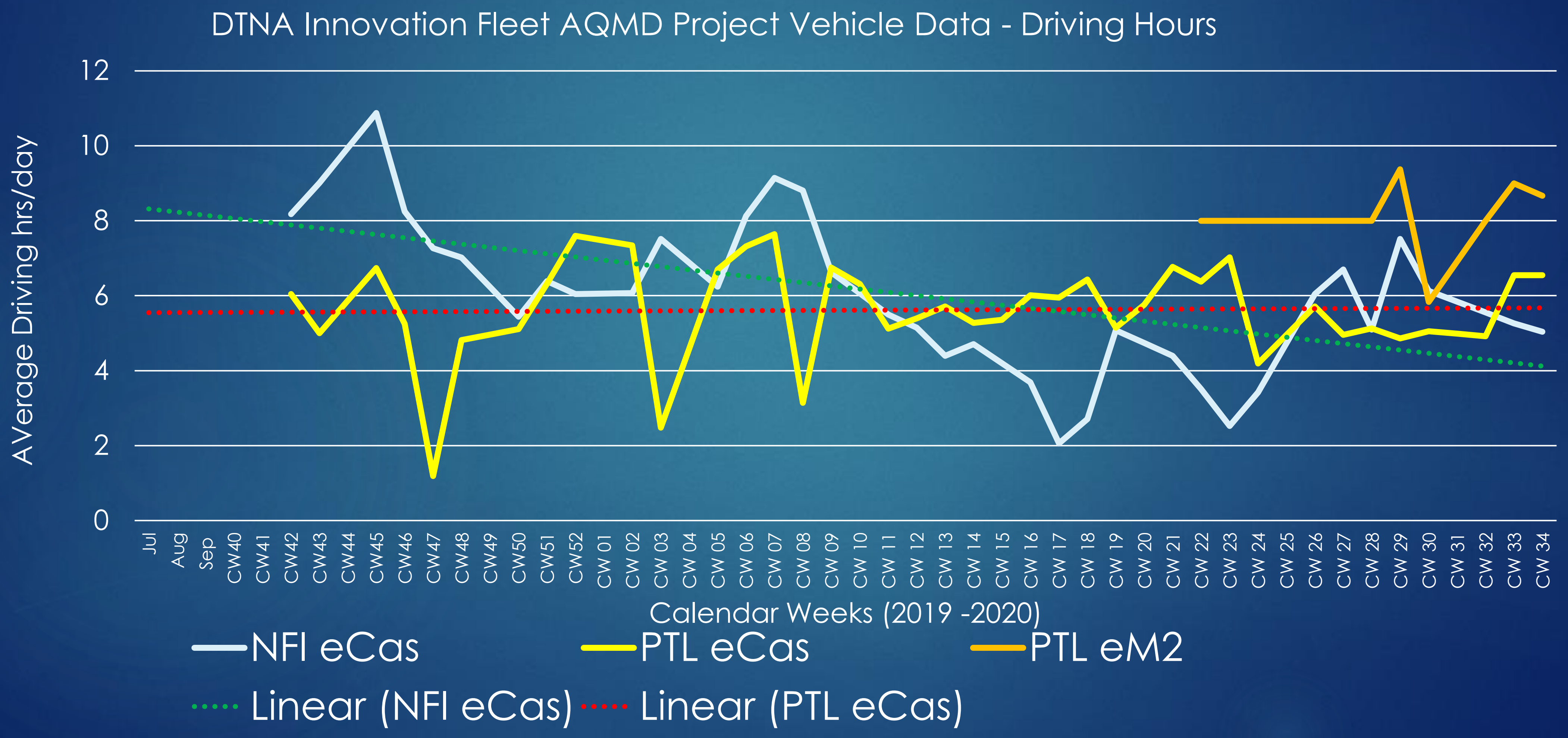
Vehicle Miles through August 2020



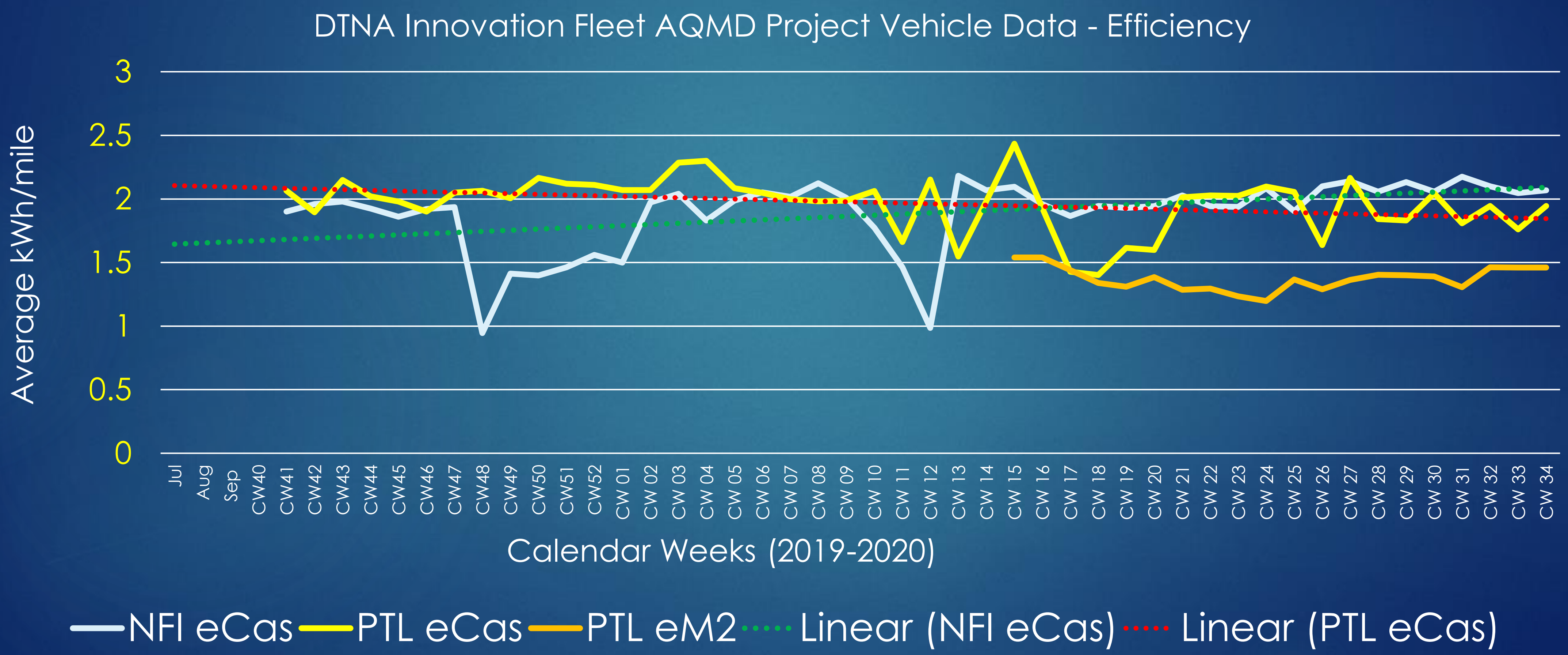
Daily Miles per Vehicle (average)



Driving Hours per Day (average)



Energy Economy (kWh/mile)



EV Infrastructure

- Infrastructure: CCS-1 DC Fast Charging
- 150 kW, 62.5 kW, 50 kW
- 11 Locations, 21 DC Fast-Chargers
- 2550 kW install
- Energy Storage System – Ontario
  - 300 kW Power
  - 800 kWh storage
  - Simulating Utility rates with Demand periods

CCS Type1 Connector

EV Infrastructure – Locations

South Coast AQMD

Penske Ontario 450 kW + 800 kWh ESS

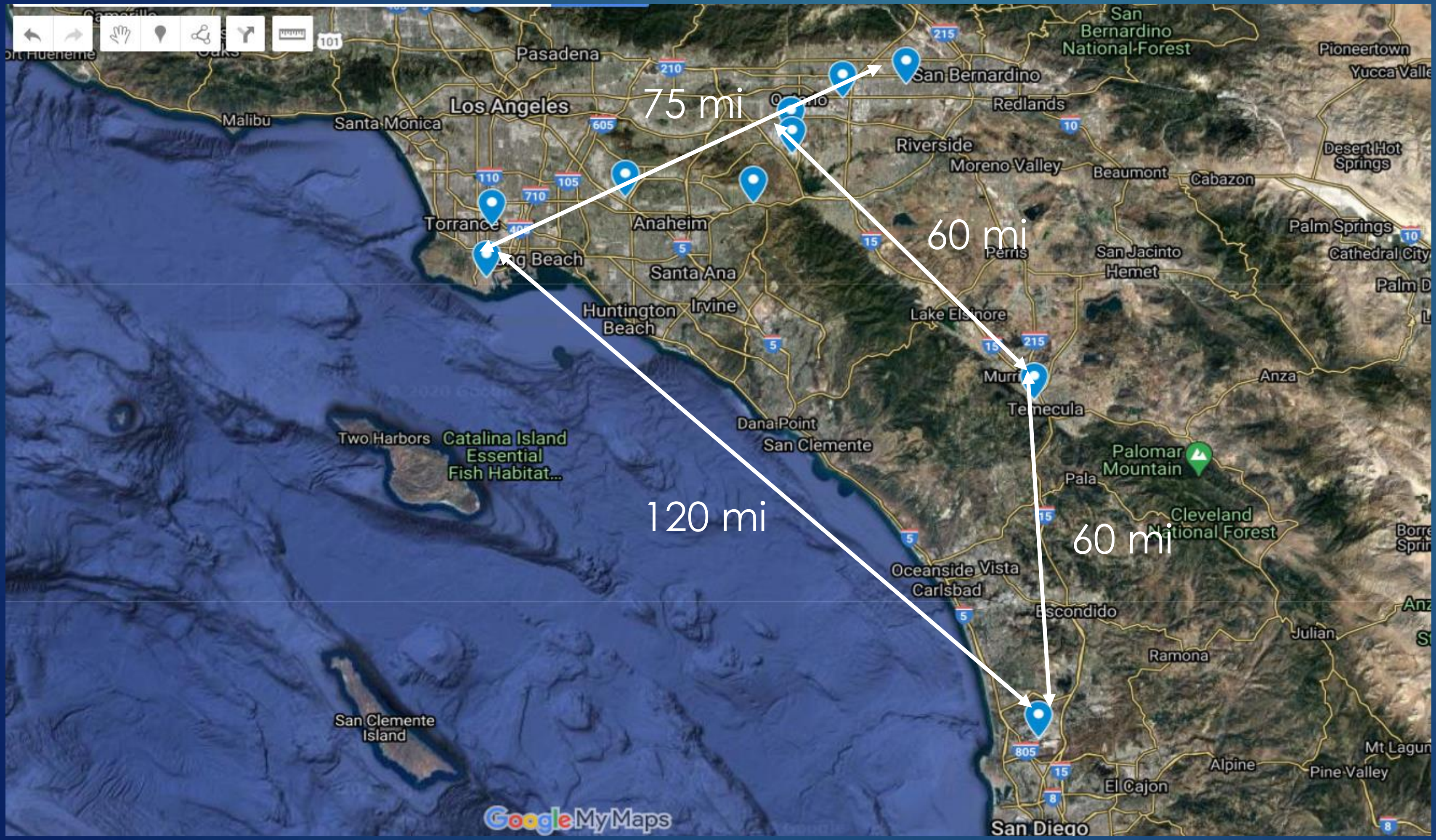
150 kW Penske San Diego

300 kW Penske La Mirada

300 kW Penske Anaheim

750 kW NFI - Chino

Infrastructure / Vehicle Distribution



Penske

- Chino: 300 kW, 1 eCas,1 eM2
- La Mirada: 300kW, 1 eCas, 3 eM2
- Ontario: 450 kW, 5 eCas, 1 eM2
- San Diego: 150 kW, 2 eCas
- Anaheim: 300 kW, 1 eCas

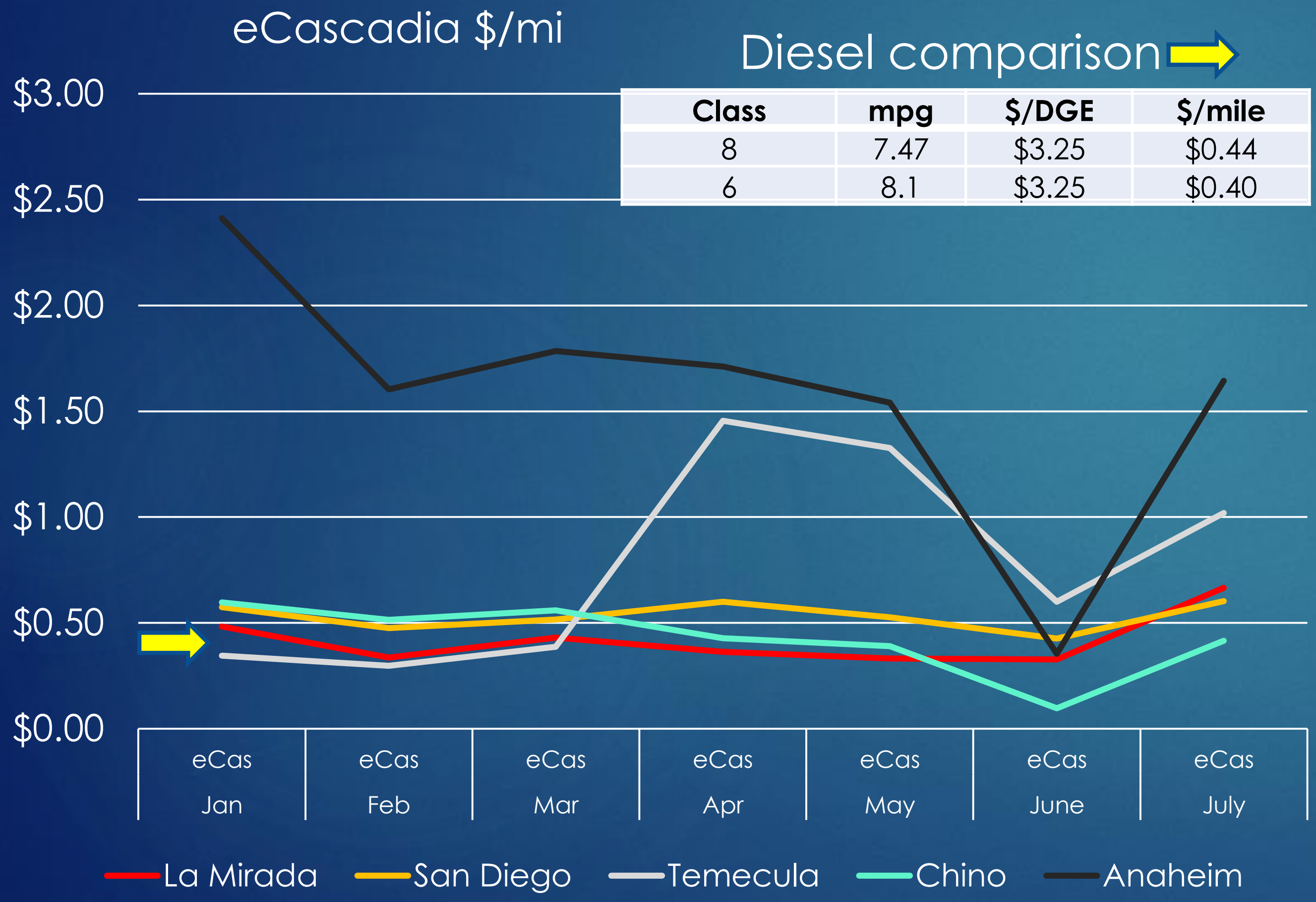
NFI

- Chino: 750 and 62.5 kW, 5 eCas

Auxiliaries: 237.5 kW

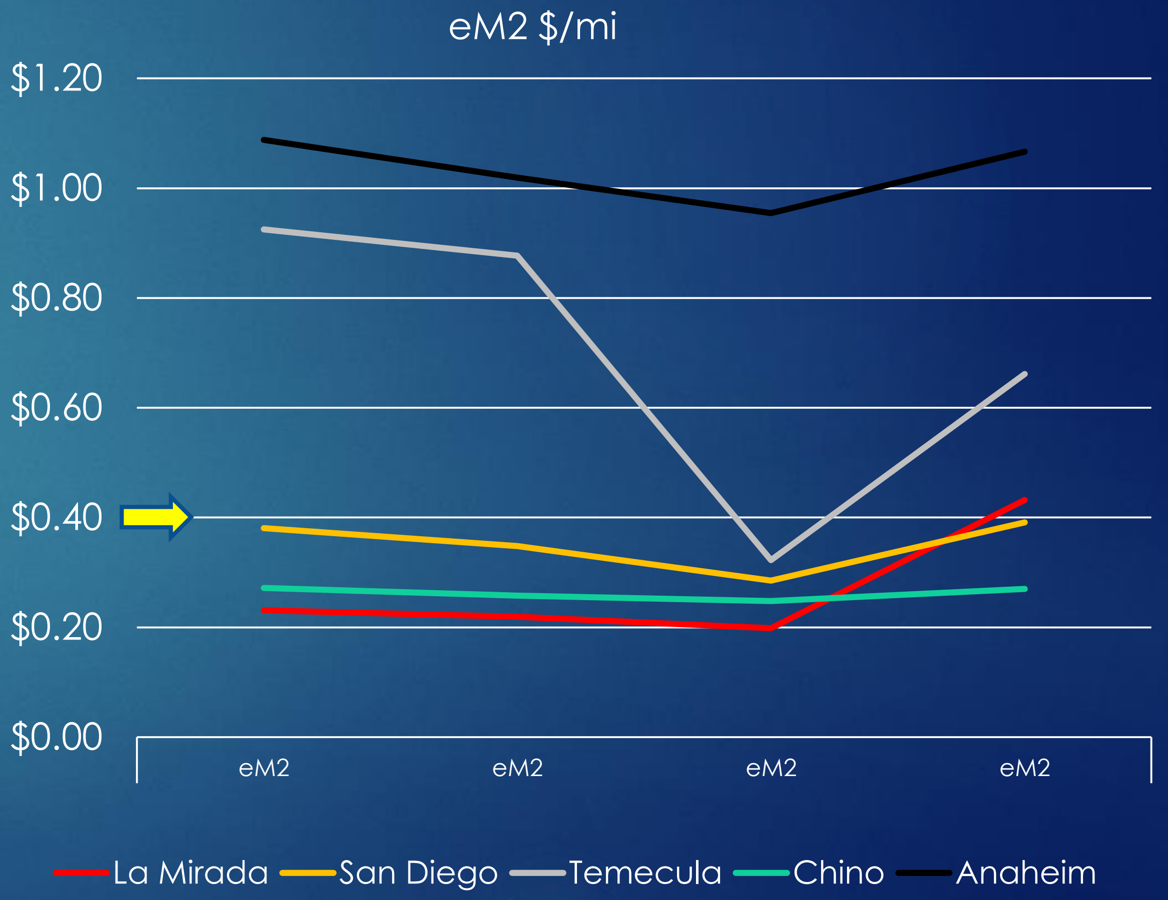
- Temecula, Carson, Fontana, San Pedro Bay Port

Electricity Costs ($/mi)



Diesel comparison

Class	mpg	$/DGE	$/mile
8	7.47	$3.25	$0.44
6	8.1	$3.25	$0.40



Tasks Status

- Task 1 Vehicle Development - complete
- Task 2 Targeted Outreach and Education - complete
- Task 3 Infrastructure – on going
- Task 4 Pilot Demonstration – on going
  - Extreme environmental conditions to be commenced
- Task 5 – Market Readiness Acceleration – on going
- Task 6 – Reporting - ongoing

Looking Forward - CX

- Customer Experience (CX) Project
- Intended to accelerate scaled volume orders of commercially viable zero emission trucks within the next two to three years
- SCAQMD and BAAQMD funding with DTNA
- Expanding exposure of eCascadia and eM2 to NorCal and SoCal fleets
- 4 eCascadia and 2 eM2 in SoCal + 2 eCascadia in NorCal

CX - Vehicles and Fleets

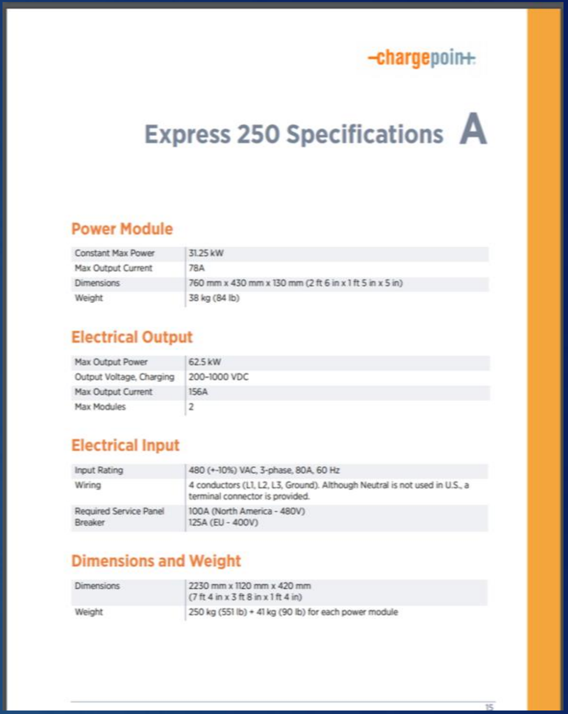
- 4 eCascadia and 2 eM2 in SoCal + 2 eCascadia in NorCal
- 2-9 months demonstrations over two years (into 2022)
- Major Fleets:

FedEx, Kroger, US Foods, Knight Transportation, Schneider, Pepsi, Sysco, Swift Transportation, Ryder, J.B. Hunt

CX - Infrastructure

- Portable DC Fast Charging
  - Minimum of Five units
  - Skid Mounted

- Charge Point Express 250
  - Input: 480V, 100A connection
  - Output:
    - 62.5kW max., 31.25kW continuous
    - 156A, 200-1000VDC
  - CCS-1, CCS-2, CHAdeMO connector



-chargepoin+

Express 250 Specifications A

Power Module

Constant Max Power	31.25 kW
Max Output Current	78A
Dimensions	760 mm x 430 mm x 130 mm (2 ft 6 in x 1 ft 5 in x 5 in)
Weight	38 kg (84 lb)

Electrical Output

Max Output Power	62.5 kW
Output Voltage, Charging	200–1000 VDC
Max Output Current	156A
Max Modules	2

Electrical Input

Input Rating	480 (+-10%) VAC, 3-phase, 80A, 60 Hz
Wiring	4 conductors (L1, L2, L3, Ground). Although Neutral is not used in U.S., a terminal connector is provided.
Required Service Panel Breaker	100A (North America - 480V) 125A (EU - 400V)

Dimensions and Weight

Dimensions	2230 mm x 1120 mm x 420 mm (7 ft 4 in x 3 ft 8 in x 1 ft 4 in)
Weight	250 kg (551 lb) + 41 kg (90 lb) for each power module

Future Plans – Pilot Commercial Deployment

- July 2019 - Board approval / funding:
  - USEPA 2018 Targeted Air Shed Grant $4.2 MM
  - DTNA $3.3 MM
  - HVIP $5 M
- Deploy commercial-ready eCascadia and eM2 to major fleets including US Foods
- Deploy 35 battery-electric heavy-duty vehicles for 6 years
  - 15 vehicle pilot deployment with US Foods
    - 10 Class 8 (eCascadia)
    - 5 Class 6 (eM2)
  - 20 vehicle deployment with prospective fleets
    - 10 Class 8 (eCascadia)
    - 10 Class 6 (eM2)
- Implement DC Fast Charge Infrastructure
- Project Contract pending

Thank You

PENSKE
ELECTRIC VEHICLE
PENSKE

PENSKE
ELECTRIC VEHICLE
E00015

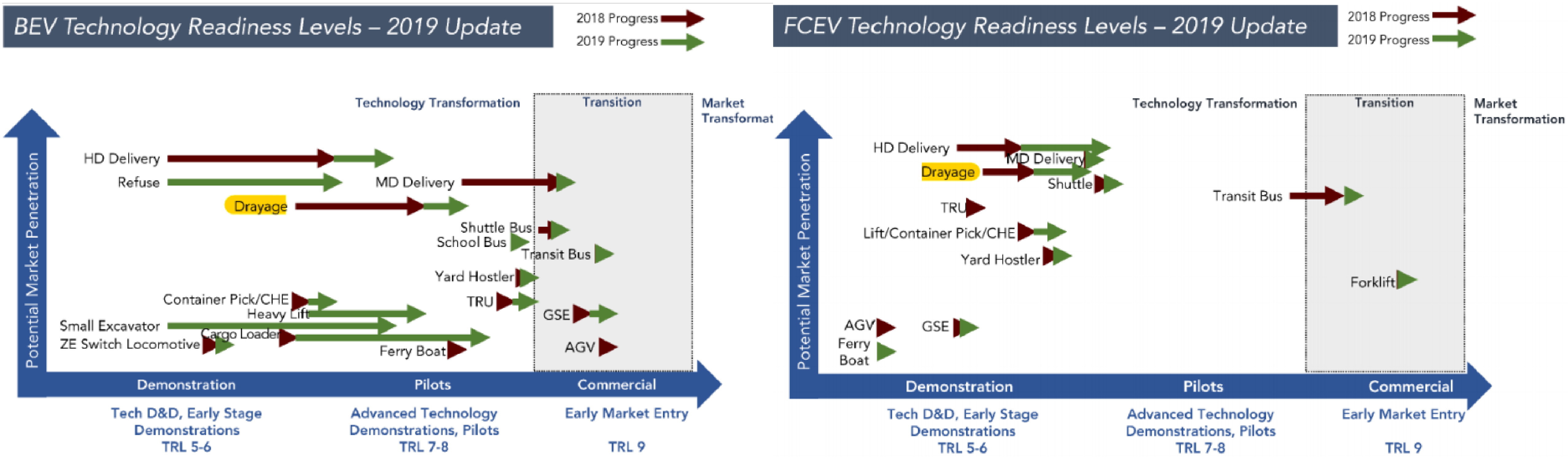
Pathway for Fuel Cell Heavy-Duty Vehicles

Technology Advancement Office
Program Supervisor

Seungbum Ha

Clean Fuels Fund Advisory Retreat
Sep. 17, 2020

Battery Electric vs. Fuel Cell Readiness Levels

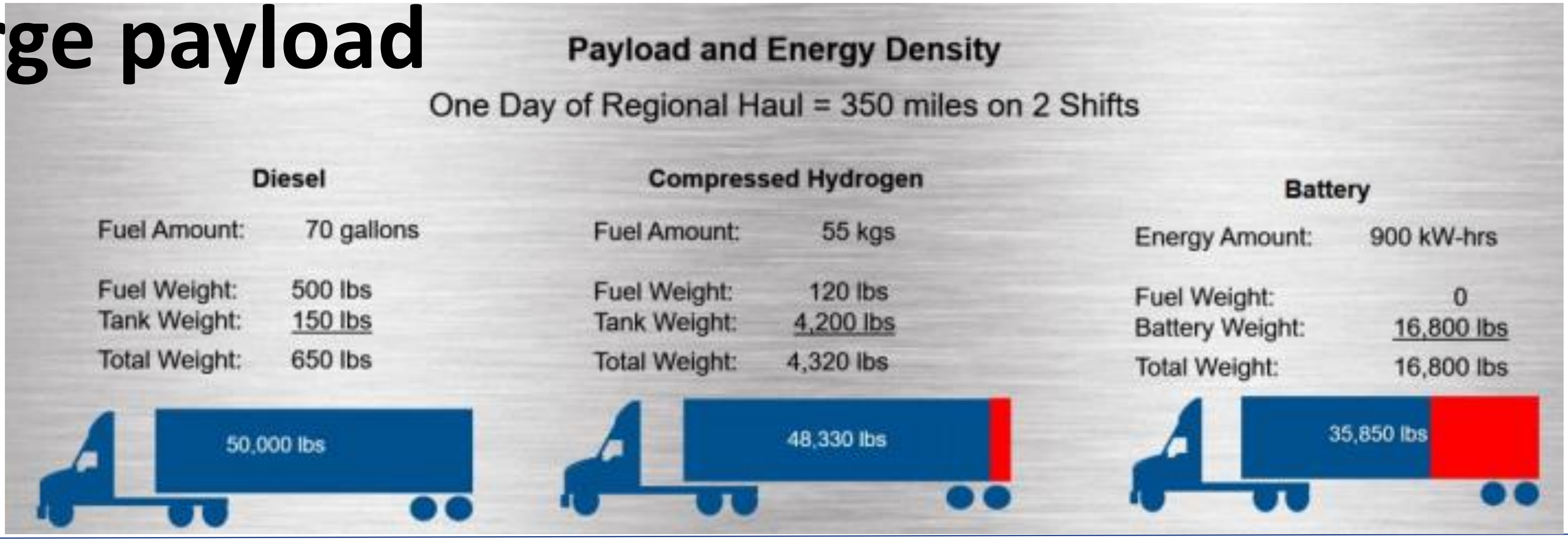


Source: Proposed Fiscal Year 2019-20 Funding Plan for Clean Transportation Incentives For Low Carbon Transportation Investments and the Air Quality Improvement Program; Appendix D: Heavy-Duty Investment Strategy" (CARB, 2019b).

Advantageous Applications

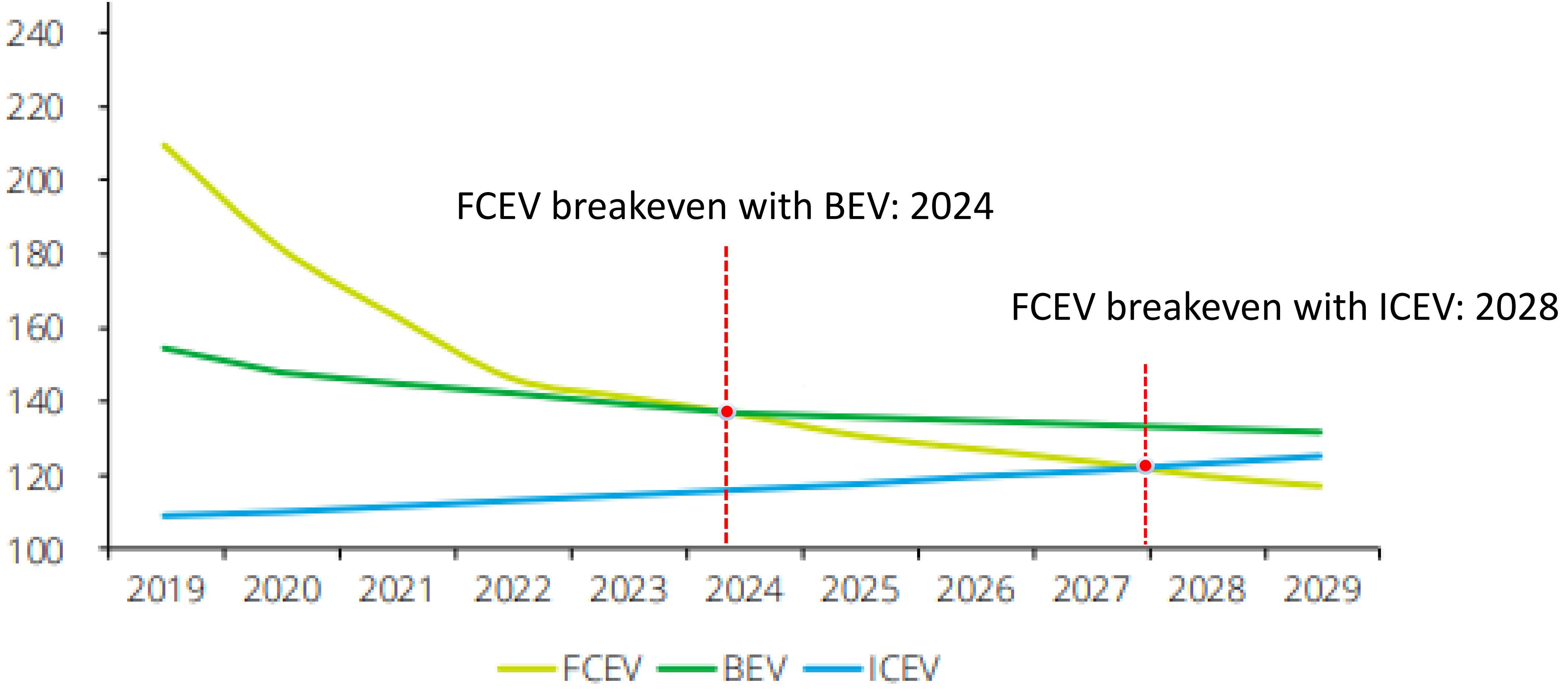
Long Range

Large payload



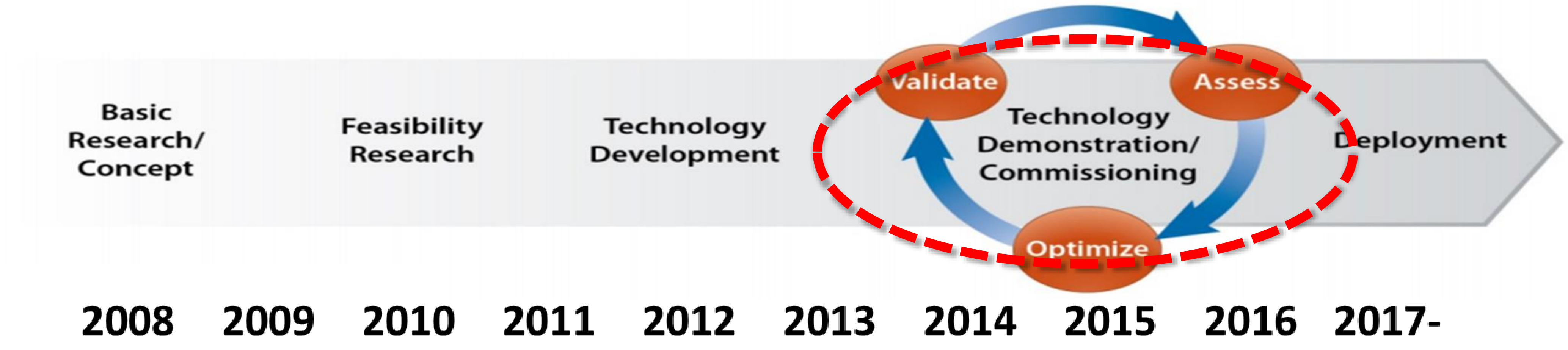
Source: Kenworth – ACT News/CHBC Webinar April 14, 2020

Total TCO /USD per 100km



https://info.ballard.com/hubfs/Other Reports/Deloitte Volume 1 Powering the Future of Mobility.pdf

AQMD Vehicle Demonstration Project



ZECT 2 – Awarded: 2014; Kickoff: 2015

- Three Technologies: Fuel Cell, Battery Electric with Fuel Cell, Battery Electric with CNG ICE
- Four technology integrators: TransPower, U.S. Hybrid, Hydrogenics, BAE/Kenworth
- Fleet Participation: Drayage fleets, Kenworth Trucks
- Funding: DOE: $10,000,000; Match Share: $7,183,979; Contractors: $3,075,841; Total Cost: $20,259,820

Approach

Vehicle Development and Deployment

	FUEL CELL TRUCKS				PHET/CNG
	TransPower	Hydrogenics (Cummins)	US Hybrid	BAE/Kenworth	
# of Vehicles	2	1	2	1	1
Platform	International	Freightliner	Kenworth T800	Kenworth T370	Kenworth T680
Mfg: Fuel Cell / APU	Hydrogenics	Hydrogenics	PureMotion	Ballard	CWI L9N NZE
Fuel Cell Power	60 kW	60 kW	80 kW	85 kW	n/a
Battery Capacity	125 kWh	100 kWh	26 kWh	100 kWh	100 kWh
Battery Chemistry	Li-ion	Li-ion	Li-ion	Li-ion	Li-ion
Traction Motors	2x 150 kW	1x 320 kW	1x 320 kW	1x 420 kW	1x 420 kW
Range (per fueling)	200 miles	150 miles	150-200 miles	112 miles	150 miles
Fuel Cap.: H2 (kg) / CNG (DGE)	27 kg @350 bar	30 kg @350 bar	20 kg @350 bar	30 kg @350 bar	45 DGE
	Deployed		Deployed	Deployed	Deployed

In-use Demonstration and vehicle performance Analysis

TCO Analysis and Commercialization Roadmap

Relevance: Goals & Objectives

2019/2020 Objectives

- Complete vehicle builds
- Operate portable hydrogen refueling for demonstration
- Continue vehicle demonstration and data collection & analysis

Results

- Six demonstration trucks including fuel cell range extended and CNG hybrid truck deployed
- Portable hydrogen fuel onsite is in operation
- Debugging and improvement while demonstrating by lessons-learned from the first demo trucks
- Vehicle performance data provided from demonstration trucks

Impact

- Pushing Zero Emission Technology and Industry Envelope by Demonstrating First Fleet of FCEV's in Drayage Service in California




South Coast AQMD

Demonstration Issues and Lessons Learned

Technical Issues while Development and Demonstration

- **Typical issues of a demonstration**
  - Blown fuses, damaged sensors
  - Data Upload Technical Difficulties

- **New technology specific improvement & issues**
  - Software Updates
  - Battery Disconnect Failures
  - Blown Internal Battery Fuses
  - Inconsistent Traction Motor Resolver
  - Transmission Shift Position Sensor
  - Fuel cell coolant contamination
  - Cooling system control for fuel cell stack
  - Leakage of Hydrogen tank valves

High

Moderate

Low


Inspection of Battery Fuses

Deteriorated FC coolant reservoir cap

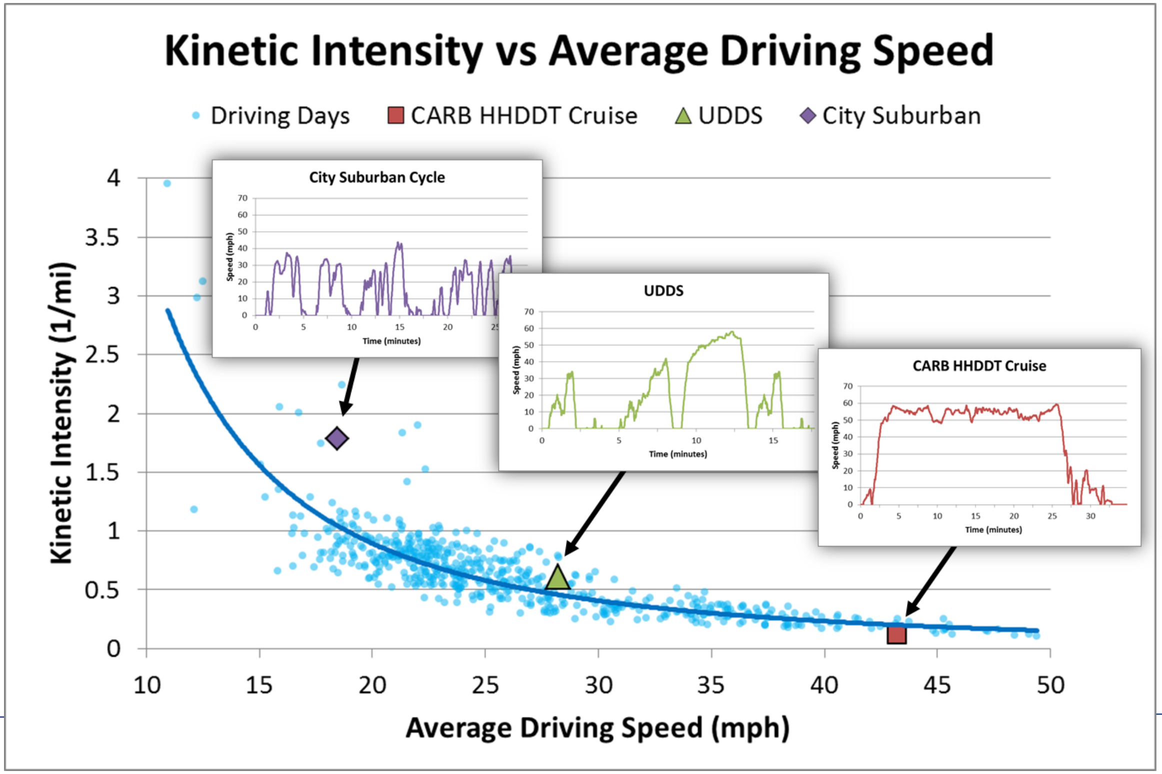

Transmission Repair

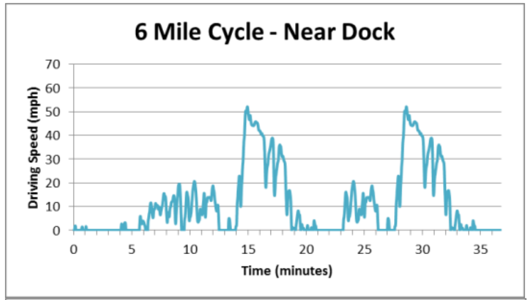
Lessons-Learned from Development and Demonstration

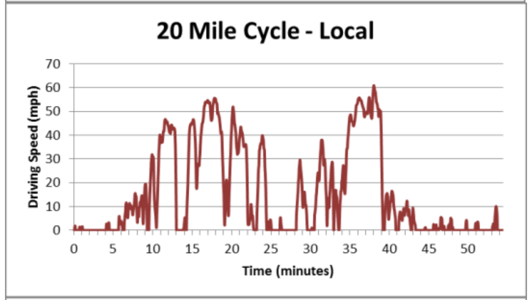
- Positive feedbacks from drivers for drivability and performance, but reliability is an issue
- Supply base is not ready and suppliers do not have broad knowledge in applications
- Too many connections (HV, LV, CAN, Cooling) and routing design is integral to chassis layout
- Cooling (particularly for FC) is challenging
- Battery technology and management systems for heavy-duty vehicles are evolving and maturing
- Power electronics firmware needs to become more automated
- Design validation is required for single larger FC stack and modular multi-stack

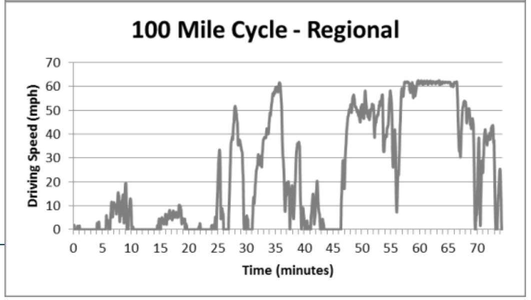
Data Analysis – Baseline Trucks

- Class 8 Tractors
- Multiple OEMs - Navistar, Volvo, Mack, Freightliner, Peterbilt & Sterling
- Trip segments grouped by maximum radius distance from the Port of LB
- Processed using NREL's DRIVE tool







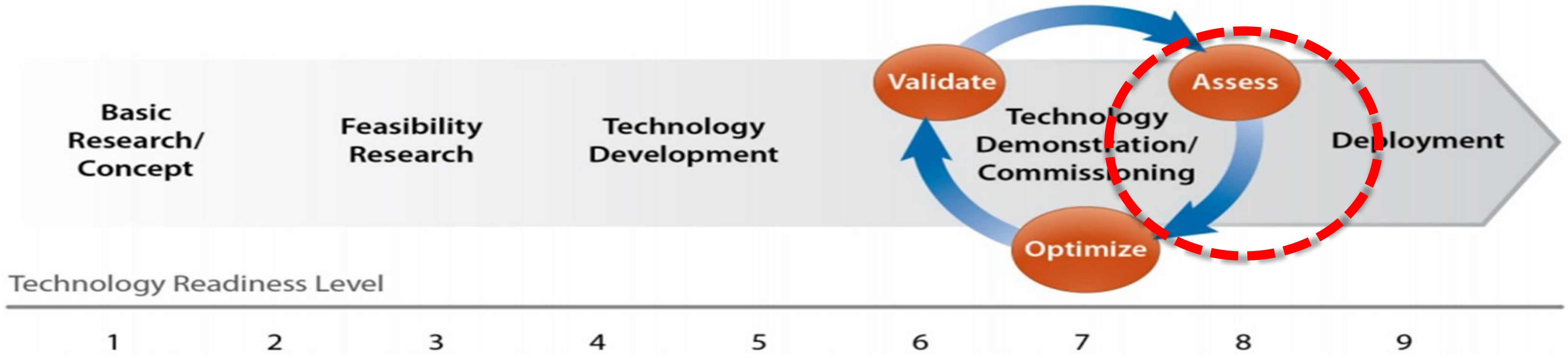


Data Analysis – Summary Table

Metric	Units	Baseline Conventional*	TransPower HEDD1	TransPower HEDD2	US Hybrid FC359	US Hybrid FC365	Kenworth ZECT
Date Range		2014-2015	11/3/2017 – 9/5/2019	10/24/2018 – 9/9/2019	5/6/2019 – 3/30/2020	5/8/2019 – 3/2/2020	6/13/2019 – 1/7/2020
Number of recorded vehicle days	#	557	152	94	106	31	29
Max daily distance	mi	—	106.5	126.9	122.7	28.0	123.3
Avg daily distance	mi	127.9	5.8	21.0	21.0	6.4	25.1
Avg operating time (key-on)	hr	10.1	10.0	5.8	2.0	0.7	3.4
Avg driving time	hr	4.5	0.3	1.1	0.9	0.3	1.2
Avg speed	mph	14	1.3	3.5	7.0	6.2	5.1
Avg driving speed (speed>0)	mph	26.5	10.6	14.4	17.8	14.1	12.3
Kinetic intensity	1/mi	0.64	1.4	0.8	1.6	2.7	2.4
Avg stops/day	#/day	124.9	14.2	62.9	50.0	17.4	86.8
Avg stops/mi	#/mile	1.38	24.6	18.1	13.5	17.7	—
Median stop duration	sec	40.8	346.7	39.2	9.5	27.4	8.3
Avg daily fuel use (H2)	kg	—	—	—	3.2	0.9	5.1
Avg daily fuel use (diesel equiv.)	gal	23.7	—	—	2.8	0.8	4.5
Avg fuel economy (diesel equiv.)	mi/gal	5.7	—	—	8.3	9.5	7.4
Avg fuel cell efficiency	%	—	—	—	53.3%	56.4%	52.3%

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

AQMD Vehicle Demonstration Project

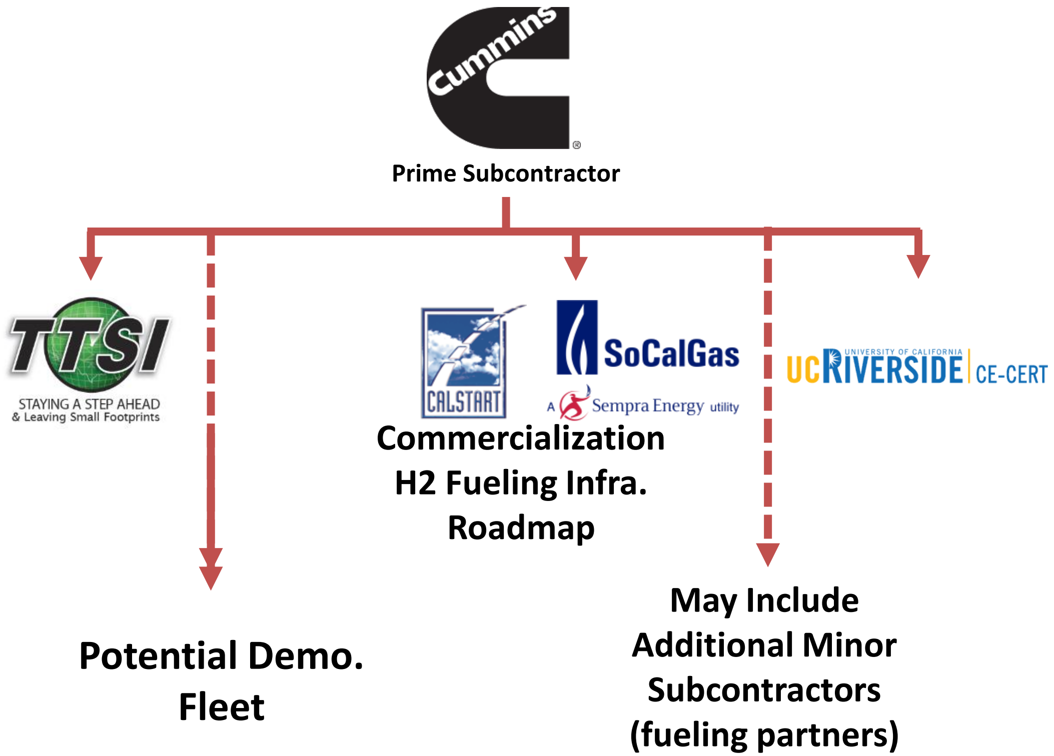


- CARB ZANZEFF Fuel Cell Truck Project
- CEC Sustainable Freight Transportation Project

CEC Sustainable Freight Transportation Project - Cummins Fuel Cell truck

- Increased subsidies and incentives focused on hydrogen-based technologies and infrastructure
- PEM fuel cells - commercial vehicle applications – long daily range needs
- South Coast AQMD - best suited for fuel cell powered Class 8 trucks
  - technical feasibility
  - financial viability
- Cummins' recent acquisition of Hydrogenics Corporation
  - first fully integrated fuel cell powertrain
  - short and regional haul applications

CEC Sustainable Freight Transportation Project



- MY2020 Kenworth T680 Day Cab
- 82,000 lbs. (Class 8)
- Hydrogenics 2 x HyPM HD90 180 kW
- Cummins Motor/Inverter w/ 4-speed Trans.
- Agility 23.5 kg @ 350 bar
- 10-15 minutes
- 150-200 mi. depending on duty cycle
- **Pilot / pre-production. Commercialization planned in 2022-2023.**

- Modular and scalable
- Plug-and-play design
- Fully integrated to pair with commercially available traction systems

Summary

- Barriers for Battery electric and Fuel Cell HD vehicles

Battery Electric	Fuel Cell
Infrastructure	Infrastructure
High cost	Cost of hydrogen fuel
Limited vendors	High Cost
Limited range	Limited vendors
Heavy batteries and axle loads	Unknown business case

- Temporary hydrogen refueling supporting vehicle testing and demonstration
  - Assessment of feasible pathway for hydrogen fueling in near and long term
  - Mobile refueler
  - Renewable hydrogen station
- Continue demonstration and data analysis for comparison to conventional diesel trucks
- TCO analysis and commercialization roadmap will be accomplished
- More OEMs' participation is required

Transit Buses – Status

MARYAM HAJBABAEI

TECHNOLOGY ADVANCEMENT OFFICE

Clean Fuels Program Advisory Group Retreat, 17 September,2020

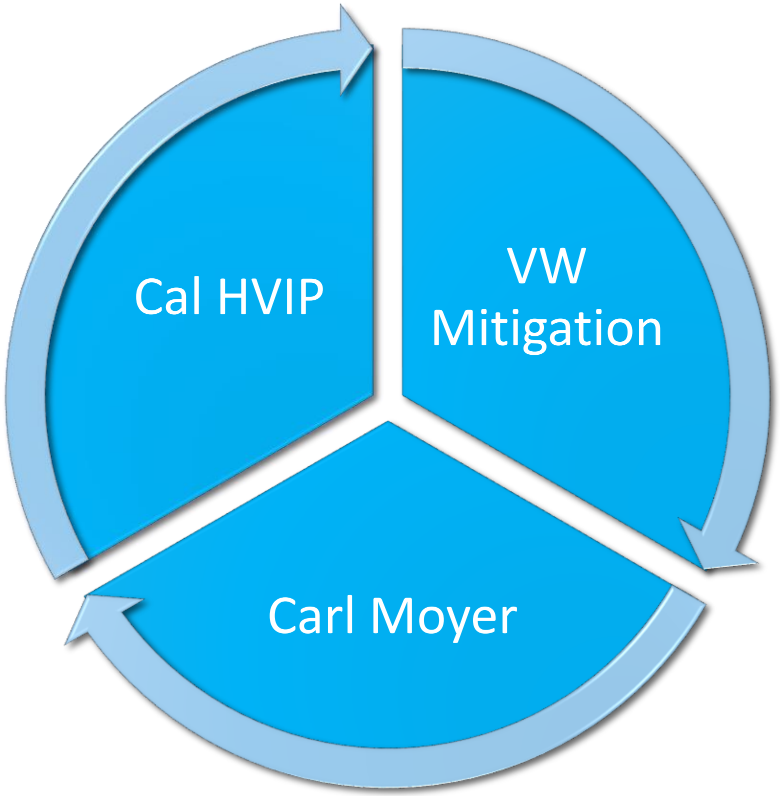
Background
Transit Buses Current Regulations + Incentives

CARB Innovative Clean Transit (ICT)

- Reduce NOx and GHG emissions
  - transit-dependent and disadvantage communities
- All public transit agencies to gradually transition to a 100% ZEB fleet
  - Beginning in 2029, 100% of new purchases must be ZEBs, with a goal for full transition by 2040

2016 AQMP Control Measure

- Reduce NOx emissions by 45% and 55% by 2023 and 2031
- Transition to zero and near-zero emission technologies in the mobile source sector
- Seek and identify significant secured funding for incentives to implement early deployment and commercialization of known zero and near-zero technologies

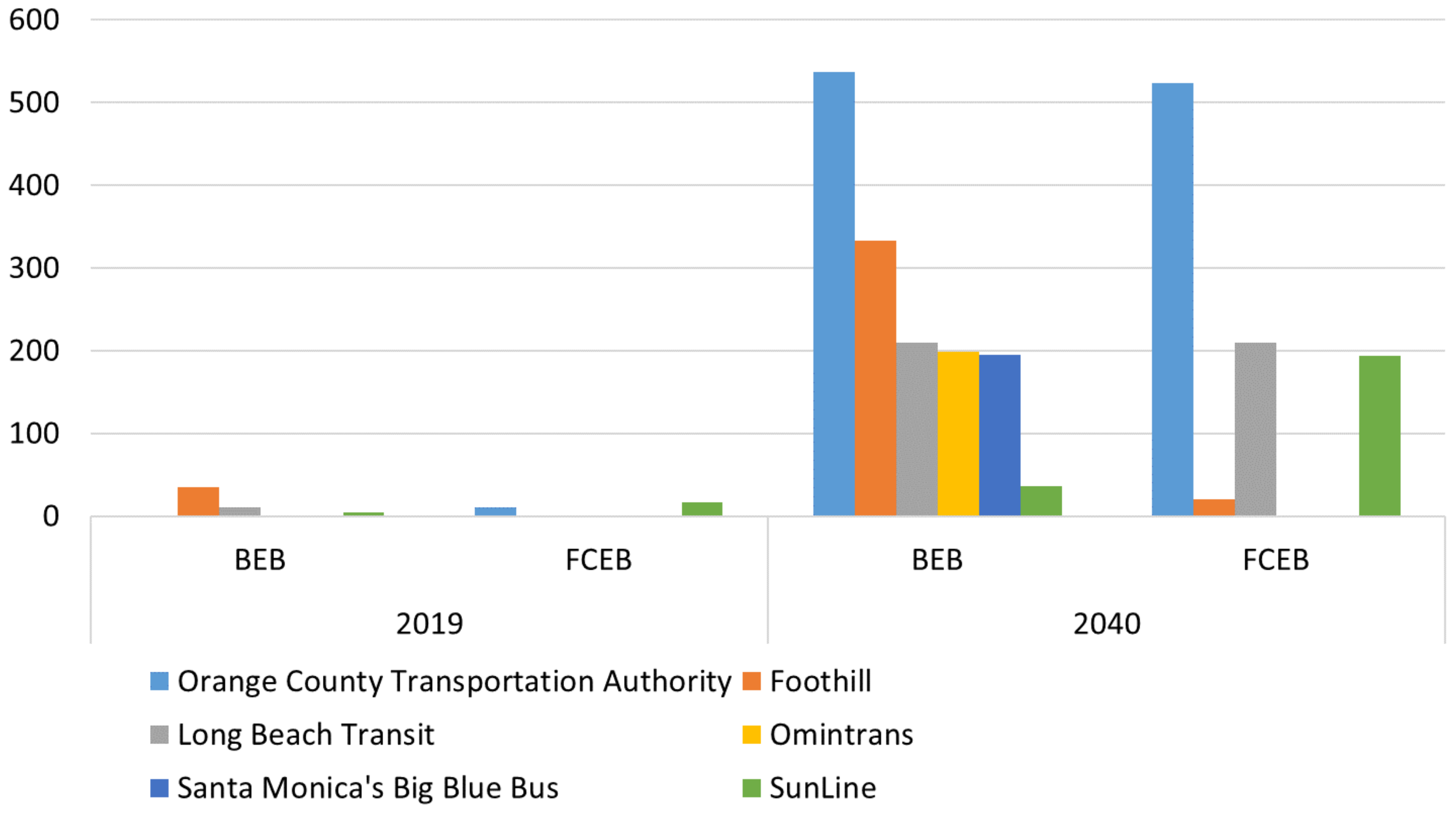


Transit Agencies Transition to ZEBs

Source : CARB ICT Transit Agencies Plan Rollouts Data (Draft) - 2020

Local Transit Agencies Plan

- Deploying Fleet of Battery Electric and Fuel Cell Buses



Fuel Cell Transit Bus Projects

<u>Ongoing Project</u>

Deployment of 20 Fuel Cell Buses at OCTA and AC Transit Agencies ($45.5 M)

Funding Source - CARB (GGRF), OCTA, AC Transit, Bay AQMD, and South Coast AQMD

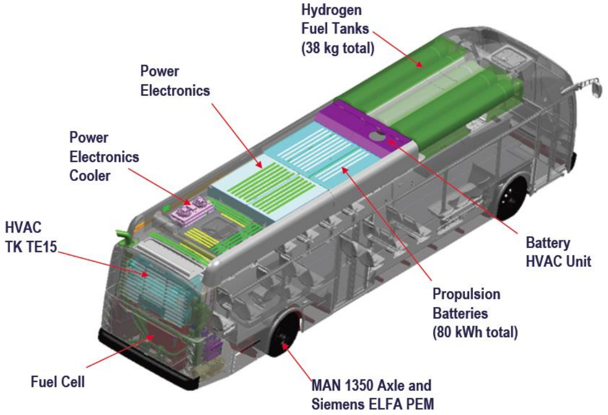
<u>Upcoming Project</u>

Deployment of 5 Fuel Cell Buses at Sunline Transit Agency ($6.9 M)

Funding Source - EPA (Targeted Airshed Grant), South Coast AQMD, and Sunline

New Flyer Xcelsior XHE40
40’ Transit Bus powered by Ballard Fuel Cell

New Flyer	
PROPULSION SYSTEM	Siemens - E-Drive All Electric Propulsion System Includes PEM 1DB2016, 160 KW Traction Drive Motor, Inverters, E-drive Controls and related components
FUEL CELL RANGE EXTENDER	Ballard FCveloCity HD85 – 85 kW
FUEL SYSTEM	H2 – 5 Hexagon Lincoln ACF tanks - total capacity of 37.5 kg
RANGE	Up to 350 miles
BATTERY ENERGY STORAGE	80 kWh battery pack Li-FePo4
SERVICE LIFE TIME	>25,000 miles



OCTA

- 10 New Flyer fuel cell buses in operation
  - 85 kW Ballard fuel cell and 80 kWh Li-FePO4 batteries
  - Each bus uses 37.5 kg/day to provide up to 350 miles range
- OCTA hydrogen fueling station
  - Developed by Trillium and Air Products Liquid Hydrogen Delivery
  - 1600 kg/day @ 350 bar
  - Capacity for fueling 40-50 fuel cell buses
  - Fueling time 6 – 10 minutes per bus
  - 280 kg peak back to back fills

OCTA Fuel Cell Buses/Station Project Status

Buses

- 10 buses successfully completed 40-hour testing – January 2020
- 9 buses were operating and in service – February 2020
- 9 buses in service and 1 bus out of service due to tank solenoid being replaced – Sept 2020
- Data collection – Started Feb 2020 - ongoing

Station

- OCTA Station Commissioning is complete – July 2020

Project Team is focusing on buses and station service to collect data

SunLine Transit Agency

- Existing fleet of 16 fuel cell and 4 battery electric buses
  - Operations in Coachella Valley area
  - Non-attainment area for Ozone/ Year 2 - Community Air Protection Program
  - Bus operation - 12 year lifetime
  - Additional 5 fuel cell buses to be delivered in Q4 2020
- Newly upgraded 900 kg/day hydrogen station
  - Capacity for fueling 30 buses
- South Coast AQMD - Awarded $5.9 M US EPA Targeted Air Shed Grant - deploy 5 additional fuel cell buses

Fuel Cell Bus Deployment Project

EPA, Sunline, and South Coast AQMD

Project Budget →

Total Project Cost	$6.9 M
EPA Targeted Airshed Grant	$5.9 M
South Coast AQMD	$205 K
Sunline Transit Agency	$806 K

New-Flyer delivers 5 buses in 2021

Procurement, delivery, and commissioning of the buses within a 3 year period

A minimum of 1 year of data collection

Clean Fuels Advisory Group Meeting
September 17, 2020

Hydrogen Infrastructure for Heavy-Duty Vehicles

Lisa Mirisola
Program Supervisor
Science and Technology Advancement
South Coast AQMD

CA Hydrogen Activities (2020 highlights so far)

CARB

- Innovative Clean Transit regulation – plan submittals
- Advanced Clean Truck regulation & Multi-state MOU
- Advanced Clean Fleet Omnibus regulation

CEC

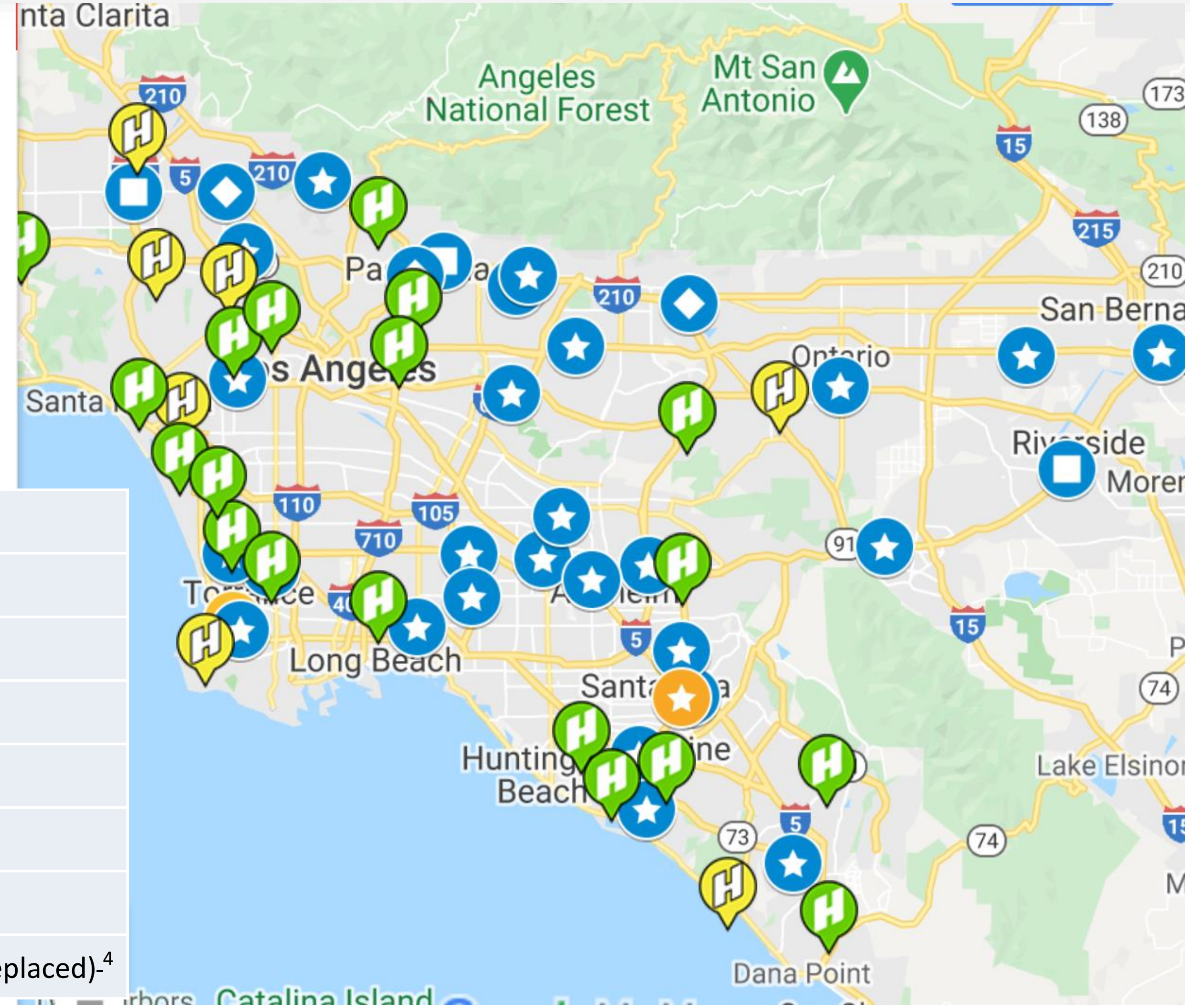
- GFO 19-602 Hydrogen Refueling Infrastructure NOPA issued 9/4/20
- Funded UCI Renewable Hydrogen Cost Study

CEC GFO-19-602 Hydrogen Refueling Infrastructure Notice of Proposed Awards – First Batch

First Element Fuel
Placentia, CA 92870
Orange, CA 92866
Baldwin Park, CA 91706
Costa Mesa, CA 92626
Aliso Viejo, CA 92656
Torrance, CA 90505
Ontario, CA 91762
Burbank, CA 91505
San Bernardino, CA 92408
El Cerrito, CA 94530
Buena Park, CA 90621
Glendale, CA 91214

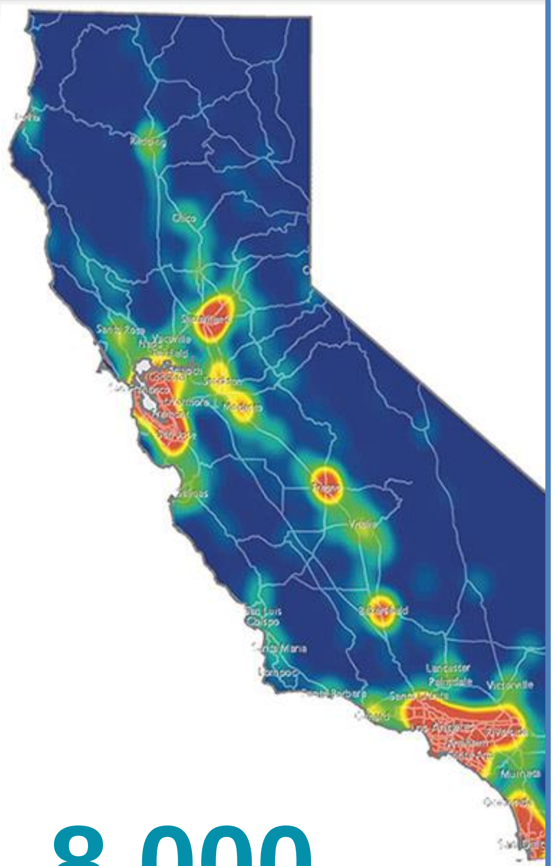
Equilon Enterprises (dba Shell)
Torrance, CA 90501
Newport Beach, CA 92660
Los Angeles, CA 90016
Long Beach, CA 90815
City of Industry, CA 90601
Artesia, CA 90701
Monrovia, CA 91016

Iwatani
Redondo Beach, CA 90278
Corona, CA 92882
Anaheim, CA 92801
Fontana, CA 92337
La Mirada, CA 90638
Hawaiian Gardens, CA 90716
~~Fadden Avenue, Santa Ana, CA 92705~~ (To be replaced)[4]



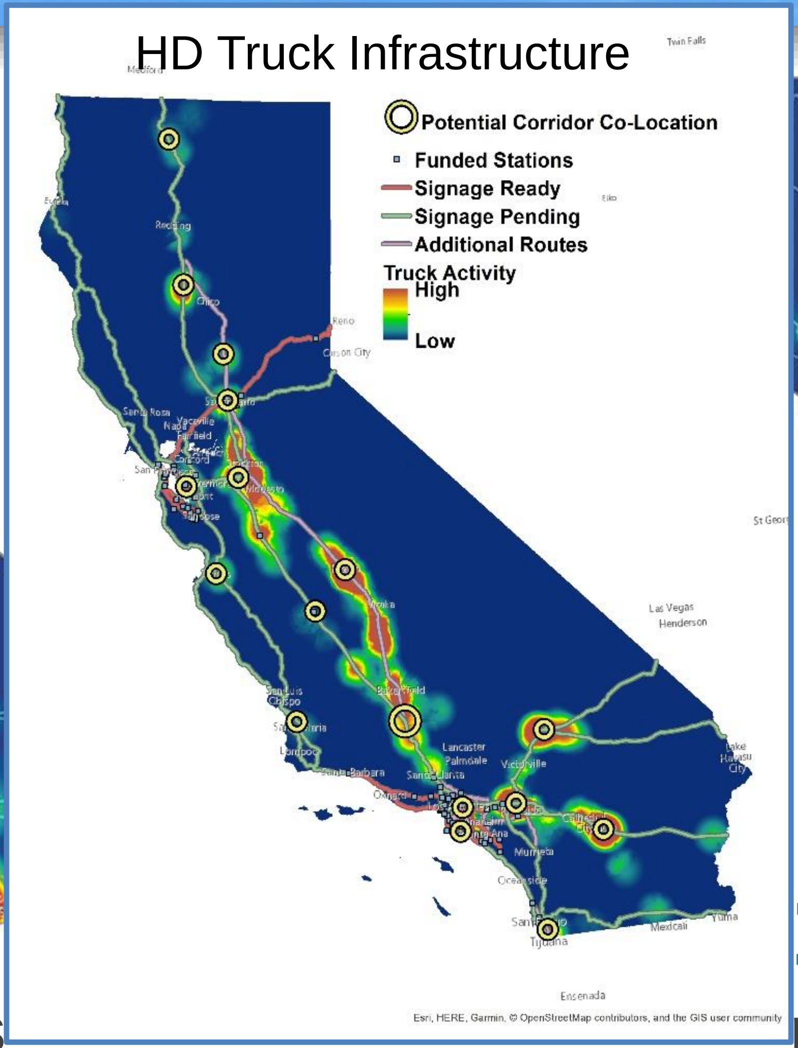
https://www.google.com/maps/d/viewer?mid=1KHY7KGJZQmRQUSA1dFD3w5T0GyFkoBqR&ll=38.986964544414725,-117.9587662698994&z=5

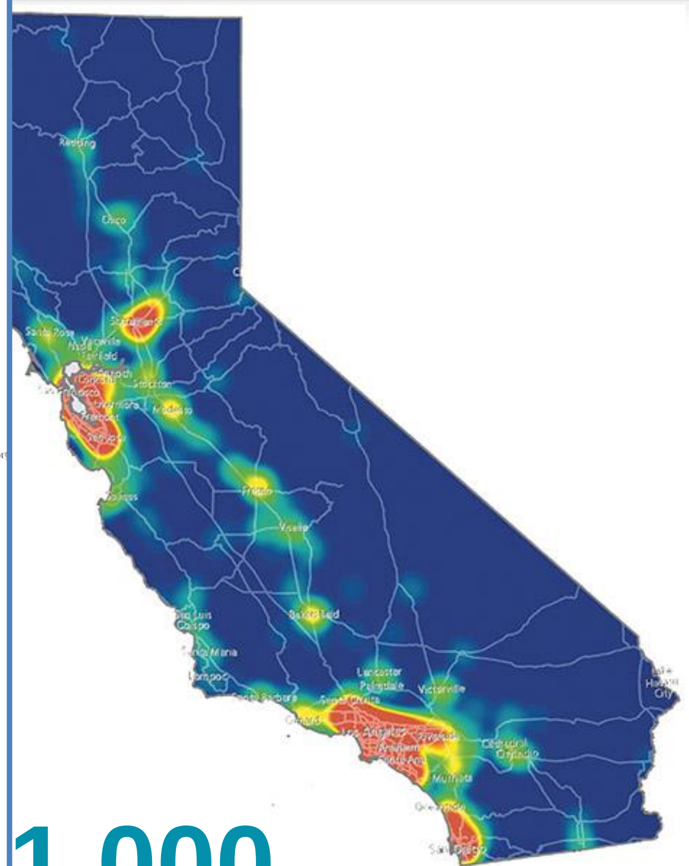
Image of a Successful Self-Sustaining Market



8,000

retail gas stations





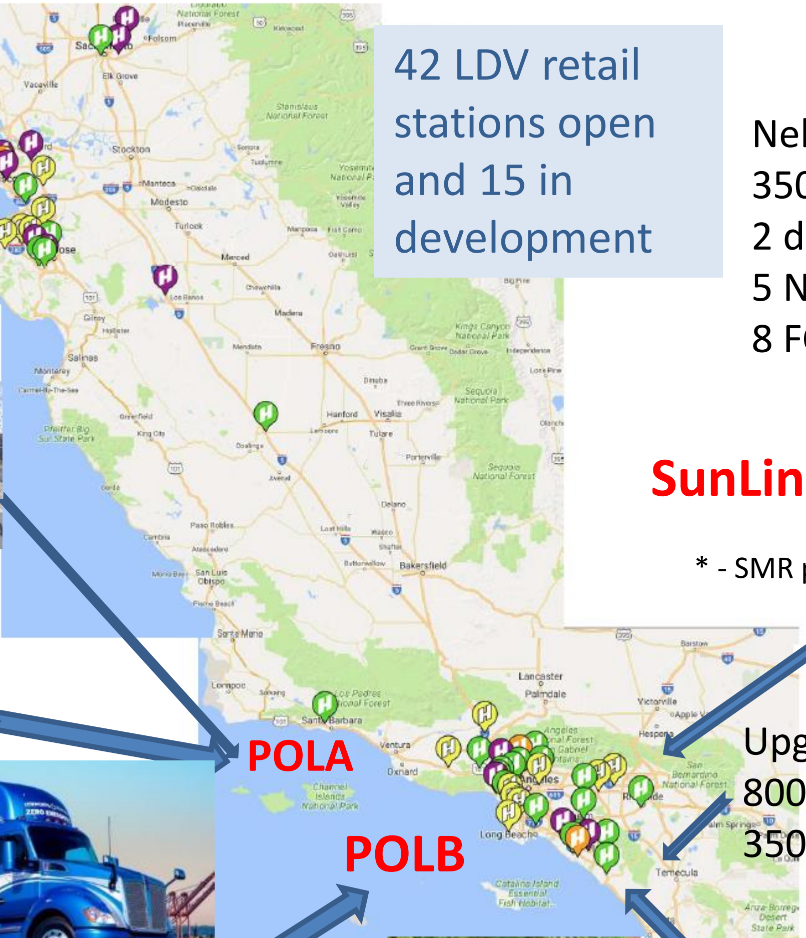
1,000

retail H2 stations

CA Hydrogen Stations

A.C. Transit

APCI Trailer
350 bar, 300 kg
10 fills/day



42 LDV retail stations open and 15 in development

Nel H2 - Proton
350 bar, 900 kg/day
2 dispensers
5 New Flyer-10 min fill
8 FCB now – 20 min fill

SunLine Transit*

* - SMR production for 10+ years

POLA ZANZEFF
Equilon (Wilmington & Ontario)
350 & 700 Bar
10 Kenworth Class 8 FC Trucks

POLA

POLB

UC Irvine

Upgrade to LH2 delivery
800 kg/day, 700 bar LD,
350 bar FC Bus (at night)

OCTA

Trillium, APCI LH2 delivery
350 bar, 1450 kg/day
10 New Flyer, 36 kg/bus,
6-10 min fill

CEC NOPA 17-603
Equilon, Toyota
350 & 700 bar, 1000 kg/day
2 dispensers, 10 Toyota CL8 FCT

(Photo: Toyota)

H2Freight Project

- 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 demonstrations by multiple operators
- Under construction
- Evaluate fueling protocols, dispenser design, station throughput/reliability, etc.

Zero Emissions Freight "Shore to Store"

- Contractor: POLA
- Total $82.5M
- Develop and demonstrate ten fuel cell trucks (Class 8 Kenworth T680 with Toyota fuel cells)
- H2 stations in Wilmington and Ontario (Shell Equilon)
- Revenue service by:
  United Parcel Services (3),
  Total Transportation Services Inc (2),
  Southern Counties Express (1),
  Toyota Logistics Services (4)

UC Irvine Hydrogen Station Expansion

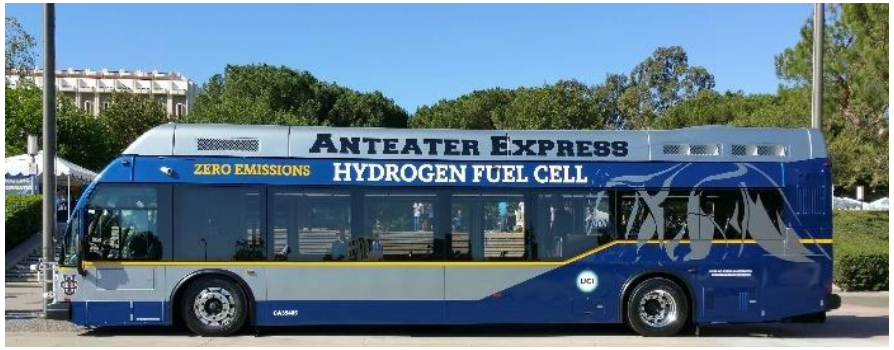
- UCI station has been operating at design capacity, needs additional capacity to fuel cars and buses.

- 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 Hydrogen Infrastructure Research Partnership

- U.S. DOE H2@Scale program with national labs, CA GO-Biz, CEC, SCAQMD, and CARB
- Joint agreement led by NREL to continue hydrogen infrastructure research efforts, focused on California near-term priorities
- Project Management Plan 2020 tasks
  - H2 Station Data Collection
  - Medium/Heavy Duty Fueling report
  - Hydrogen Contaminant Detection
  - Nozzle Freeze Lock
  - CA Hydrogen integration
  - Technical Assistance

[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

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

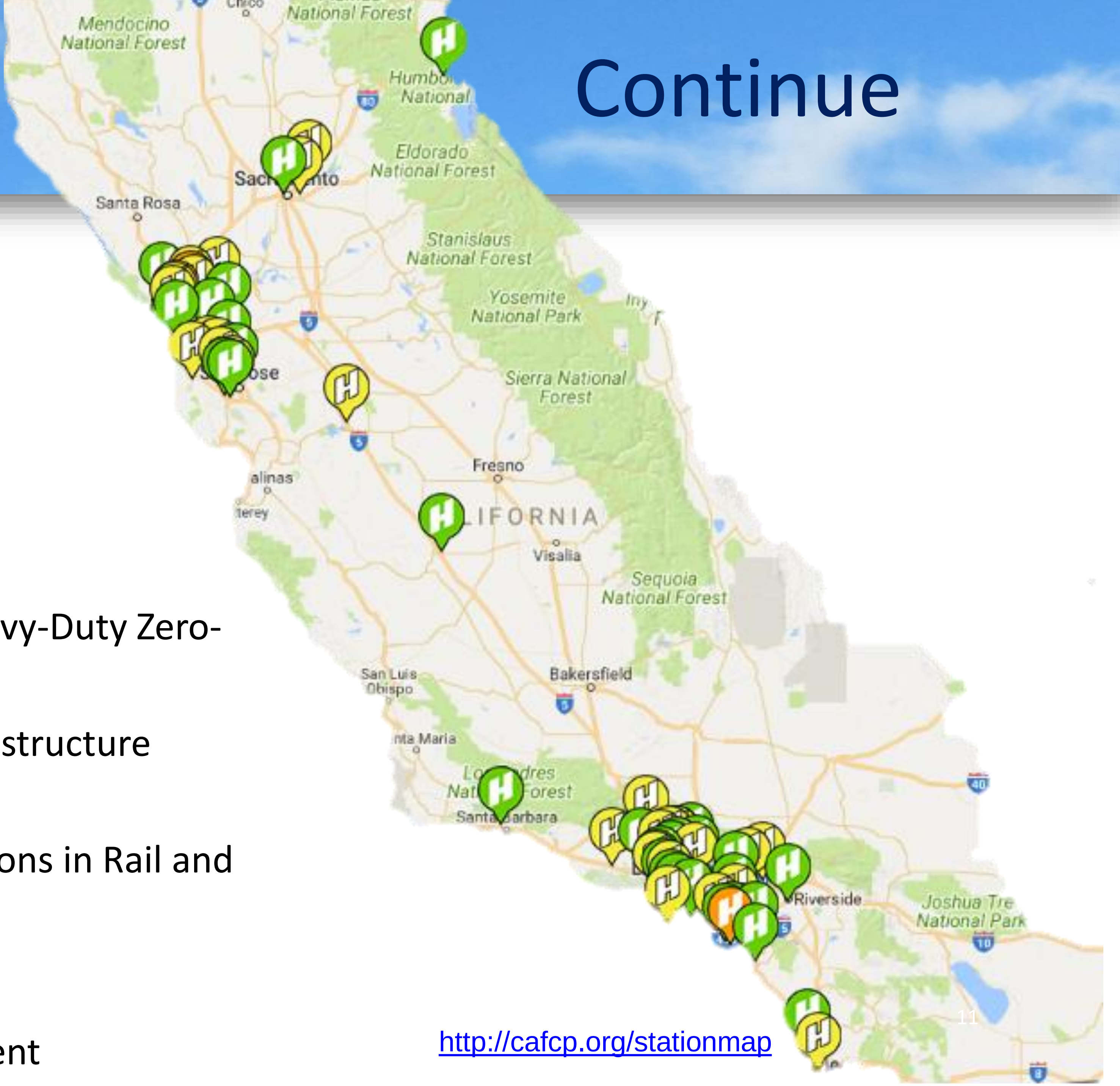
CA Activities Continue

- GoBiz
  Hydrogen Station Permitting Guide
  update & webinar

- CARB
  AB 8 report
  HySTEP evaluations

- CEC
  IEPR workshops
  GFO 20-601 - Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure
  Proposals due Nov 13, 2020
  GFO-20-602 - Zero-Emission Transit Fleet Infrastructure Deployment
  Proposals due Oct 2, 2020
  GFO-20-604 - Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports (H2RAM)
  Proposals due Oct 8, 2020

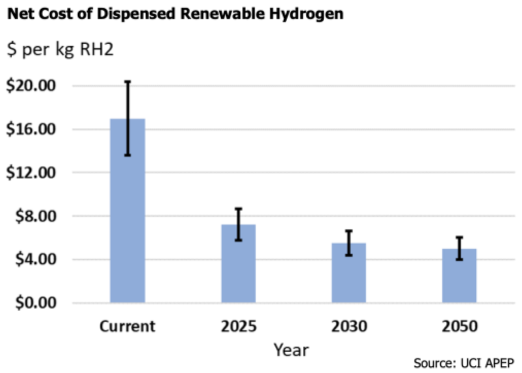
- CaFCP
  Holistic Heavy-Duty Truck Vision in development



http://cafcp.org/stationmap

Infrastructure Challenges

- Cost, funding & policy predictability
- Supply Chain:
  H2 Production, distribution, parts
  (need multiple suppliers) scale
- Skilled labor, workforce training
- CEQA/Permits
- Need higher capacity stations (OCTA operating & several funded), with refined HD fueling protocols to become "Recommended Practice"
- Short-term network fragility
- Site specific development & op issues



Where are near term opportunities?

- Large freight fleets that are already familiar with fc forklifts
- Larger transit agencies
- Smart grid integrated with hydrogen storage
- Holistic hydrogen modeling study building on recent UCI renewable hydrogen cost study
- US DOE H2@Scale CRADA call proposal participant

- Ideas?