CLEAN FUELS PROGRAM ADVISORY GROUP AGENDA
FEBRUARY 6, 2020, 9:00 AM – 3:30 PM
South Coast AQMD
21865 Copley Drive
Diamond Bar, CA 91765
Conference Room GB

Members of the public may address this body concerning any agenda item before or during consideration of that item (Gov't. Code Section 54854.3(a)). Please provide a Request to Address the Committee card to the Committee Secretary if you wish to address the Committee on an agenda item. If no cards are available, please notify South Coast AQMD staff or a Board Member of your desire to speak. 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	Naveen Berry, Assistant Deputy Executive Officer
(b)	Incentives	Vicki White, Manager, Implementation Group
(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)	In Use Testing Project	Sam Cao, PhD, Air Quality Specialist
(b)	Near-zero Engine Technologies Projects	Joseph Lopat, Program Supervisor
(c)	Zero Technologies – Volvo LIGHTS Project	Patricia Kwon, Program Supervisor
(d)	Zero Technologies – Daimler Truck Project	Phil Barroca, Program Supervisor
(e)	Zero Technologies – ZECT 2 Projects	Seungbum Ha, PhD, Air Quality Specialist
(f)	Zero Technologies – Blue Bird Projects	Mei Wang, Program Supervisor
Feedback and Discussion		All
	Lunch 12:00 PM – 1:00 PM	
2.	**EV and H2 Infrastructure to Support Fleets – 1:00 PM – 2:30 PM**	
(a)	Hydrogen Infrastructure for Heavy Duty Vehicles	Lisa Mirisola, Program Supervisor
(b)	EV Infrastructure & Microgrids for Heavy Duty Vehicle Deployment	Seungbum Ha, PhD, Air Quality Specialist
(c)	SCE Update on Charge Ready Transport	Justin Bardin, Senior Project Manager, SCE

3.	Wrap-up – 3:00 PM – 3:30 PM	
(a)	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.

Incentive Programs Update

Vicki White
Technology Implementation Manager

Main Incentive Programs

Carl Moyer Program

- Trucks
- Transit buses
- Refuse trucks
- Public agency/utility vehicles
- Emergency vehicles
- Construction/Ag
- Marine Vessels
- Shore Power
- Locomotives
- Cargo Handling
- Infrastructure

- **1998 – Present**
- **$530 Million**
- **7,977 vehicles**
- **Emissions Reduced (tpy): NOx: 8,600 PM: 248**

Prop 1B

- Trucks
- Shore Power
- Locomotives
- Cargo Handling
- TRUs

- **2009 - Present**
- **$479 Million**
- **7,314 vehicles/equipment**
- **Emissions Reduced (tpy): NOx: 7,214 PM: 220**

Replace Your Ride

- Light-Duty Vehicles
- Alternative Mobility Options (transit passes, car sharing)
- Electric vehicle chargers

- **2015 - Present**
- **$46 Million**
- **5,900 vehicles**
- **Emissions Reduced (tpy): NOx: 27 HC: 6.4**

Lower Emission School Bus Program

- School buses
- Infrastructure
- CNG tank replacements

- **2001 - Present**
- **$325 Million**
- **5,200 vehicles**
- **Emissions Reduced (tpy): NOx: 234 PM: 25**

Incentive Project Types

South Coast
AQMD

2019 Progress

Community Air Protection Program (CAPP) Incentives

- 21 contracts executed for $12 million
- 71 new on- and off-road engines
- 36 tpy NOx, 2.4 tpy PM
- At least 80% in disadvantaged and low-income communities

Carl Moyer Program

- 35 contracts executed for $22 million
- $16.6 million expended for 103 new on- and off-road engines
- 122 tpy NOx, 5.9 tpy PM

On-Road Heavy-Duty Vehicles Voucher Incentive Program

- Designed for small fleets of 10 trucks and less
- $4.2 million expended for 100 truck replacements
- 69 tpy NOx, 0.5 tpy PM

2019 Progress (cont'd)

Proposition 1B – Goods Movement Emission Reduction Program

- 10 contracts executed for $6.6 million
- $10.1 million expended for replacement of 118 trucks
- 140 tpy NOx, 0.5 tpy PM

Lower Emission School Bus Program

- 16 grants amended for an additional $3.2 million
- Replacement of 82 older diesel buses with new, near-zero and zero emission buses

Electric School Bus Program

- $3.2 million expended for 14 electric school buses
- As of January 2019, 28 out of 29 electric school buses are delivered
- South Coast AQMD's funds leveraged with CARB's HVIP funds

South Coast AQMD

2019 Progress (cont'd)

Enhanced Fleet Modernization Program (Replace Your Ride)

- $17.9 million expended for replacement of 2,191 passenger vehicles
- 94% of participants located in disadvantaged communities

Volkswagen Environmental Mitigation Program

- Executed Project Agreement with CARB
- Finalized administrative budget for 10-yr program
- Finalized Implementation Manual
- Launched website and developed 1st phase of Grant Management System
- Released 1st solicitation for Combustion Freight and Marine Projects

Incentive Funding in 2019

Program Title	Description	Funding Amount
Community Air Protection Program (CAPP) Incentives	Approved by Governor as part of state budget each year. Funds projects that reduce emissions in disadvantaged and low-income communities. Supports the goals of AB 617.	Year 2 (SB 856) - $85.57 million Status: 85% of funds awarded to qualifying projects, 15% remaining for stationary source and other community-identified projects.
Carl Moyer Program	Provides incentives to owners to purchase cleaner-than-required vehicles/equipment, including infrastructure for zero and near-zero emissions vehicles.	$30.5 million (+ $4.6 million in local match) Status: Increased funding from AB 1274, all funds awarded in December 2019, begin contracting in Qtr 1 2020.
CEC Grant for Near Zero Emission, Natural Gas Drayage Trucks	Accelerate deployment of near zero emission, natural gas trucks that service the Ports	$8 million (+ $6 million in cost-share from South Coast AQMD, POLB and POLA) Status: All funds awarded for 140 trucks, 22 trucks paid, CEC approved 1-yr extension of grant term (ending 6/15/21).
Enhanced Fleet Modernization Program (Replace Your Ride)	Funds for EFMP allocated by CARB each year. Provides vouchers to low and moderate income motorists to scrap and replace older vehicles with cleaner models.	$13.4 million Status: Executed grant agreements with CARB, received 1st installment ($6 million), spent funds in 4 months, requested 2nd disbursement ($5.4 million).

Incentive Funding in 2019

Program Title	Description	Funding Amount
Voluntary NOx Remediation Measure Funding	Funds mobile source projects that will reduce NOx emissions to mitigate NOx emissions increase from biodiesel use.	~$2.67 million Status: Executed MOA with CARB in 2/2019, one large project fell through, reallocated funds to another project.
EPA Targeted Air Shed Program Grant – Lawn and Garden Equipment	Funds zero emission, electric lawn and garden equipment for commercial use in environmental justice areas	~$2.47 million (with local match of $628k) Status: Program launched in January 2019, 6 manufacturers, 70 distribution centers, program modified from 50% to 75% discount.
Lower Emission School Bus Program	Fund the replacement of older, high-polluting school buses with near-zero emission school buses	~$35.6 million total (incl. $32.5 million from SCAQMD and $3.1 million from EPA) Status: Executed grants for 206 buses, paid out $22.8 million for 141 buses.
FARMER Program	Fund the replacement of agricultural equipment using the Carl Moyer Program Guidelines	~$1.84 million Status: Projects awarded in December 2019, contracts in progress
Volkswagen Environmental Mitigation Program	Intended to mitigate the excess NOx emissions caused by VW actions.	$165 million to South Coast AQMD (10-yrs) Status: Release solicitation for Combustion Freight and Marine Projects (closing 3/4/20).
	Total:	>$218 million

Summary of Awards – Near Zero and Zero Emission Trucks

Program	NZ Emission (0.02 g/bhp-hr)	Funding	Zero Emission	Funding
CAPP	445	$24,140,396	3	$600,000
Moyer *	10	$400,000	0	$0
Prop 1B	625	$61,245,000	86	$17,100,000
Total	**1,080**	**$85,785,396**	**89**	**$17,700,000**

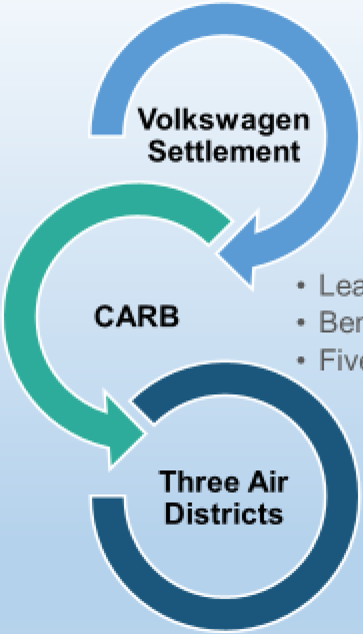
* Many applications received under Moyer for zero and near-zero emission trucks will be funded through CAPP.

Incentives Paid for Near Zero Emission Trucks*

Engine Displacement	# of Trucks	Funding
11.9 Liter	129	$12,854,647
8.9 Liter	142	$14,200,000
6.8 Liter	30	$1,415,464
Total	**301**	**$28,470,111**

* As of January 31, 2020

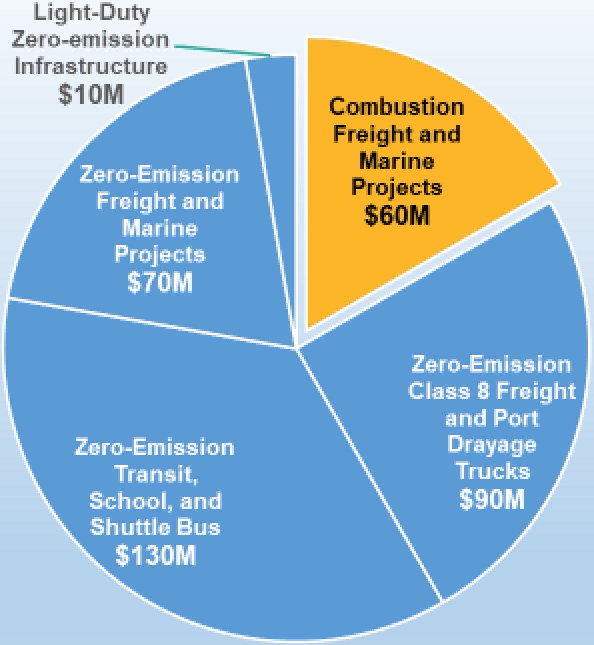
VW Mitigation Funds for California



- VW Mitigation Trust
- Consent Decree

- Lead Agency
- Beneficiary Mitigation Plan
- Five Funding Categories

- Program Administrators
  - South Coast AQMD
  - San Joaquin Valley APCD
  - Bay Area AQMD



California VW Mitigation Trust

South Coast AQMD

VW Funds for Combustion Freight and Marine Projects

Equipment Type	Engine Year (to be replaced)	Replacement Technology	Project Type	Applicant Type	Maximum Percentage of Funding (of cost)	Maximum Funding Limit (per Engine/ Vehicle)
Class 7 & 8 Freight Trucks (including Waste Haulers, Dump Trucks, Concrete Mixers)	Non-Drayage: Engine Model Years 2005-2012 Drayage: Engine Model Years 2007-2012	Low NOx (certified at 0.02 g/bhp-hr)	Replacement	Non- Government	25% (or 50% for Class 8 port drayage)	$85,000
				Government	100%	
			Repower	Non- Government	40%	$35,000
				Government	100%	$50,000
Freight Switcher Locomotive	Pre-Tier 1	Tier 4	Replacement	Non- Government	25%	$1,350,000
				Government	100%	
			Repower	Non-Government	40%	
				Government	100%	
Ferry, Tugboat, Towboat	Pre-Tier 3	Tier 4, or Hybrid w/ Tier 4-equivalent NOx emissions	Repower	Non- Government	40%	$1,000,000
				Government	100%	

AB 74 (Budget Act of 2019)

- $275 million for Community Air Protection
  - Of these funds, $245 million for financial incentives
  - To reduce emissions from mobile and stationary sources in support of AB 617 community emissions reduction programs
- For 2020, Governor proposing $200 million for Community Air Protection, however air districts are working to secure higher funding levels for Community Air Protection

Questions/Contact Info

Questions:

Vicki White (909) 396-3436
vwhite@aqmd.gov

South Coast AQMD

South Coast
Air Quality
Management District

March 2020

Clean Fuels Program

2020 Draft Plan Update

Technology Advancement Office

Leading the way to zero and near-zero emission technologies

Background

2019 Annual Report and 2020 Plan Update

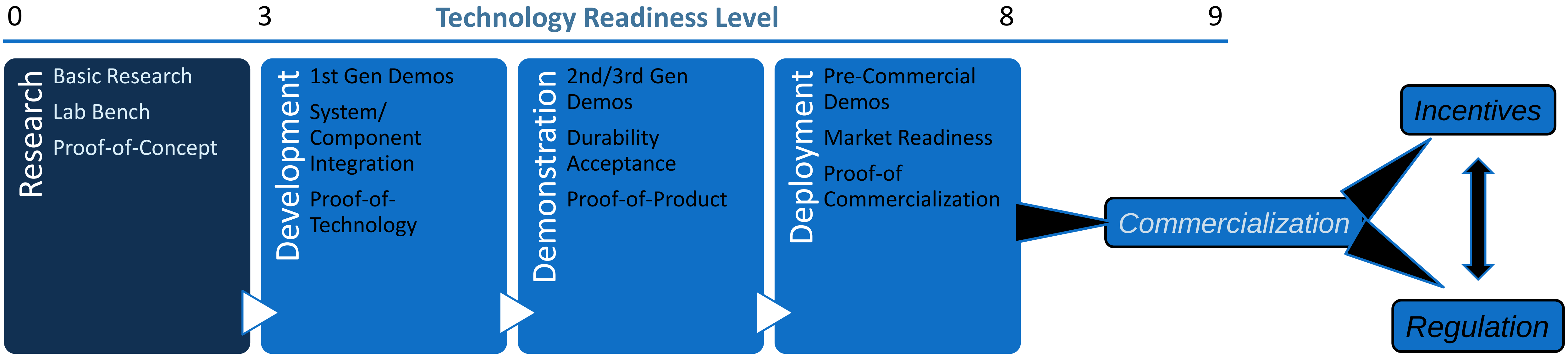
- Annual Report on Clean Fuels Program (HSC 40448.5.1)
- Technology Advancement Plan (Update) (HSC 40448.5)
- Draft 2020 Plan Update submitted to Technology Committee October 18, 2019
- Annual public hearing to approve Annual Report and adopt final Plan Update
- Submit to Legislature by March 31 every year

Input and Feedback

- Advisory group meetings
  - ➢ September 2019 and February 2020
  - ➢ Technology Advancement/Clean Fuels
  - ➢ Invited technical experts
- Meetings - agencies, industry groups, technology providers and other stakeholders
- Symposiums and conferences
  - ➢ CALSTART Symposium (March 2019)
  - ➢ ACT Expo (April 2019)
  - ➢ DOE Annual Merit Reviews (May & June 2019)

- Clean tech partnerships
  - ➢ VELOZ
  - ➢ California Fuel Cell Partnership
  - ➢ California Hydrogen Business Council

Clean Fuels Program - Overview



Clean Fuels Program-Core Technologies

- Hydrogen/Fuel Cell Technologies and Infrastructure
- Engine Systems/Technologies (ultra-low emission NG HDVs)
- Electric/Hybrid Technologies and Infrastructure
- Fueling Infrastructure and Deployment (NG/RNG)
- Stationary Clean Fuel Technologies
- Fuels/Emissions Studies
- Emission Control Technologies
- Health Impacts Studies
- Technology Assessment/Transfer and Outreach

2019 – Key Funding Partners

Total = $19.9M

Targeted Airshed – CATI - DERA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CALIFORNIA AIR RESOURCES BOARD

CALIFORNIA CLIMATE INVESTMENTS

THE PORT OF LOS ANGELES

Port of LONG BEACH The Green Port

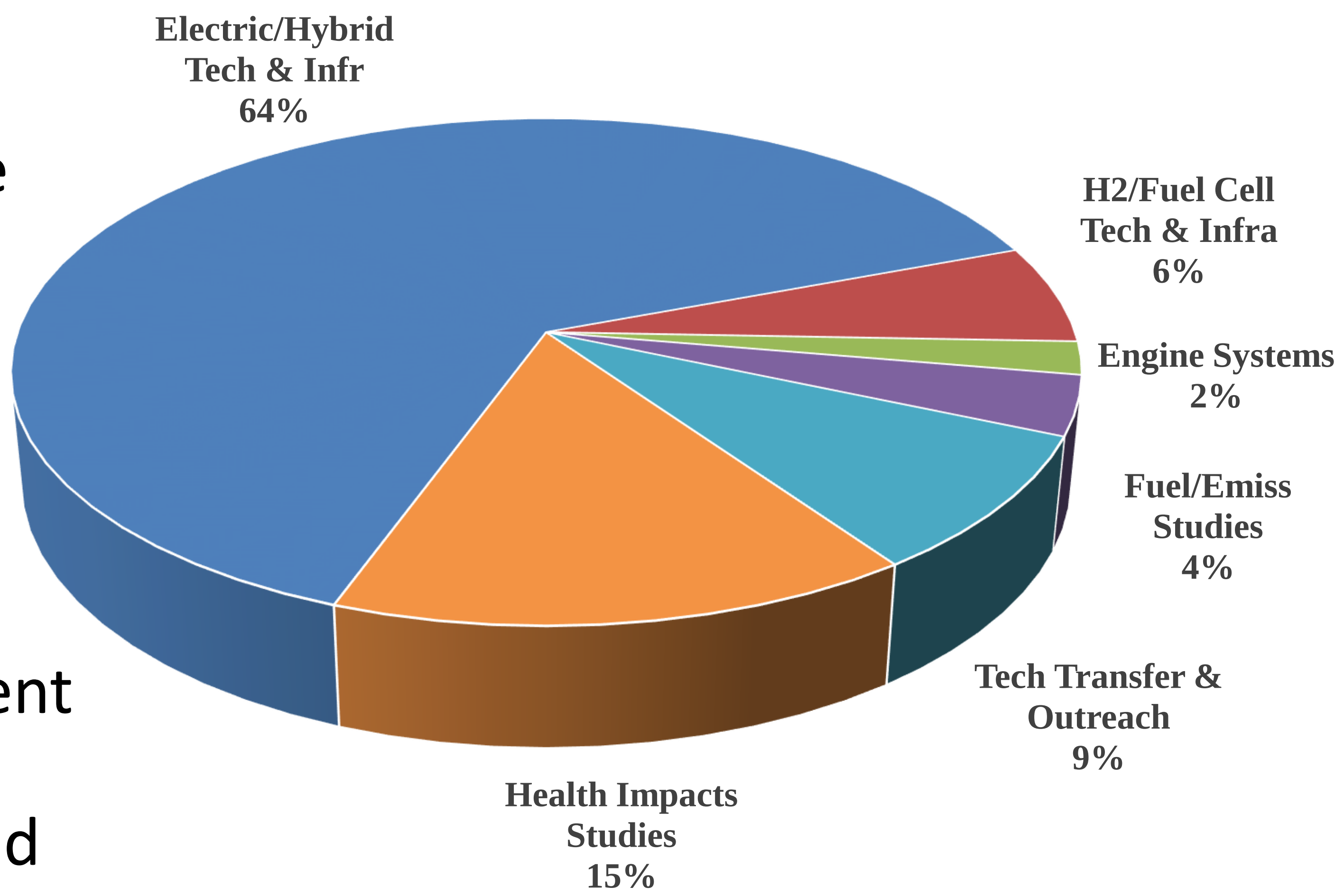
SoCalGas

A Sempra Energy utility

CY 2019 Accomplishments

- 72 contracts executed or modified adding dollars
  - ➢ $11.9M – total contract value
  - ➢ $3.1 revenue recognized
  - ➢ $134M – total project costs
  - ➢ $1:$14+ leveraging*
- 33 completed projects
  - ➢ 15 research, development, demonstration and deployment projects
  - ➢ 18 technology assessment and transfer/outreach projects

Distribution of Executed Contracts



Historical cost leveraging is $4 per every Clean Fuels $1

2019 Key Contracts Executed

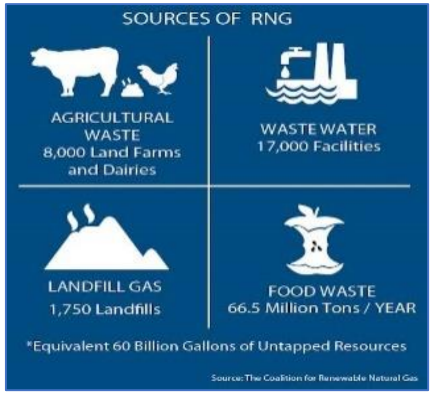

- Volvo LIGHTS
- Zero emission cargo handling vehicle demonstration
- Battery electric shuttle bus transportation
- Natural gas engine emissions and efficiency improvements
- Solid oxide fuel cell and gas turbine hybrid technology
- UCI hydrogen fueling station expansion
- UCR emission studies



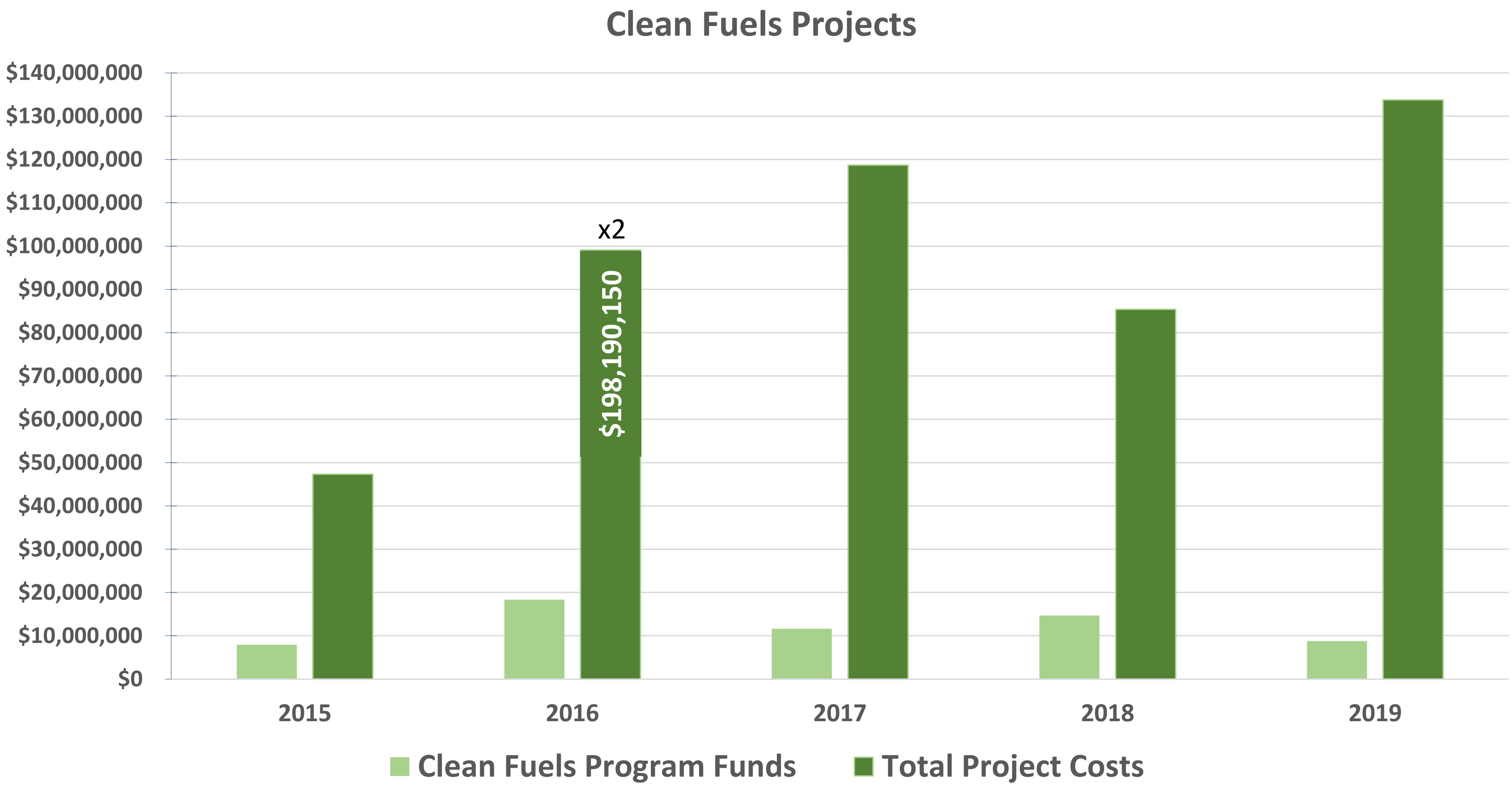

2019 Key Projects Completed

- Electric/hybrid technologies
  - Vehicle-to-grid technology development for school buses
  - Plug-in hybrid electric retrofit system Class 6-8 trucks
  - Electrification study for EJ communities

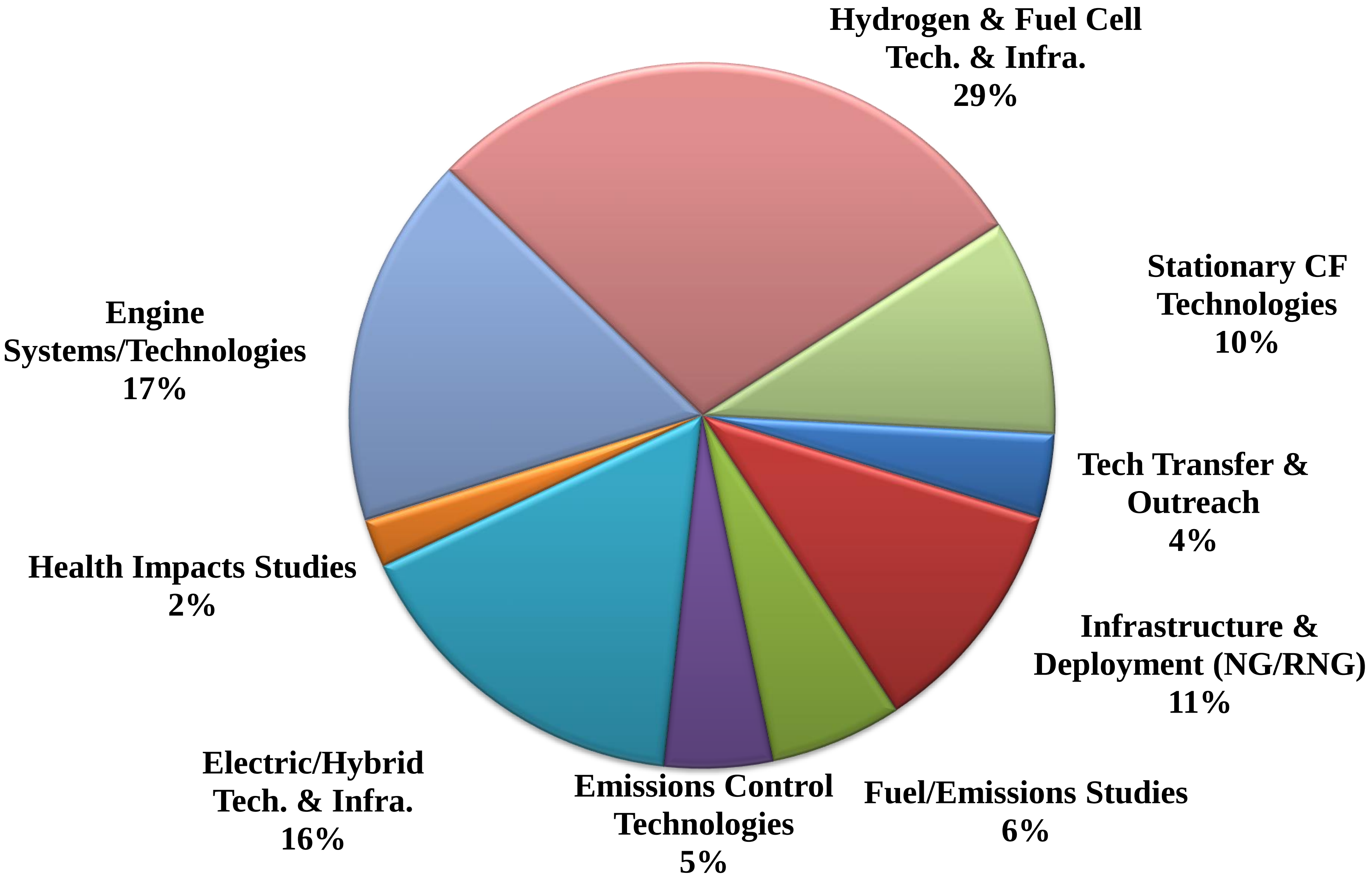
- Infrastructure & Deployment
  - Upgrade/expand NG stations including renewable natural gas
  - Support Renewable Natural Gas Center
- Emissions control technologies – develop aftertreatment systems for large diesel engines



Five-Year Snapshot of Clean Fuels Program Funding

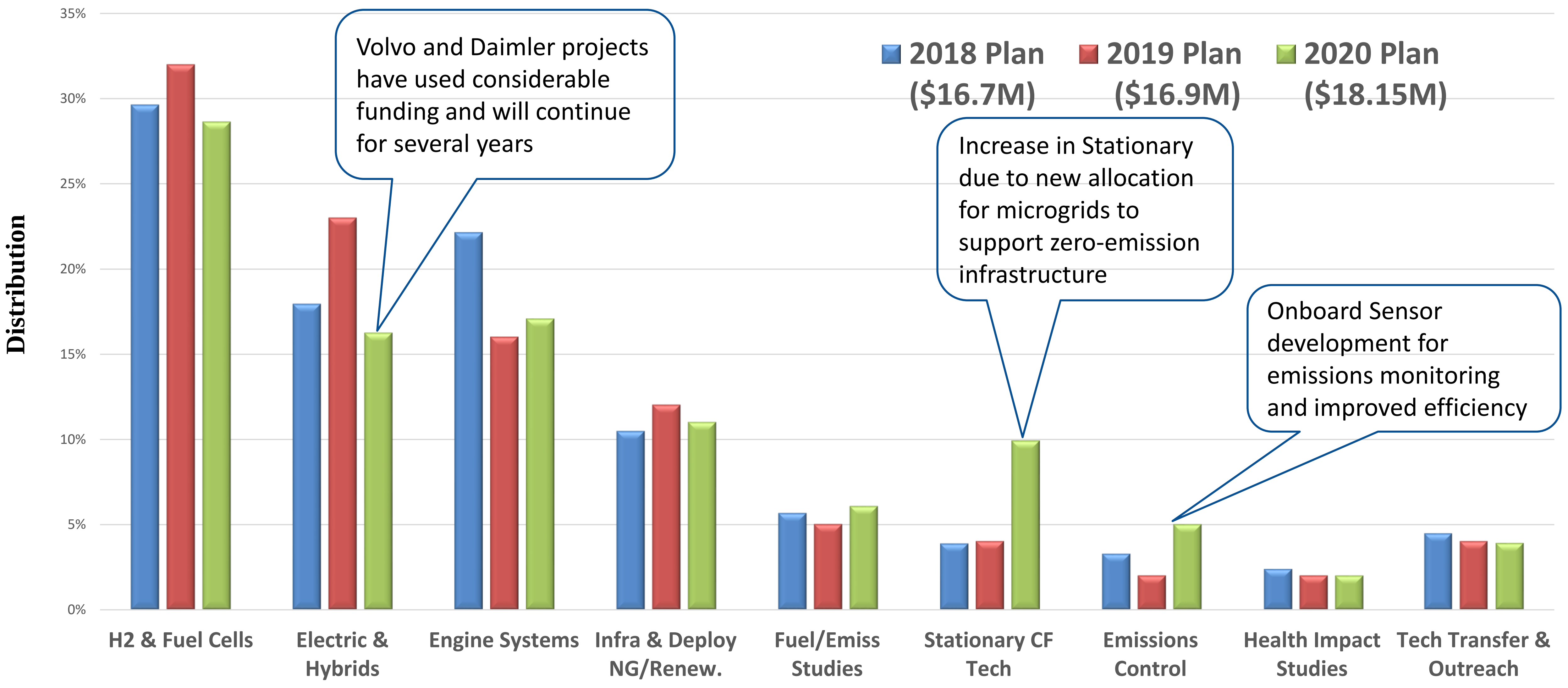


Proposed 2020 Plan Distribution



$18.15M

Plan Update Comparison



Proposed Distribution

	2019 Plan	Draft 2020 Plan
H2 & Fuel Cells & Infra	32%	29% ↓
Electric & Hybrids & Infra	23%	15% ↓
Engine Systems/Technologies	16%	↑ 18%
Infrastructure & Deployment (NG)	12%	11% ↓
Fuels & Emissions Studies	5%	↑ 6%
Stationary CF Tech	4%	↑ 10%
Emissions Control Technologies	2%	↑ 4%
Health Impacts Studies	2%	↑ 3%
Tech Transfer/Assessment & Outreach	4%	4%
	100%	100%

Development Schedule

➢ Technology Committee	October 18, 2019 (Draft 2020 Plan Update)
➢ Advisory Group Review	September 19, 2019 February 6, 2020
➢ Technology Committee	February 21, 2020
➢ Board Approval	March 6, 2020
➢ Due to State Legislature	March 31, 2020

Recommended Actions

Approve	Approve Clean Fuels Program 2019 Annual Report
Adopt	Adopt Clean Fuels Program Plan Update for 2020
Approve	Approve Resolution finding no duplicate projects or programs funded by other state/local agencies
Approve and adopt	Approve and adopt Clean Fuels Advisory Group membership changes
Receive and file	Receive and file Technology Advancement Advisory Group membership changes
Staff	Direct staff to forward documents to State Legislative Analyst by March 31, 2020

South Coast AQMD

200 Vehicle In-Use Emissions Testing Program

Clean Fuels Advisory Group | Sam Cao - Air Quality Specialist | February 6, 2020

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

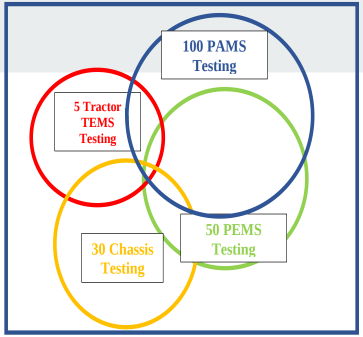
5

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

Technologies Covered

9

Propane (4), CNG 0.02 (28), CNG 0.2 (79), No SCR Diesel (10), Diesel 0.2 (72), Diesel-Hybrid (6), BEV (12), FCEV (2), HDPI (4)



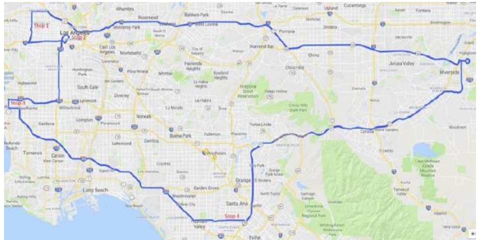
Experimental

1. **(200) PAMS** – ECM + telematics data logging for up to 4 weeks, fleet survey and maintenance/fuel records collection. Data to be used from new cycle development

2. **(100) PEMS testing** – one full-day operation, NTE analysis, ECM + telematics, regulated gaseous data only

3. **(60) Chassis** – Fully lab equipment, regulated and unregulated gaseous, PM, PN, toxic and metals analysis, subset of 8 chassis cycles depending on vocation, 4 new cycles developed from PAMS

4. **(10) On-road trailer testing** – Full lab equipment (same as chassis) on 4 real-world routes in SCAB (drayage, goods movement x2, grocery)



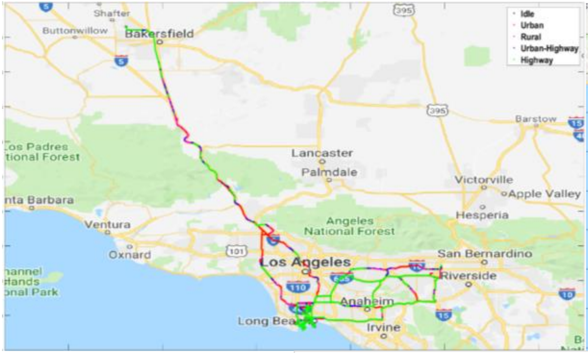
South Coast AQMD

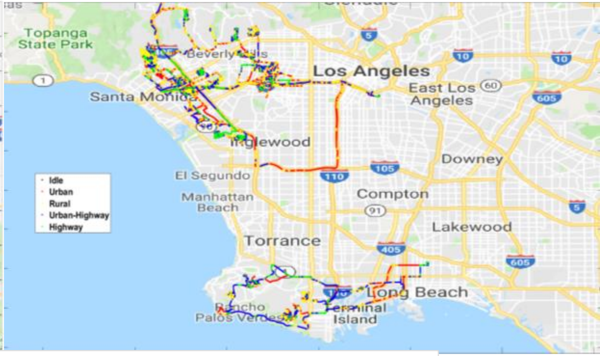
Testing Phase Update

Testing Phase	Assigned	Recruited	Completed
Portable Activity Monitoring System (PAMS)	200	219	206 (complete)
Portable Emissions Measurement System (PEMS)	100	100	94
Chassis Dynamometer	60	62	34
Real-World In-Use Trailer	10	10	5

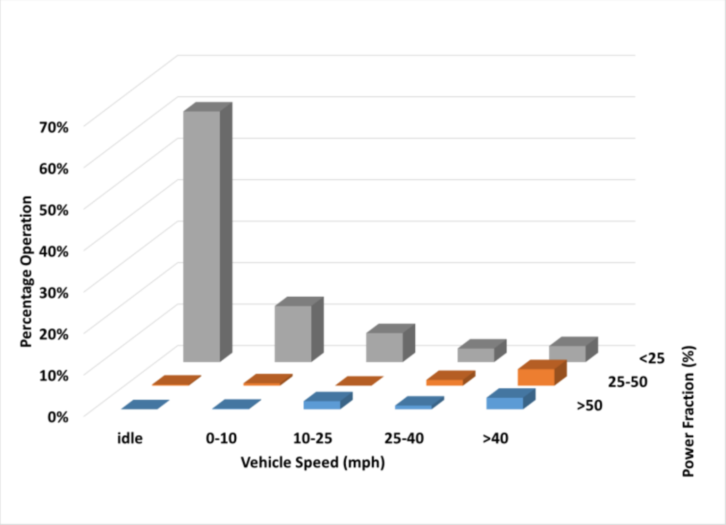
Testing Target Completion – May 2020

Preliminary Key Findings - PAMS



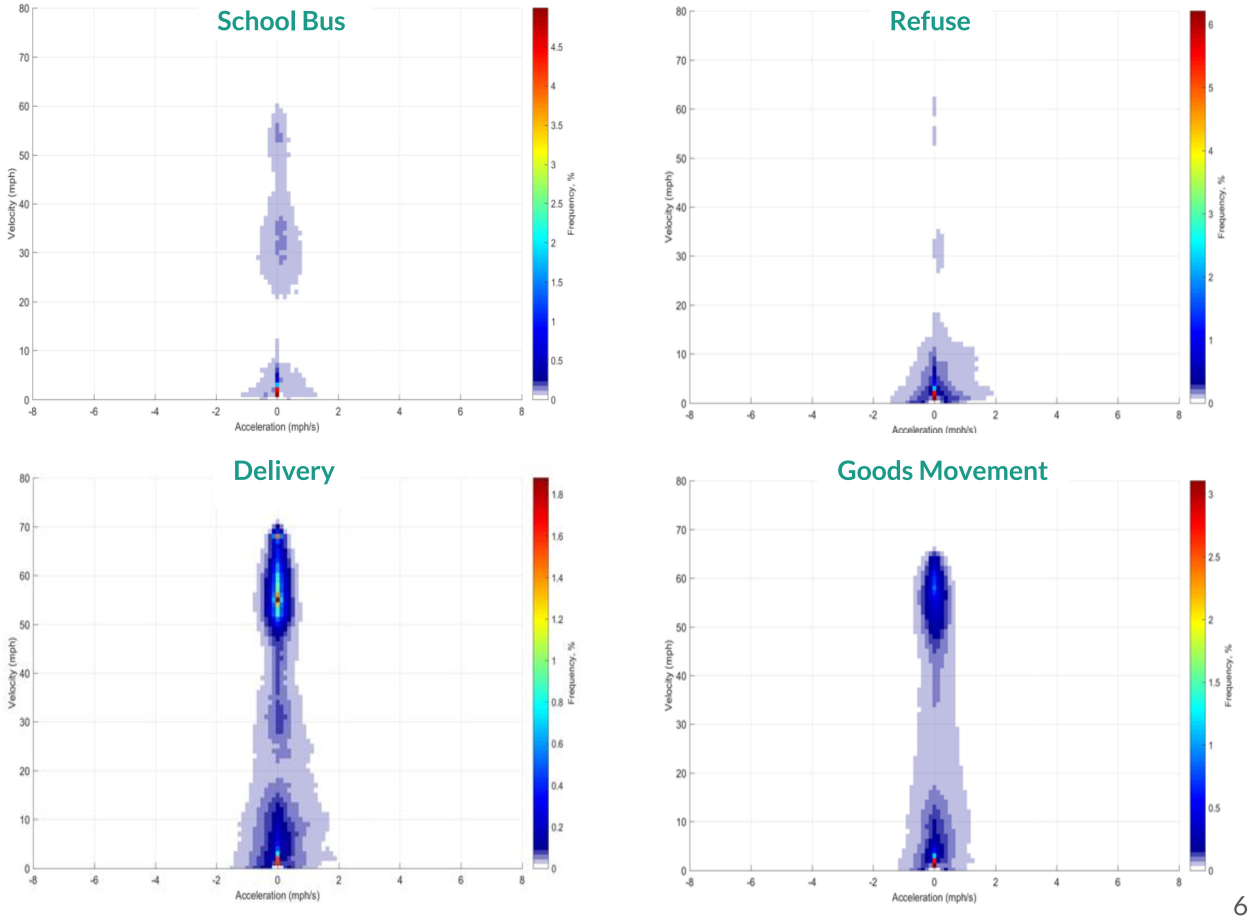


- Idle, low-speed, low power operation dominated the activity data set
- Higher vehicle speed for delivery and goods movement, transit and school buses lower, refuse lowest
- More detailed vocation specific analysis to be done in final report
- PAMS data submitted to CARB for additional analysis



Top: A real-world route and speed characteristics of goods movement trucks (left), refuse (right)
Bottom: Distribution of vehicle speed and power bins of CNG goods movement trucks (WVU)

Preliminary Key Findings - PAMS



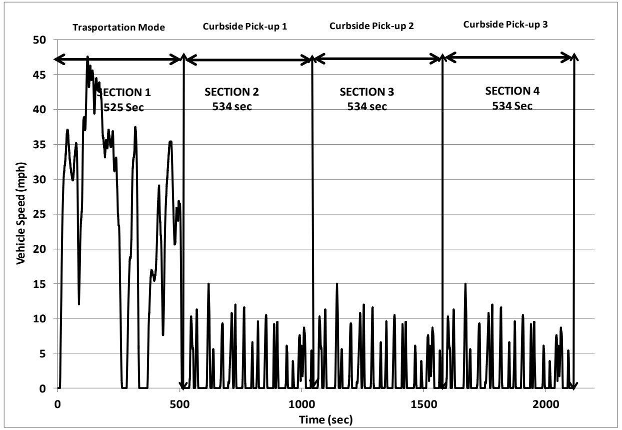
- Distinct speed profiles per vocation, as expected
- Idle time : 34-46% (UCR data set , more in WVU data set)
- Data used for new duty cycle development

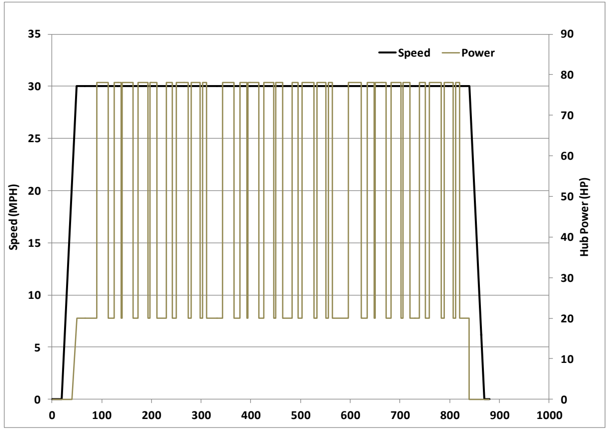
Source: UCR VMT data analysis

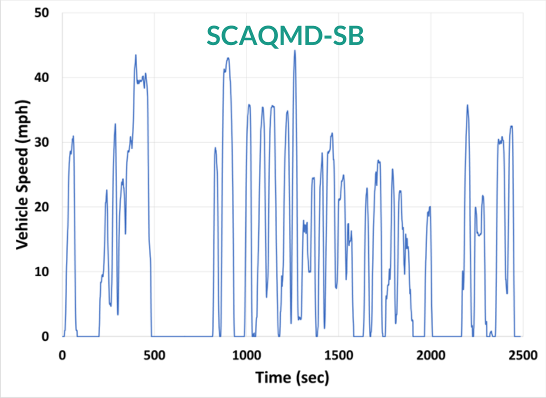
New Chassis Test Cycles Developed

- Standard cycles: UDDS, CARB HHDDT, CBD, OCTA
- New cycles derived from this study : Goods Movement Cycle, SCAQMD School Bus, Delivery, Modified SCAQMD refuse

Modified SCAQMD Refuse + Compaction Cycle for Hydraulic Load







Source: Final chassis test plan, submitted to SCAQMD

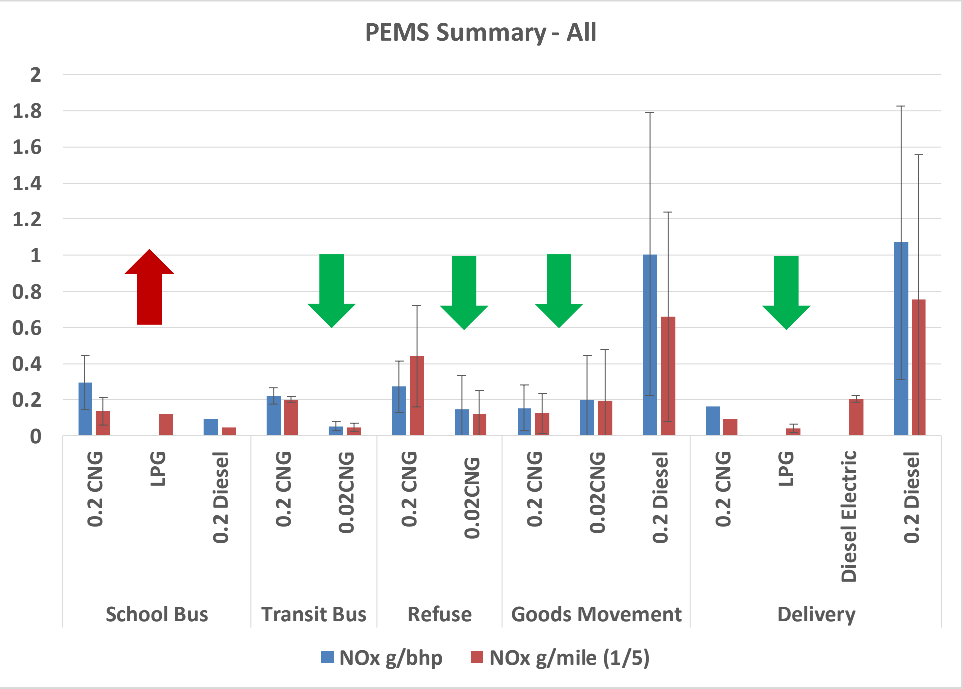
South Coast AQMD

Final Chassis Test Matrix

	Test Cycle	Vocation				
		Transit	School Bus	Refuse	Delivery	Goods Movement
	UDDS	X	X	X	X	X
	CARB HHDDT				X	X
new	Modified SCAQMD Refuse Cycle			X		
new	Port Drayage Cycle (Markov)/GMC					X
	CBD	X				
	OCTA	X				
new	South Coast School Bus (Markov)		X			
new	Delivery (Markov)				X	

Preliminary Findings – PEMS

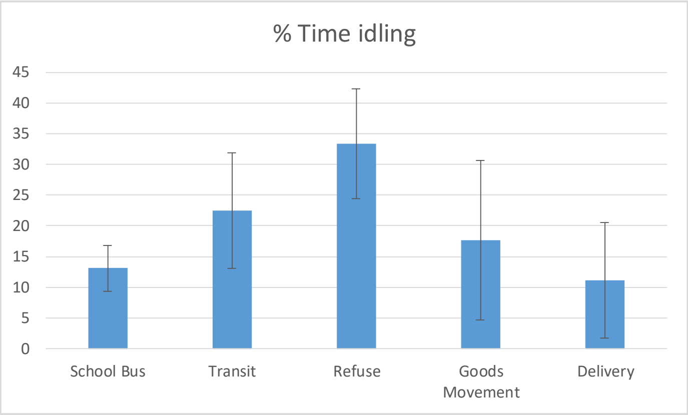
- One day of operation, gaseous only, ~ 50 vehicles
- NOx emissions vary greatly by technology and vocation but in general 0.02 CNG < 0.2 CNG /LPG < diesel 0.2
- Goods Movement and Delivery category highest emissions and variability suggest further break down and investigation
- CNGs across the board lower variability

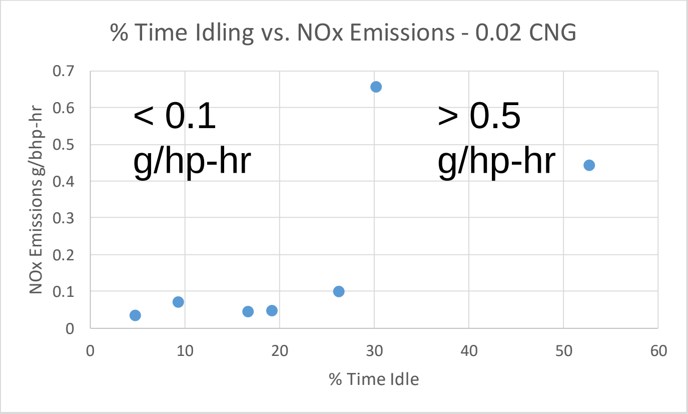


Source: UCR interim report to SCAQMD

Preliminary Findings – PEMS

- Idling (2%-50% observed) impacts in-use emission greatly, more investigation needed
- Traditional engine dyno certification cycles/chassis cycles does not reflect the low-load operation
- Key to compare PEMS data to chassis data

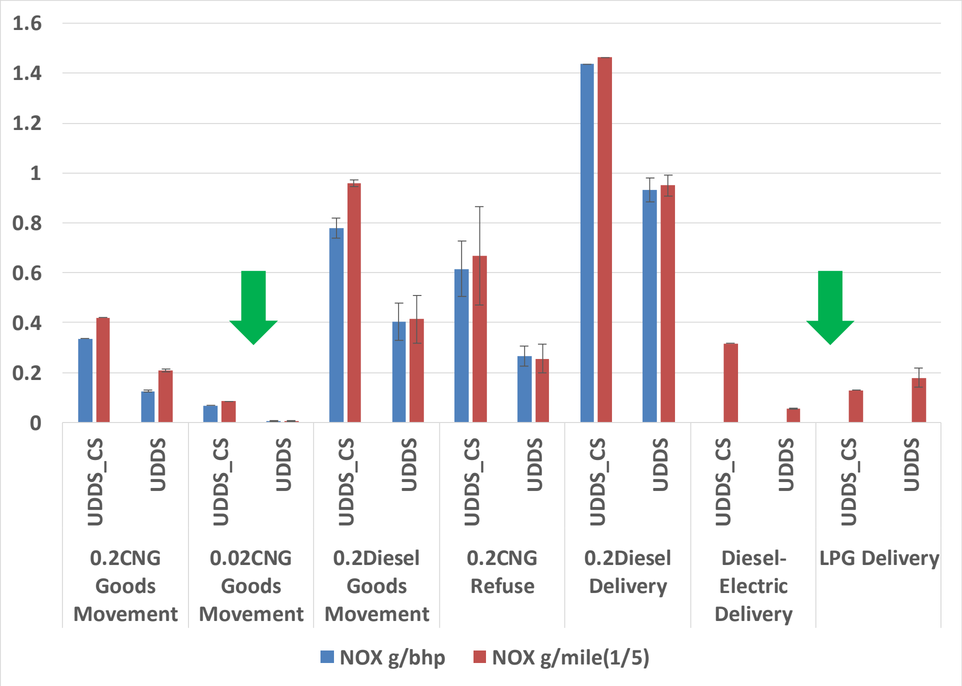




Source: UCR & WVU interim report to SCAQMD

Preliminary Findings – Chassis – All

- Limited data set, ~17 vehicles, pre-2010 diesel removed
- NOx emissions vary by vehicle vocation and technology
- CNG/LPG 76%-99% lower compare to 0.2 diesel baseline
- 0.02 CNG 98%+ lower than 0.2 CNG

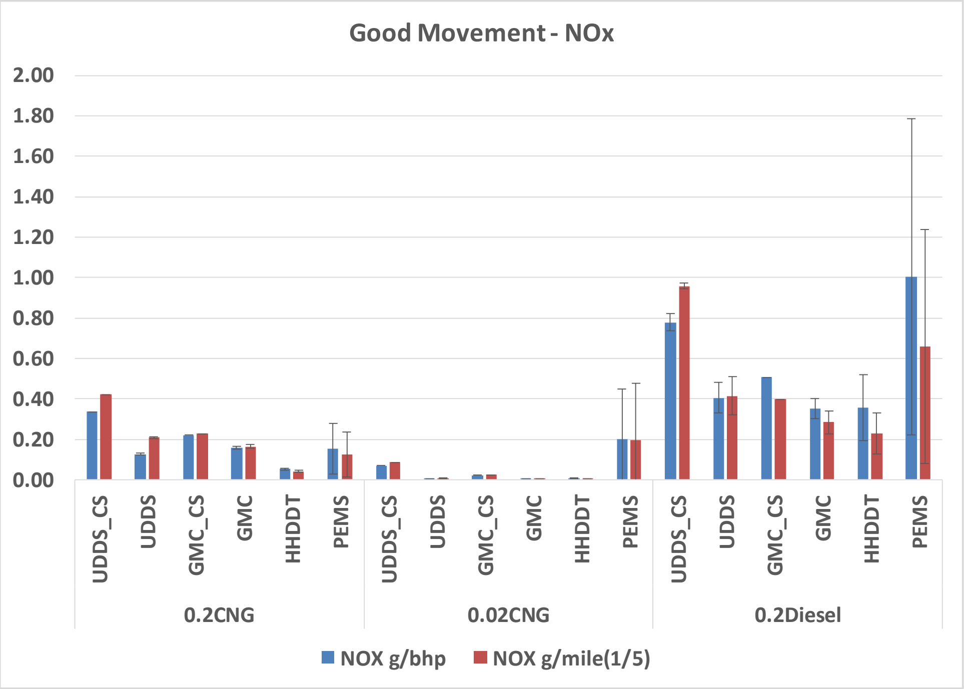


[1]Diesel-electric engine bhp-hr invalid (no powertrain work)
[2]LPG vehicle ECM data not available

Source: UCR&WVU interim report to SCAQMD

Preliminary Findings – Chassis - GM

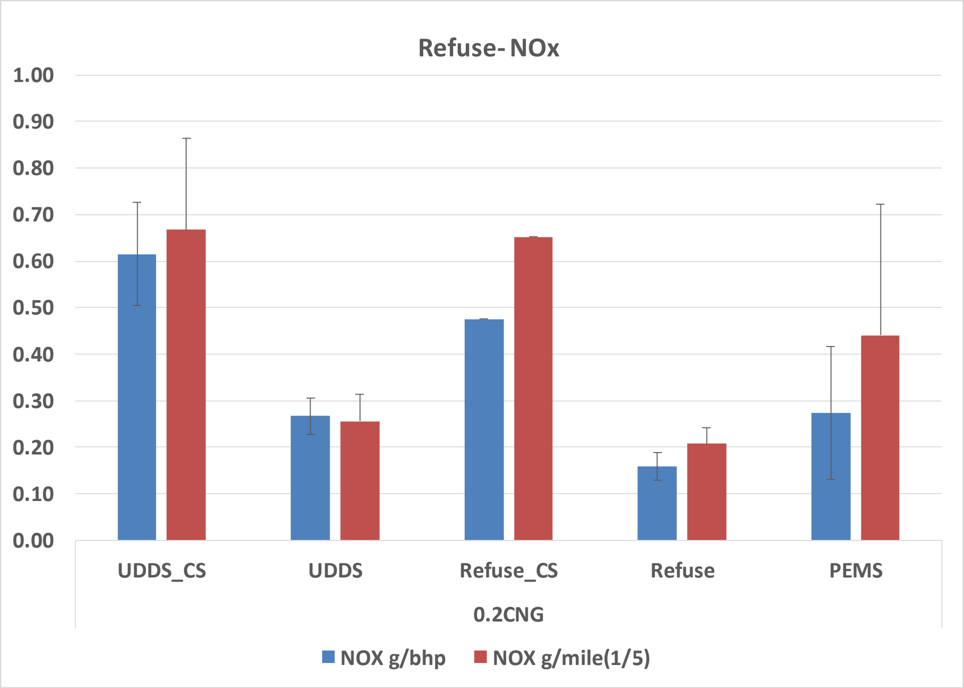
- Vocation specific chassis cycles more represented to true in-use emissions
- Chassis finding 0.02 CNG < 0.2 CNG < 0.2 Diesel
- PEMS finding suggest additional investigation needed



Source: UCR&WVU interim report to SCAQMD

Preliminary Findings – Chassis - Refuse

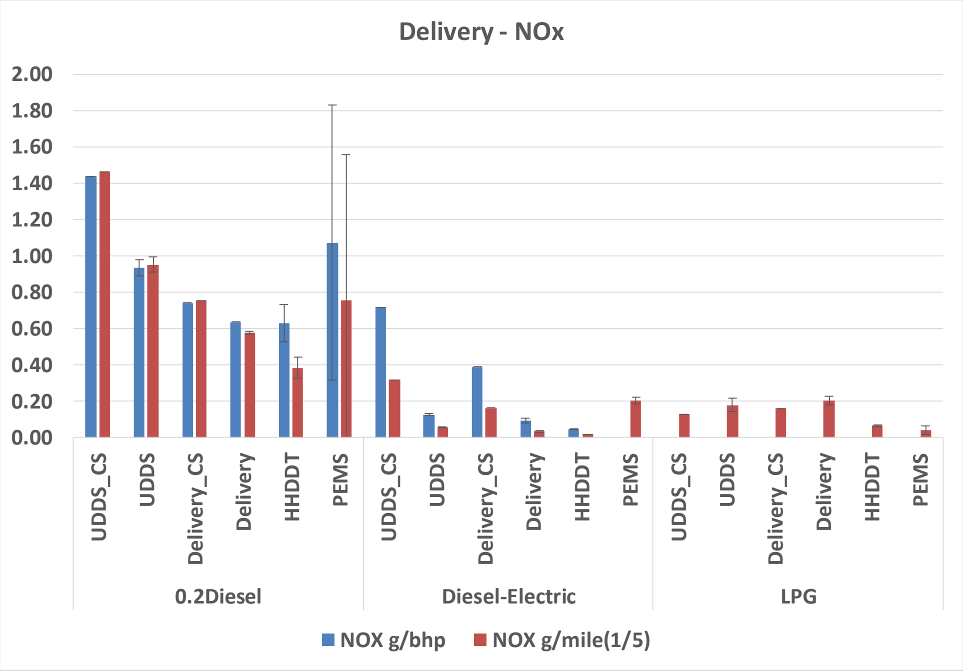
- Slightly higher emission on refuse cycle
- Refuse 0.2 CNG also higher emissions compare to other vocations due to nature of refuse duty cycle
- Chassis data inline with PEMS
- Current data set all 0.2 CNGs, more 0.02 CNGs, and 0.2 diesels planned



Source: UCR & WVU interim report to SCAQMD

Preliminary Findings – Chassis - Delivery

- Delivery category highest 0.2 diesel emissions (highest one was a class 8 truck), finer breakdown?
- Diesel electric presents a excellent emissions reduction pathways towards diesel Low NOx
- LPG: UDDS 83%, Delivery 80%, HHDDT 94% lower
- PEMS results comparable



Source: UCR & WVU interim report to SCAQMD

In-Use Emissions - Key for Future NOx Regulation

- CARB released Staff White Paper outline plans for next rounds of low NOx rule making, significantly changes to HDIUT
- EPA CTI outlines similar in-use requirements
- Onboard sensor based measurement, Remote sensoring

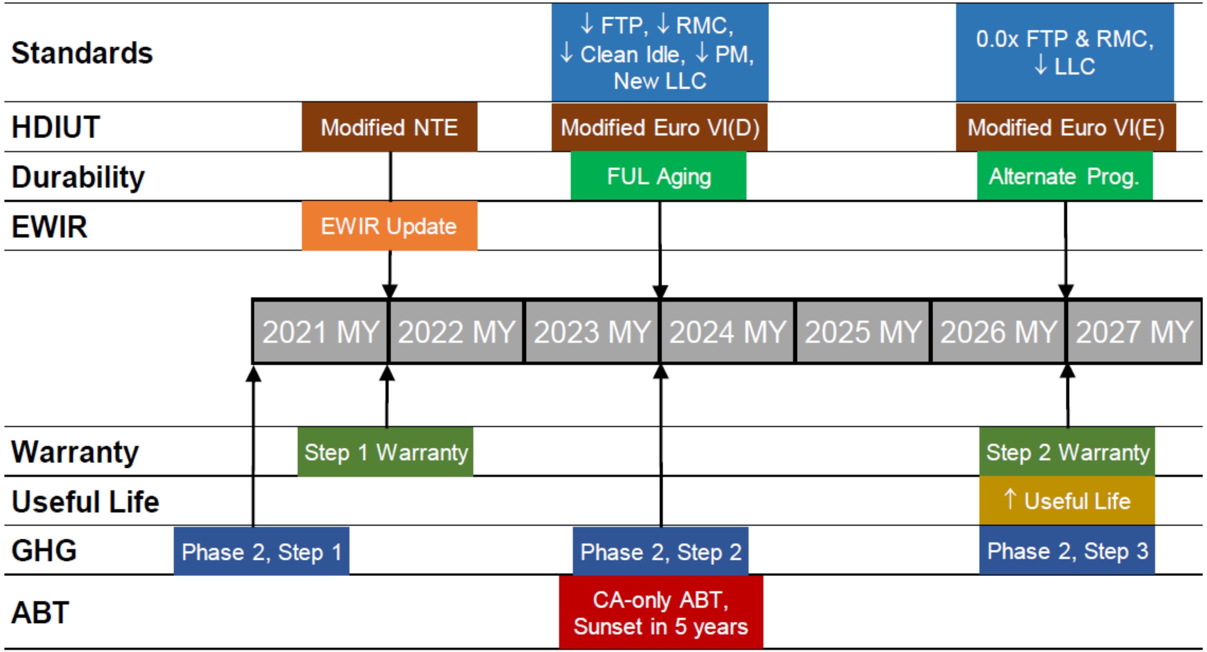


Figure 12 CARB Heavy-Duty Low NOx Rulemaking Implementation Timeline

Source: CARB Staff White Paper

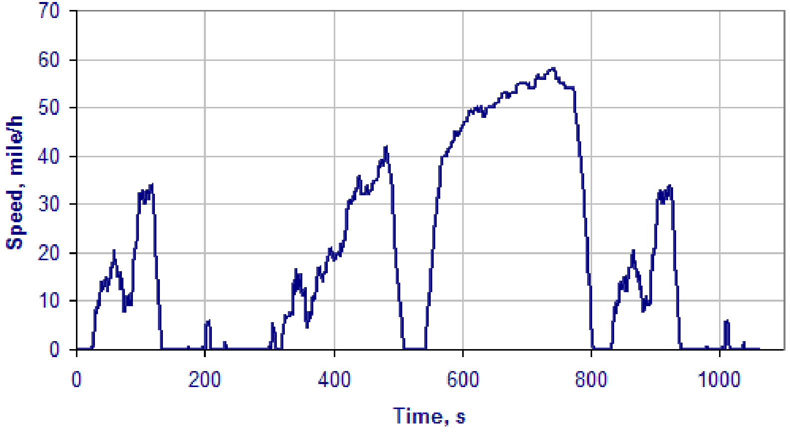
Team

Contractors: WVU, UCR/CE-CERT

Funding Partners: CEC, CARB, SoCalGas and South Coast AQMD

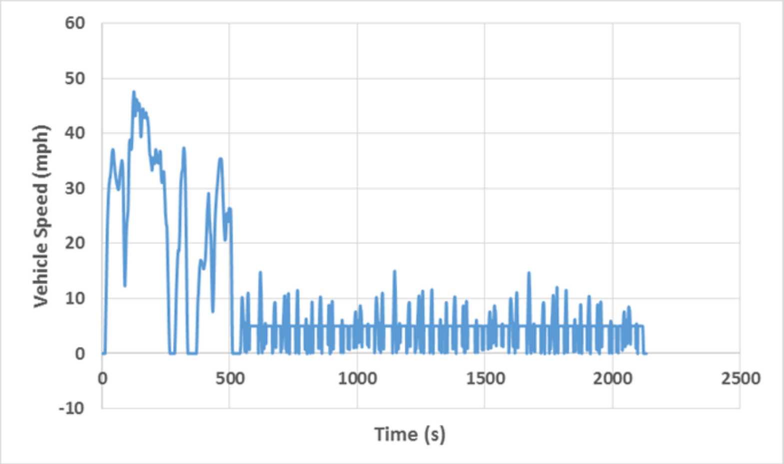
Thank you.

HD-UDDS Cycle



-Ave. Speed: 18.86 mph / 30.4 km/h
-Max. Speed: 58 mph / 93.3 km/h

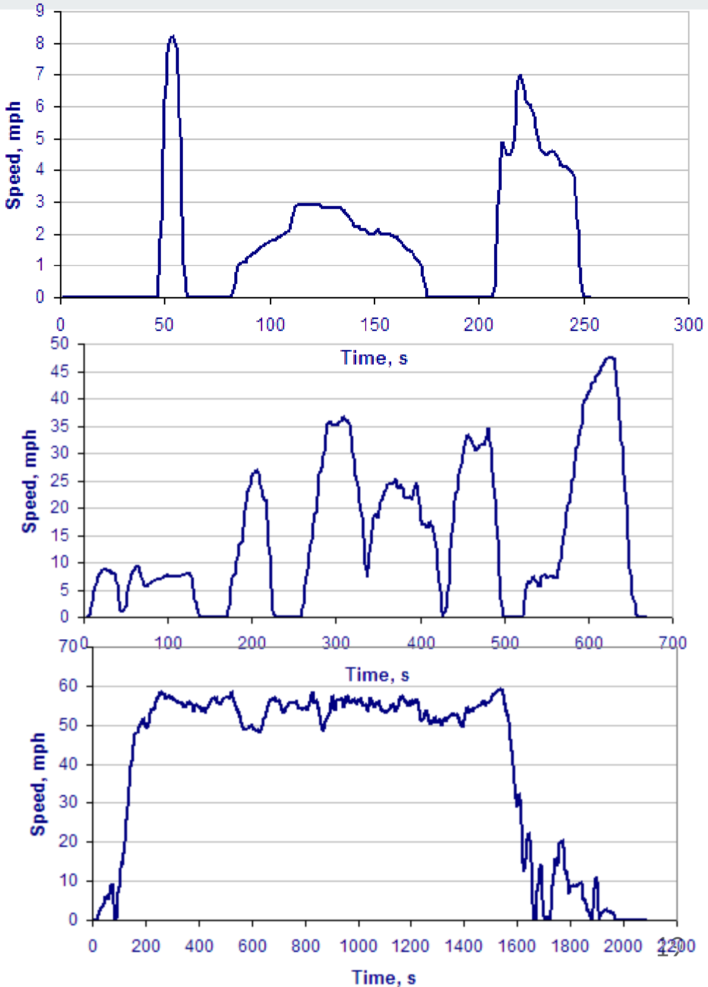
AQMD RTC Cycle

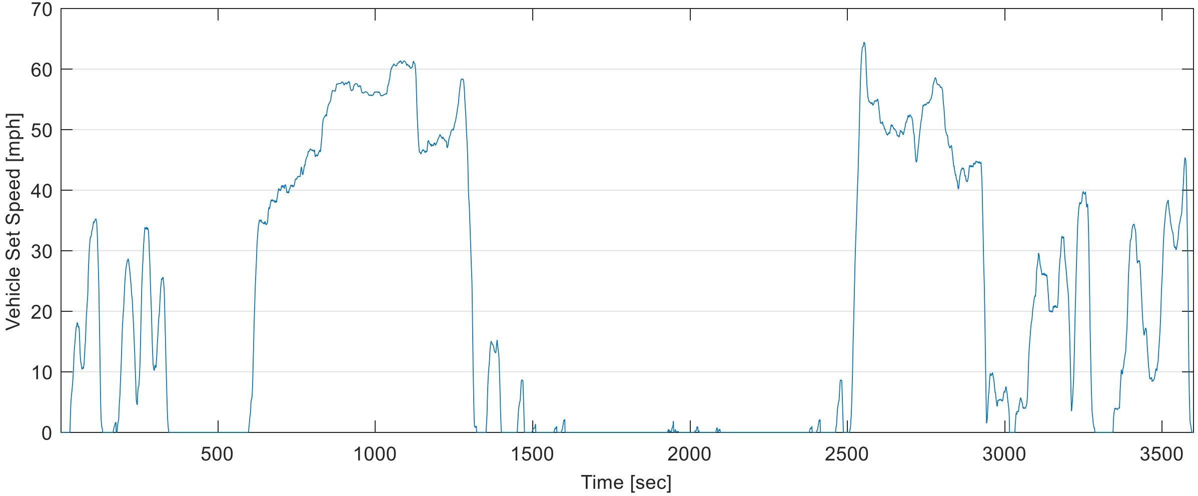


-Ave. Speed: 9.57 mph
-Max. Speed: 47.6mph

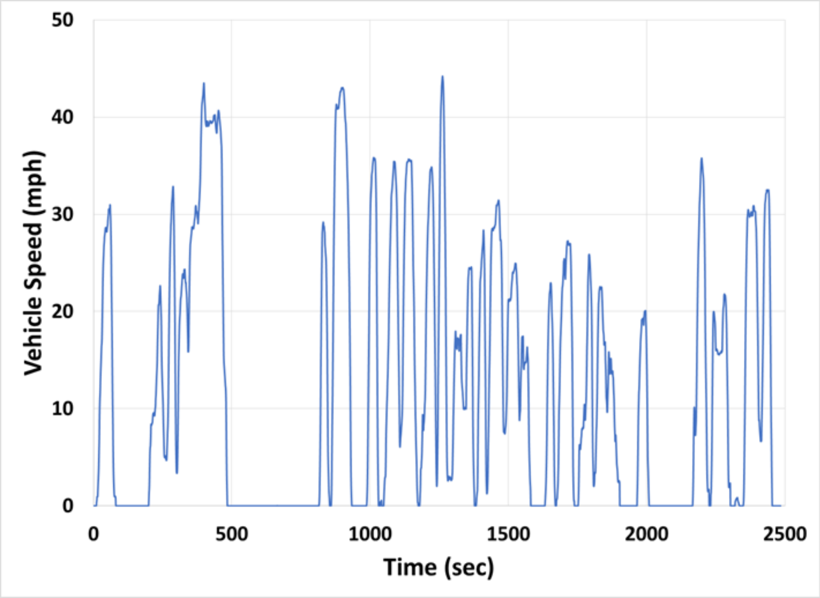
HHDDT Cycle

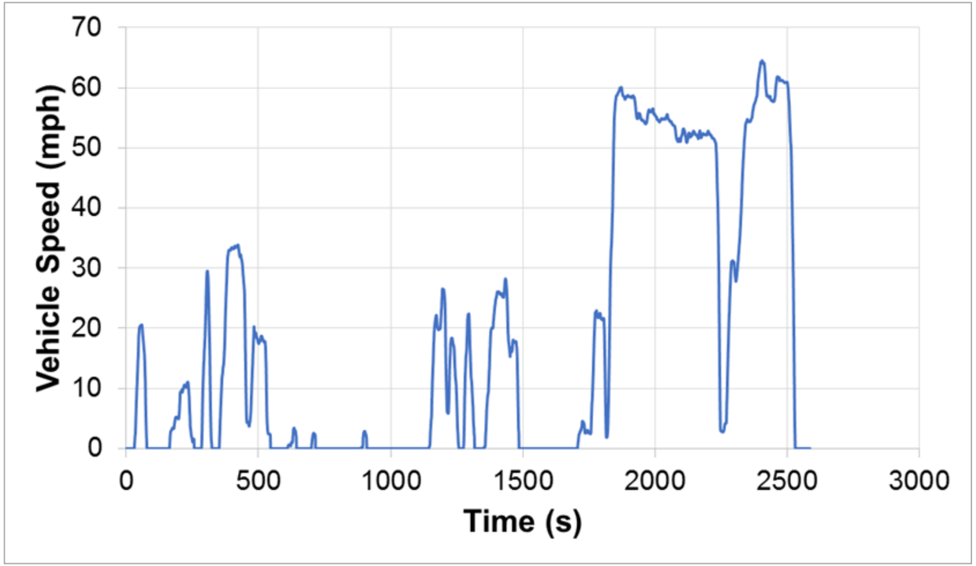
Parameter	HHDDT Creep	HHDDT Transient	HHDDT Cruise	UDDS
Duration, s	253	668	2083	1063
Distance, mi	0.124	2.85	23.1	5.55
Average Speed, mph	1.77	15.4	39.9	18.8
Stops/Mile	24.17	1.8	0.26	2.52
Max. Speed, mph	8.24	47.5	59.3	58
Max. Acceleration, mph/s	2.3	3.0	2.3	4.4
Max. Deceleration, mph/s	-2.53	-2.8	-2.5	-4.6
Total KE, mph^2	3.66	207.6	1036	373.4
Percent Idle	42.29	16.3	8.0	33.4





Cycle	GMC
Cycle duration [sec]	3600
Cycle distance [miles]	20.1
Avg. vehicle speed [mi/h]	20.1
Max. vehicle speed [mi/h]	64.1
Avg. RPA [1)] [m/s²]	0.1054
Share [%] (time based)	
- idling (≤2 km/h)	42.18
- low speed (>2≤50 km/h)	22.97
- medium speed (>50≤90 km/h)	14.33
- high speed (>90 km/h)	20.52



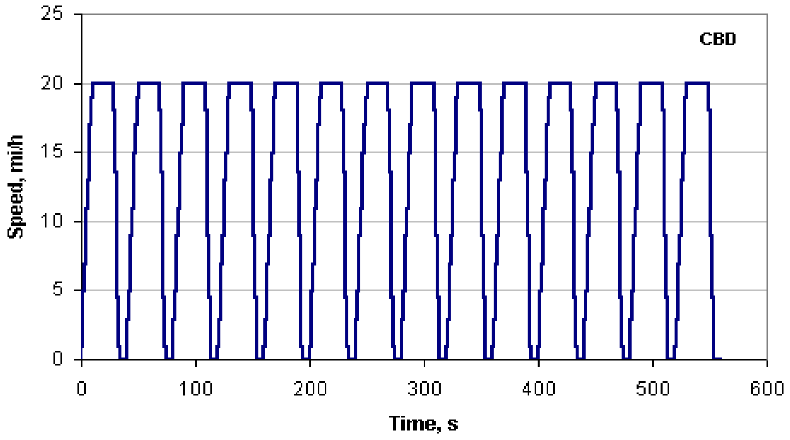


School bus cycle
Ave. Speed: 12.3 mph / 19.68km/h
Max. Speed: 45 mph / 72 km/h

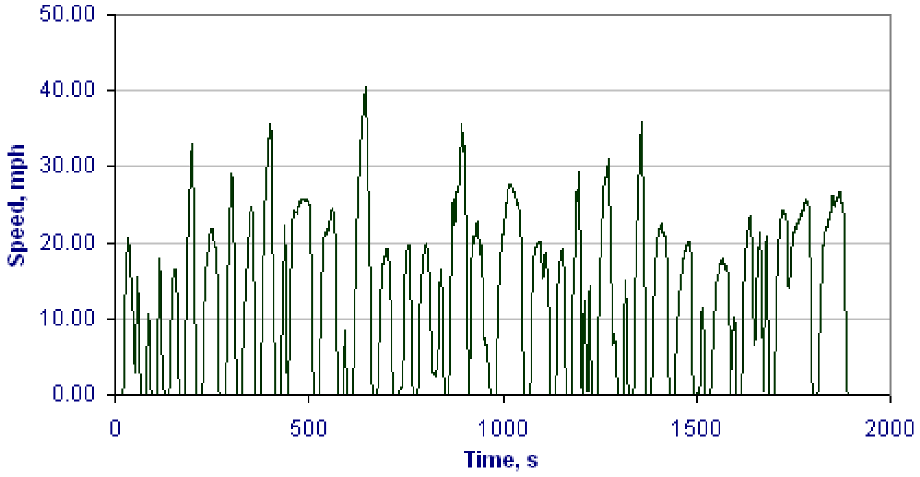
Delivery cycle
Ave. Speed: 17.4 mph / 27.84km/h
Max. Speed: 64 mph / 102.4 km/h

Test Cycles

CBD cycle



OCTA cycle



-Ave. Speed: 12.6 mph / 20.2 km/h
-Max. Speed: 20 mph / 32.18 km/h

-Ave. Speed: 12.4 mph / 19.8 km/h
-Max. Speed: 40.6 mph / 64.9 km/h

HEAVY-DUTY ENGINE TECHNOLOGY UPDATE

Joseph Lopat

2019 sales of class 8 diesel trucks 264,000, up 18 %

97% Diesel

On-road transport increasing

4.9 Million on road

ADVANCED TECHNOLOGY - ICE

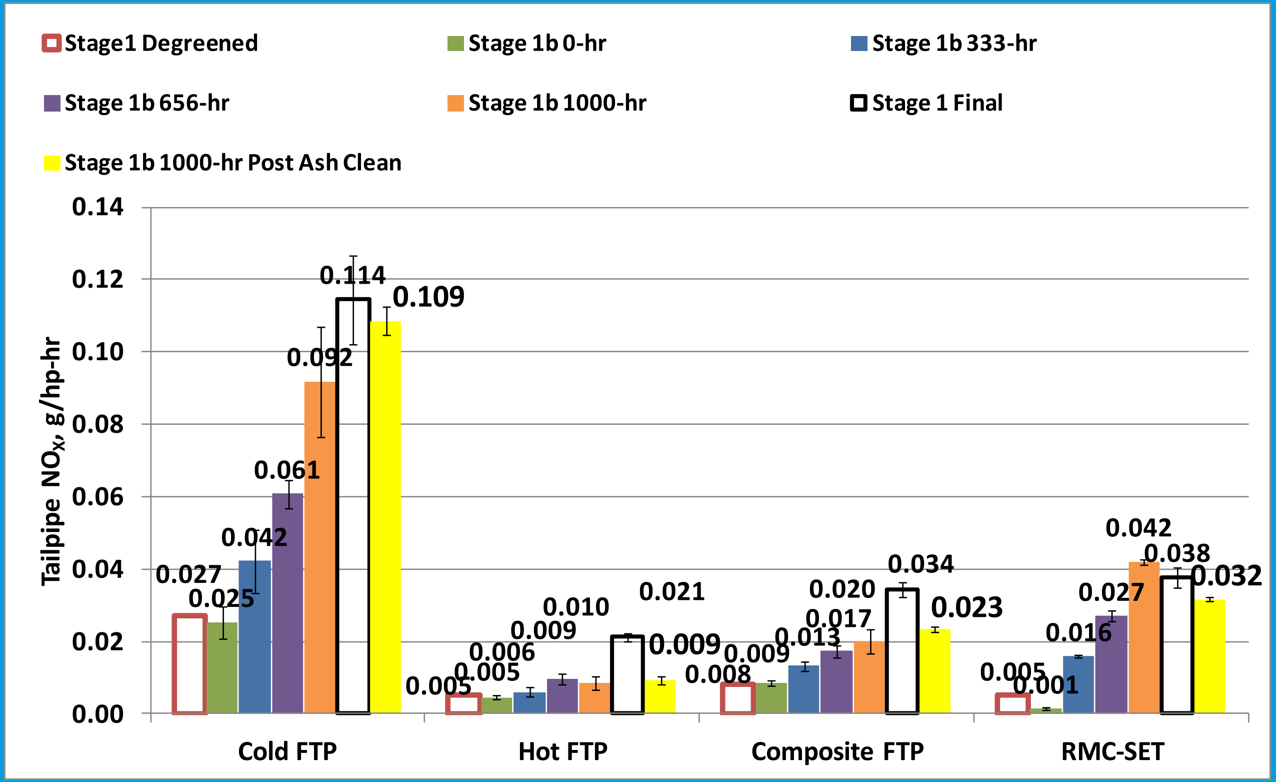
Renewable Diesel
Commercially Available

- Implementation of 6.7, 6.8, 8.9, and 12 liter certified optional low NOx standard CNG engines
- Near-zero emission liquid fueled engines - aftertreatment technologies using close coupled catalysts and heated dosing
- Opposed Piston Engine technology integrated in to Class 8 truck
- MECA white paper on conclusions of near-zero NOx HD diesel engines

0.02
g/BHP-HR
NOX

HEAVY-DUTY DIESEL ENGINE DEVELOPMENT

- SwRI, West Virginia University, EPA on-going testing
- Cylinder deactivation currently studied in chassis for durability
- Best current available options for low NOx selected with no CO_2 penalty
  - Close coupled catalyst
  - Heated dosing
  - Heated catalyst
  - 48 volt operating system
- Opposed piston engine technology integrated and testing



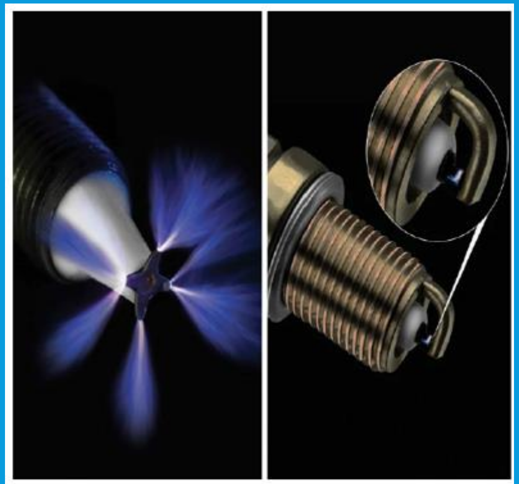
http://www.meca.org/resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf

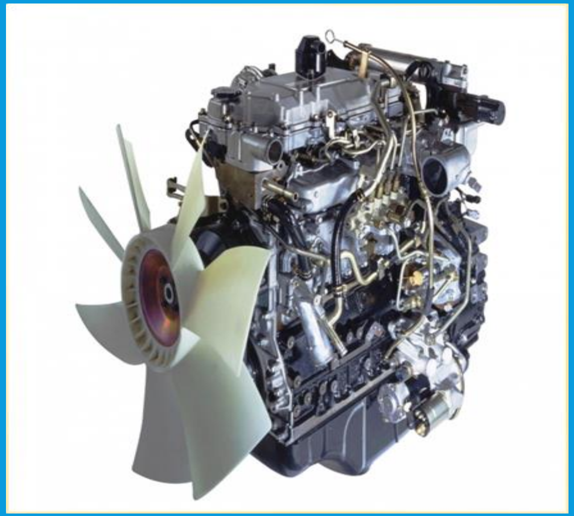
OPPOSED PISTON ENGINE TECHNOLOGY
NEAR-ZERO NOX

- $16.7M Project started in January 2018
- 3 engines completed and tested
- Integration into truck beginning for in-use testing

NREL NATURAL GAS ENGINE PROJECTS

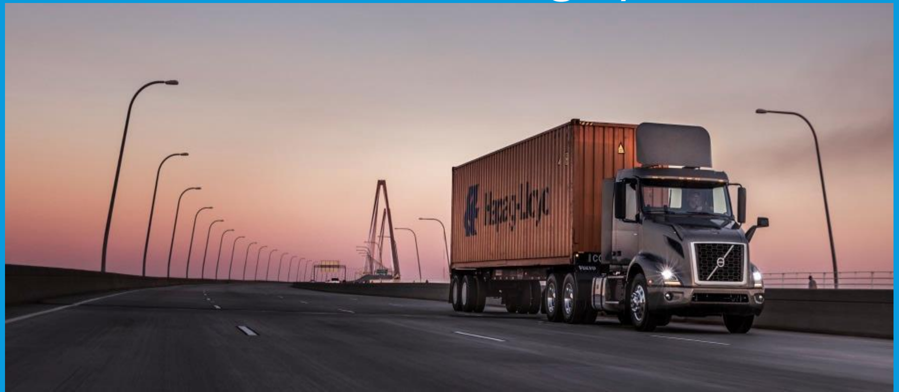
- Cummins Inc.- Development of a higher efficiency near-zero NOx CNG engine for heavy-duty applications
- US Hybrid- Development of a CNG hybrid class 8 truck using the near-zero 8.9-liter CNG engine
- Southwest Research Institute- Development of a CNG near-zero NOx Isuzu engine for class 6-7 hybrid trucks
- SCAQMD awarded $1,225,000 cost share combined with the CEC, SoCal Gas, and the DOE for a total cost of $22,950,000





DIESEL HYBRID PROJECTS

- Volvo diesel plug in hybrid demonstration project.
- Advanced Aftertreatment with mini burner
- Technology transfer pathway to ecodrive
- Smart drive analysis leading to automated driving systems



FUTURE PATHWAYS

- 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 heated catalysts , cylinder deactivation and variable valve timing without fuel penalty
- Continued near-zero NOx CNG and LPG projects. Two 7.3 -Liter engines to be certified at the optional low NOx standard
- 48 volt hybrid systems
- Promotion of a 0.02 g/bhp-hr optional low NOx standard for diesel engines
- Close coordination with CARB's Omnibus Regulation and USEPA's Clean Truck Program

VOLVO LIGHTS UPDATE

Clean Fuels Advisory Committee
February 2020

Patricia Kwon
Program Supervisor
Technology Advancement Office

PREVIOUS DEMO PROJECTS VOLVO

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

South Coast AQMD

- DOE: Volvo developed prototype Class 8 plug-in hybrid electric diesel truck with significantly reduced NOx emissions capable of drayage service to Ports
- CARB GGRF: Volvo refined plug-in hybrid electric diesel drayage truck with EcoDrive and geofencing to drive in zero emission mode. Phase 2 truck to be deployed mid-2020
  - EcoDrive 2.0
  - Mini-burner aftertreatment
- CARB ZANZEFF: Volvo LIGHTS - first Class 8 battery electric drayage trucks

Demonstrating innovations critical to the commercial success of battery electric trucks and equipment for goods movement

LIGHTSproject.com

Advanced Vehicle Technologies

Charging Infrastructure

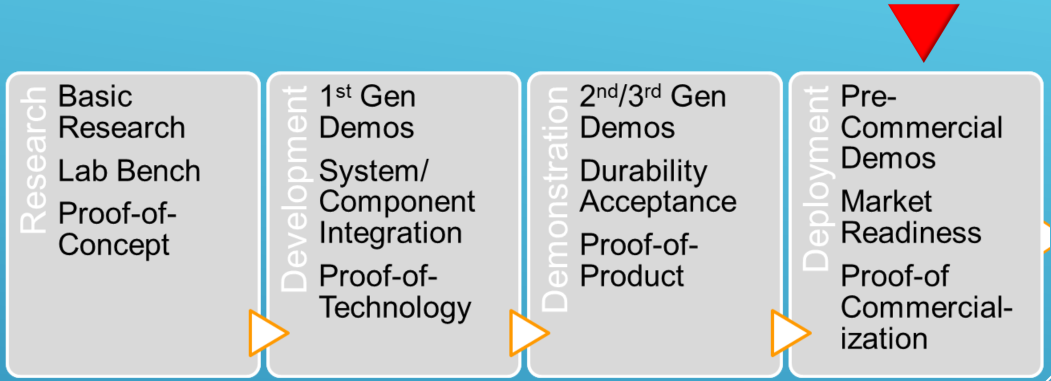
Sales & Service Network

Project Partners

Volvo LIGHTS is part of California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment —particularly in disadvantaged communities. www.caclimateinvestments.ca.gov

VOLVO LIGHTS

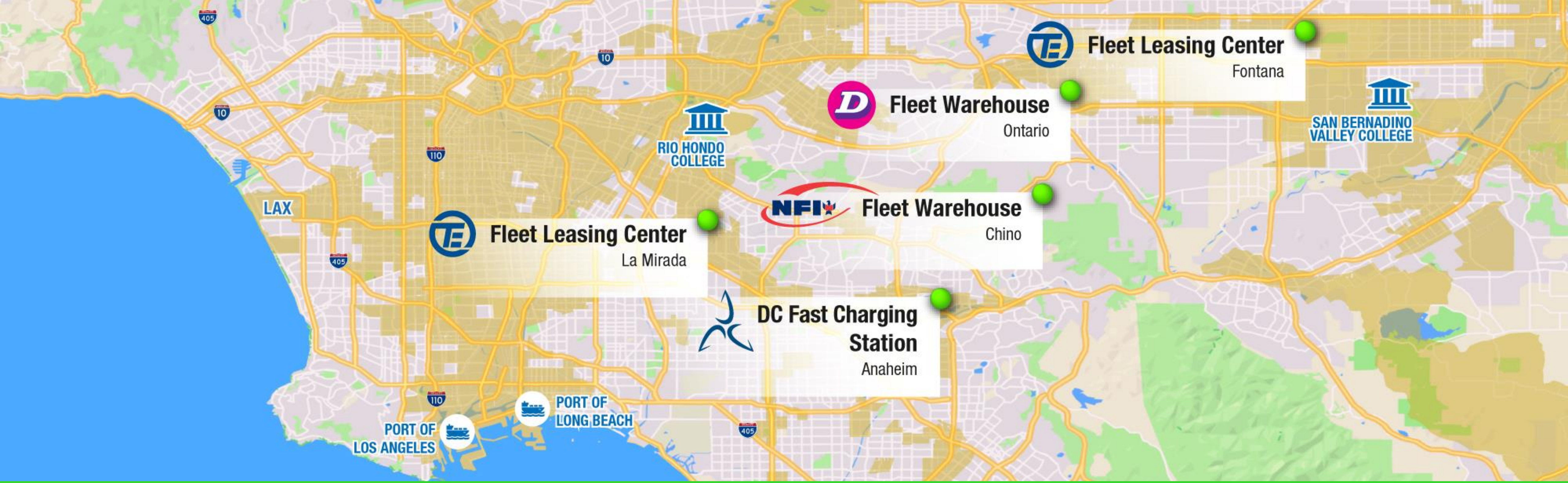
- Volvo LIGHTS (Low Impact Green Heavy Transport Solution)
  - Funded with $44.8M from CCI, $4M SCAQMD, $41.6M from Partners
- Showcases zero-emission freight movement
- Pre-Commercial introduction of Class 8 HDBETs
- Installation of 58 DCFC + Level 2 chargers
- Installation of 1.8 Million kWh solar and facility upgrades
- Public outreach, data collection and reporting



VOLVO LIGHTS

Freight Haul Demonstration

- Develop 8 pilot and 15 production Class 8 battery electric trucks and 29 battery electric forklifts/yard tractors
- VNR Electric perfect platform for short regional haul applications
- From Ports to Inland Empire warehouse locations



23 Battery Electric Heavy-Duty Trucks

29 Battery Electric Equipment

58 Public & Private Chargers

2 Electric Truck After Market Service Centers

2 Colleges Designing Electric Truck Maintenance Programs

1.8 Million KWH Solar Energy Generation

2 Ports Providing Infrastructure Planning

Disadvantaged Communities Disproportionately Exposed to Unhealthy Air

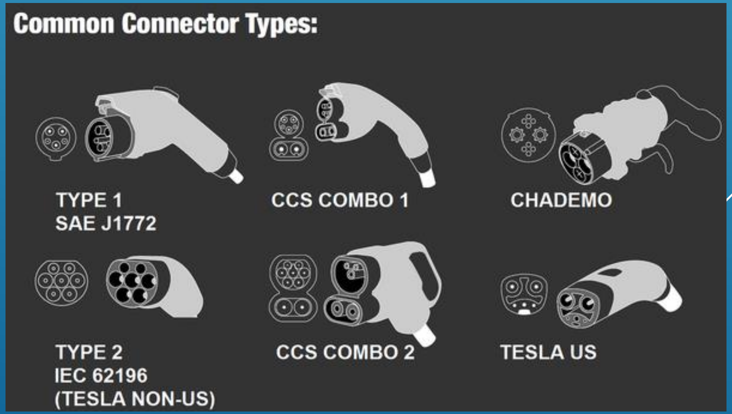
TRUCK UPDATE

- Two pilot trucks and three pilot tractors (60,000 lb) built at Greensboro
- Five trucks delivered to California in December 2019
- Testing trucks on local roads in South Coast AQMD (almost 10,000 miles)

- Unloaded range on rigid trucks 100+ miles, 50% more range on tractors
- Loaded performance testing underway
- Next pilot tractors (80,000 lb) scheduled for spring 2020

INFRASTRUCTURE UPDATE

- Public fast charging stations - Trillium truck stop in Placentia with two 150 kW DCFC
- Field certification - CCS2 connector with two ABB 50 kW DCFC - TEC Fontana
- 150 kW DCFC to be completed in February 2020
- UL inspectors visited REMA factory in South Carolina - factory certification of CCS2 connector
- ABB – approval of production variant of CCS2 connector prior to shipping



FLEET UPDATES

- NFI
  - DCFC installation - March 2020
  - Level 2 for battery electric forklifts - April-June 2020
- DHE
  - Level 2, DCFC installation - April 2020
  - Battery electric yard tractors on site
  - Solar installation - July 2020
  - Battery electric forklifts - March 2020

NEXT STEPS

- Technology Showcase in Fontana - Feb 11, 2020
- Zero emission powertrain certification – for commercial sales
- Production line for battery electric trucks - modify final assembly plant
- Plans to increase sales to top fleets in southern California

Daimler BETs & Infrastructure

Project update

South Coast
AQMD

Clean Fuels Advisory Meeting

South Coast Air Quality Management District

February 6, 2020

Phil Barroca
Program Supervisor, Technology Demonstration
Technology Advancement Office

Overview

South Coast AQMD

- 15 Class 8 - eCascadia DTNA
- 5 Class 6 - eM2 Agility/DTNA
- Infrastructure
  - DC Fast Charging
  - Energy Storage Systems
- Demonstration/Outreach
  - Penske Truck Leasing and NFI
- Cost Sharing: $31MM
  - DTNA, SCAQMD,POLA, POLB, EPA

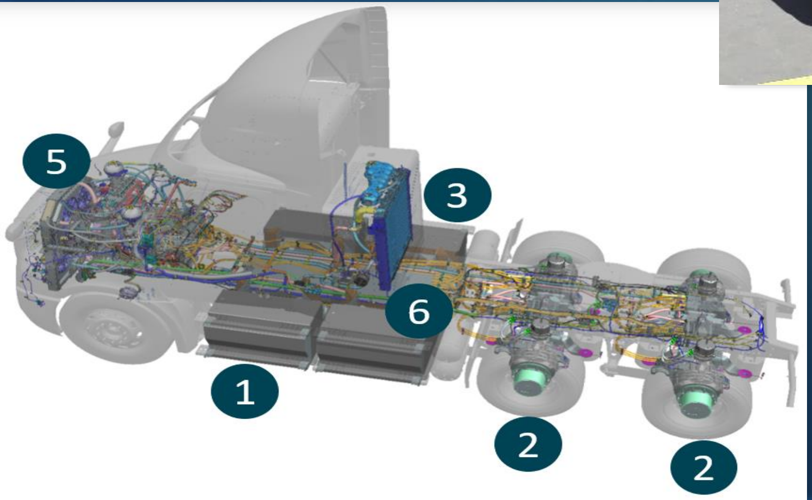
DAIMLER

Agility® fuel solutions

eCascadia – Construction

DTNA - Portland,OR

Class 8
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

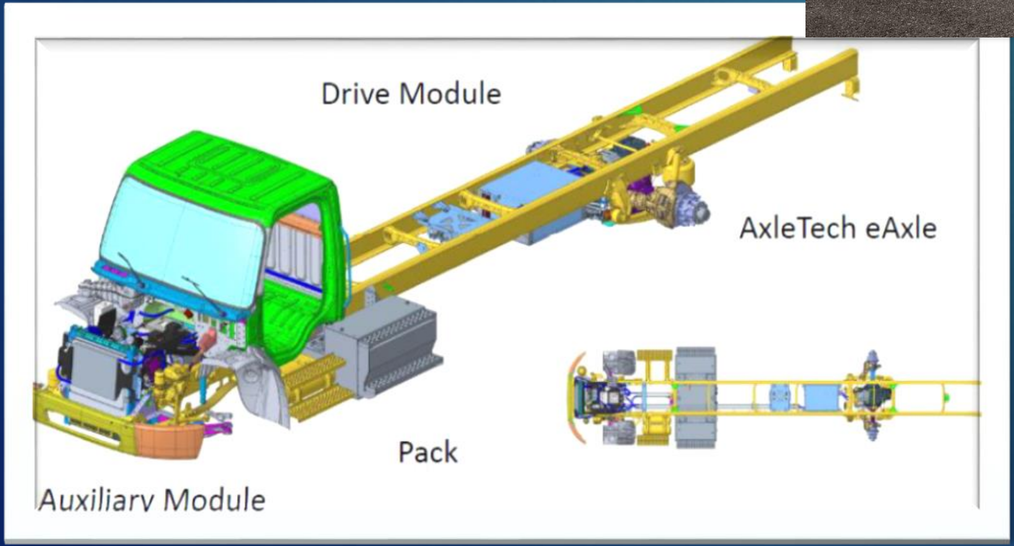


1. Battery (Agility/Romeo)
2. E-Axle (ZF-Germany) – four (4)
3. Power Distribution Unit (Agility)
4. Inverter (Semikron)
5. Vehicle Control Unit (Bosch)
6. Brake Resistor (Backer)

DAIMLER

eM2 – Construction
Agility (Fontana, CA)/DTNA

Class 6
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



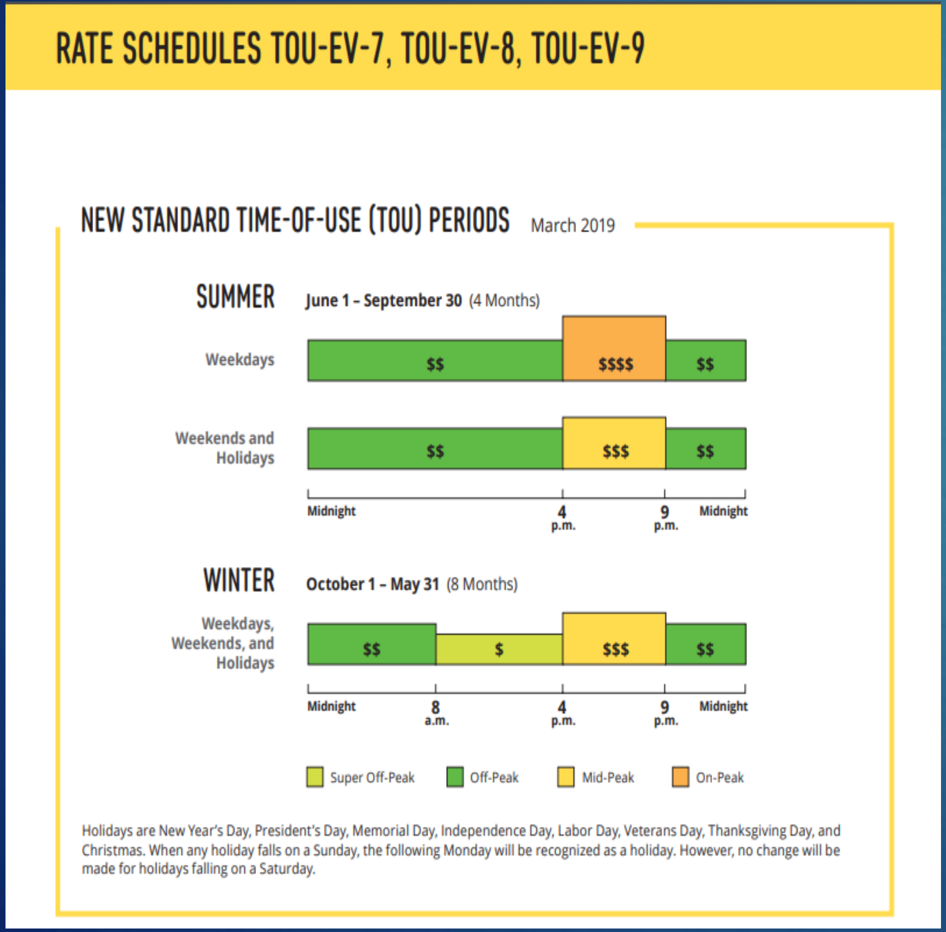
Battery (Agility/Romeo)
E-Axle (Meritor) – single unit
Power Distribution Unit (Agility)
Inverter
Vehicle Control Unit
Brake Resistor (energy dissipation through auxiliary systems, e.g. cabin heating)

EV Infrastructure

- Infrastructure: CCS-1 DC Fast Charging
- 150 kW, 62.5 kW, 50 kW
- 10 Locations, 20 DC Fast-Chargers
- Energy Storage System – Ontario
  - 300 kW Power
  - 800 kWh storage
  - New Utility rates affecting ROI

CCS Type1 Connector

SCE Rates



TOU-EV-8 Rate Option Is available for customers with charging demands above 20 to 500 kW.
TOU-EV-9 Rate Option Is available for customers with charging demands exceeding 500 kW.

Time-Of-Use (TOU) energy charges are the cost per kilowatt-hour (kWh) of energy used in each TOU period. TOU periods vary by time of day, day of the week, and season (see Standard TOU Periods chart). Facilities-Related Demand (FRD) charges apply year round and are calculated per kilowatt (kW) according to the highest recorded demand during each monthly billing period, regardless of season, day of week, or time of day.
Please note that from 2019-2023 FRD charges are not applicable.

Project Status

eCascadias

- All 15 tractors have been 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 - 5 customers for project term
- NFI operating routes between Warehouse and SPBPorts
- Drivers feedback:
  - **Pros**
    - Quiet, no torsional twist, easy to drive
    - Learning benefits of Recuperative braking
    - No reduction in performance
  - **Cons**
    - Larger turning radius
    - Concern on tire wear (Michelin study results pending)
    - Back of Cab radiator obstructing view of fifth wheel

LOGISTICS • TRANSPORTATION • DISTRIBUTION NFI

South Coast AQMD

PENSKE

Metrics - eCascadia

South Coast AQMD

	BET Vehicle	eCascadia		
	No. Vehicles	5	5	5
	Demonstration Fleet	Penske Logistics	Penske Leasing	NFI
	Total Miles	14000+	N/A	29,000+
Averages	Driving hrs/day	3.1	N/A	7.2
	Miles/day	95	N/A	154
	Energy Economy (kWh/mile)	2.3	N/A	1.84
	SOC - % used/shift	30%	N/A	50%
	Charging hrs/day	0.5	N/A	3.6
	Payload, lbs	N/A	N/A	28,501

Two trucks with >10,000 miles

eM2s

- All 5 eM2s have been built
- All are being commissioned
- Agility taking lead on resolving software to integrate systems; DTNA providing technical support
  - Vehicles experiencing shifting issues and peak power output, and shutdowns while driving
- Expecting deployment to Penske Leasing by March
- Penske has three customers identified; seeking two more; customers to use vehicles for term of project and recharge at Penske DCFCs
- Operational profiles of participating fleets –
  - generally local pick-up and delivery, and
  - combination of first/last mile services.

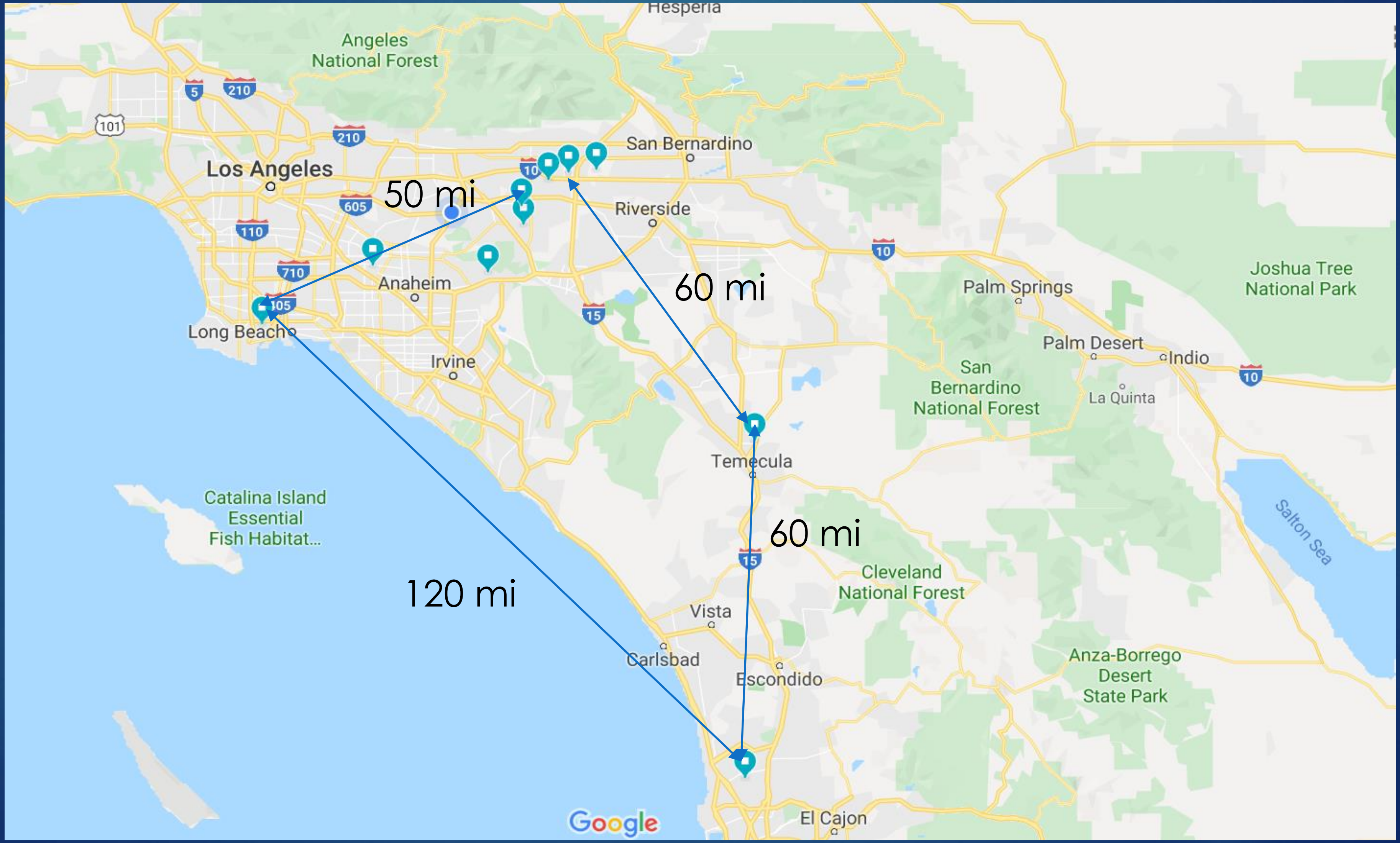
EV Infrastructure – Locations

Fleet	Location	Type	Chargers	Dispensers	kW/ Charger	Total kW	Status
Penske	Anaheim	CCS-1	2	4	150	300	Complete
Penske	Temecula	CCS-1	1	12	50	50	Complete
Penske	Chino	CCS-1	2	4	150	300	Complete
Penske	La Mirada	CCS-1	2	4	150	300	Complete
Penske	San Diego	CCS-1	1	2	150	150	Complete
Penske	Ontario	CCS-1	3	6	150	450	Q1-20
NFI	Chino	CCS-1	5	5	150	750	Complete
NFI	Port Location	CCS-1	1	1	62.5	62.5	Q1-20
NFI	Shop Location	CCS-1	1	1	62.5	62.5	Q1-20
DTNA	Fontana	CCS-1	2	2	62.5	125	Q1-20
Penske Total	**6**		**11**	**21**		**1550**	**2**
NFI Total	**3**		**7**	**7**		**875**	**1**
DTNA Total	**1**		**2**	**2**		**125**	**0**
Totals	**10**		**20**	**30**		**2550**	**3**

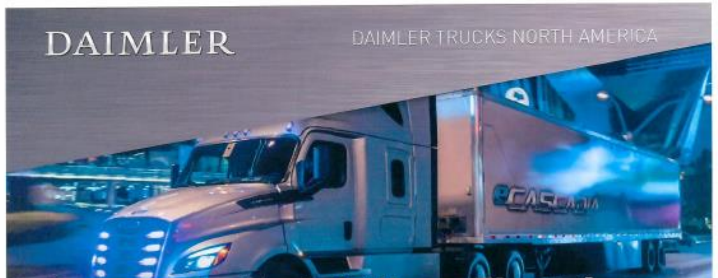
2 at Penske – La Mirada

5 at NFI - Chino

Infrastructure Deployment



Press Releases



Daimler's Freightliner Electric Innovation Fleet

Validating the Readiness of Battery-Electric Commercial Truck

In 2018, the South Coast Air Quality Management District (SCAQMD) and Daimler Trucks North America LLC (DTNA) launched a demonstration project, of which SCAQMD funded $16M, to develop and deploy 30 battery-electric trucks to real-world commercial fleet operations. The operation of these electric trucks will help achieve the Air District's air quality goals by reducing harmful tailpipe emissions.

The Freightliner® Electric Innovation Fleet includes 20 Class 8 eCascadias and 10 Class 6/7 eM2 prototypes that will be deployed in 2019, along with the required charging infrastructure. DTNA is working with project partners, Penske Truck Leasing and NFI Industries, to gather data and demonstrate how electric trucks can be effectively used in day-to-day freight transportation. There is growing market potential for these vehicles in several applications, including regional short haul operations, food and beverage service, as well as port drayage. The fleet will operate throughout the South Coast Air Basin and highlight the potential for zero-emission goods movement in Southern California's freight corridor.

The Freightliner® Electric Innovation Fleet prototypes will provide the foundation for commercialized production of medium and heavy-duty electric trucks that are fully capable, durable and cost-effective.

The Freightliner® eCascadia is based on the Cascadia, the best-seling Class 8 truck in the North-American market.

eCascadia Specifications[1]	
Horsepower	730 hp
Range	250 miles
Power Storage	550 kwh
Charge Time	80% in 90 minutes

The Freightliner® eM2 106 is intended for local distribution operations in the food sector and last-mile delivery services.

eM2 Specifications[1]	
Horsepower	480 hp
Range	230 miles
Power Storage	325 kwh
Charge Time	80% in 60 minutes

[1]Represents pre production estimates

Leading the Transport Sector into a Cleaner Future

The Electric Innovation Fleet is yet another proof point that Daimler believes the future is electric. This fleet will collect millions of miles of commercial electric vehicle test data and experience to meet the growing needs of the U.S. freight market.

Production of both eCascadia and eM2 is expected to begin in late 2021. Incentives from local, regional, and state agencies are critical factors in the success of battery electric technology and support accelerated testing and validation along with early adoption.

Along with the construction of a larger charging network, DTNA's Freightliner® Electric Innovation Fleet pilot project is paving the way for the next generation of electric commercial truck models. Series production of the Freightliner® eCascadia and eM2 begins in late 2021.

Project Funding Partners:

South Coast AQMD
THE PORT OF LOS ANGELES
The Port of LONG BEACH
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Daimler Trucks North America is the leading heavy-duty truck manufacturer in North America and is a Daimler company, the world's leading commercial vehicle manufacturer.

Gladstein, Neandross & Associates (GNA) is assisting with project development and project management.

Plans for next Quarter

- Continue to monitor progress on eM2 software integration
- Deliver and deploy all five eM2's to Penske Leasing
- Infrastructure
  - Installation of DCFC at DTNA dealersjip in Fontana
  - Penske to complete Ontario DCFC
- Conduct more technician and driver training as more vehicles delivered and more drivers are introduced
- NFI to host a "Ride&Drive" press event at their Chino facility
- Monitor and track performances, resolve any issues
- DTNA to work with fleet partners to finalize data collection plan
- Continue monthly reporting

Project Funding - $31,340,144

Thank You

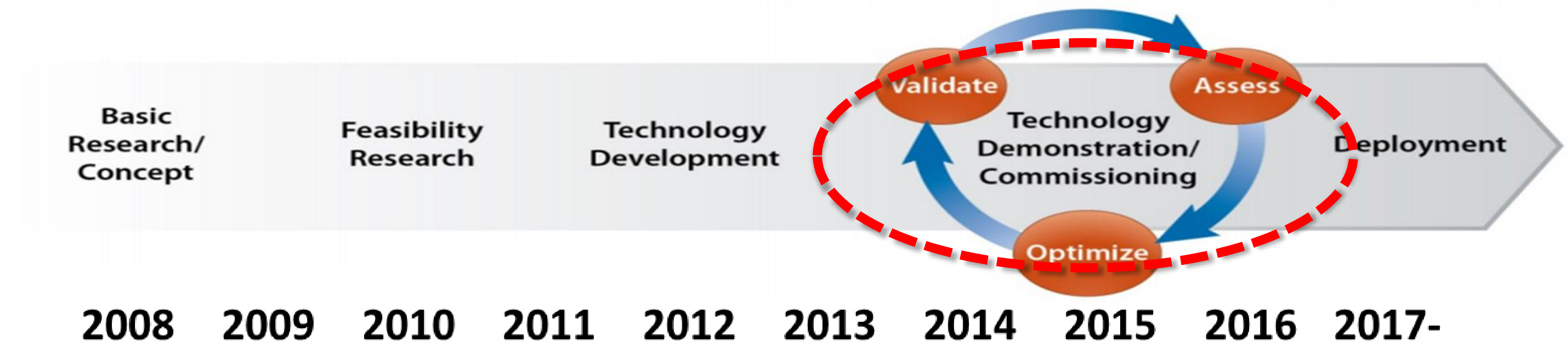
South Coast AQMD

Zero Emission Cargo Transport II

Technology Advancement Office
Air Quality Specialist

Seungbum Ha

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

Advantageous Applications

UC Irvine NFCRC, Jack Brower, Presentation at Sunline Transit, March 6, 2019

Project Overview

Dates: 12/16/2015 – 9/30/2021
Grantee: South Coast Air Quality Management District
Partners: Peterbilt/Transpower, Kenworth, U.S. Hybrid, Hydrogenics, BAE, CTE, GTI, multiple demonstration fleets and technology partners
Grant Amount:
DOE Contribution: $10,000,000
Matching Funds: $10,543,314
Project Total: $20,543,314

Goal

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

Barriers & Challenges

- Fueling Infrastructure: Availability and location
- Costs: Fuel Cells, batteries and infrastructure
- System Integration: Safe and efficient deployment of the technology Barriers & Challenges

Approach: 6 Fuel Cell & 1 CNG Hybrid Truck

	FUEL CELL TRUCKS				PHET/CNG
	TransPower	Hydrogenics	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

Technical Progress – Hydrogen Stations

Portable hydrogen refueling at Kenworth test site (Mt. Vernon, WA) and Port of LA demonstration site (San Pedro, CA)

- Air Products supports both fueling stations
- San Pedro equipment will remain active throughout the vehicle demonstration period for all vehicles under this program
- San Pedro site features 2x Air Products HF-150 mobile refuelers:
  - Capacity: ~300 kg/day
  - Pressure: 350 bar

Photo: Kenworth

Mobile Refueler – Mt. Vernon

Photo: CTE

Mobile Refueler – San Pedro

Technical Progress

- The vehicle was delivered to the operator, TTSI, at the Port of LA on February 4th, 2019
- Approximately 20-25 miles route up to four times a day with freight varying between 10,000-39,000 lbs.
- The truck has accumulated over 10,000 miles at the end of the reporting period.

Climbing 30% slope at 80,000 GVW

Parameter	Target	Measured
Range Total	112 miles	216 miles
Top Speed	70 mph	70 mph
Grade-ability Speed 6.5 %	35 mph	36 mph
Speed 5.0%	40 mph	40 mph

Technical Progress

- Fuel Cell Truck #1, #2 have been deployed at TTSI, Q4 2017 and Q2 2019
- FC #2 has been reliable and has seen increasing use in service as the truck continued to provide reliable drayage service.
- FC2 – 1456 miles - Q3 & 1,806 miles - Q4

Technical Progress

- Fuel Cell Truck #1, #2 have been deployed at TTSI, Q3 2018 and Q2 2019
- FC #1 - increasing usage - truck continues to provide reliable drayage service
- US Hybrid - increasing H2 tank capacity for FC#2 from 25kg to 35kg for max 280 miles range; After tank upgrade and testing, deploy to TTSI

Technical Progress

- Base Truck Status (CEC Truck) has been deployed to fleet operator
- Cummins (Hydrogenics)- full support for truck and demonstration
  - Truck is expected to be deployed July 2020
  - 24 month demonstration

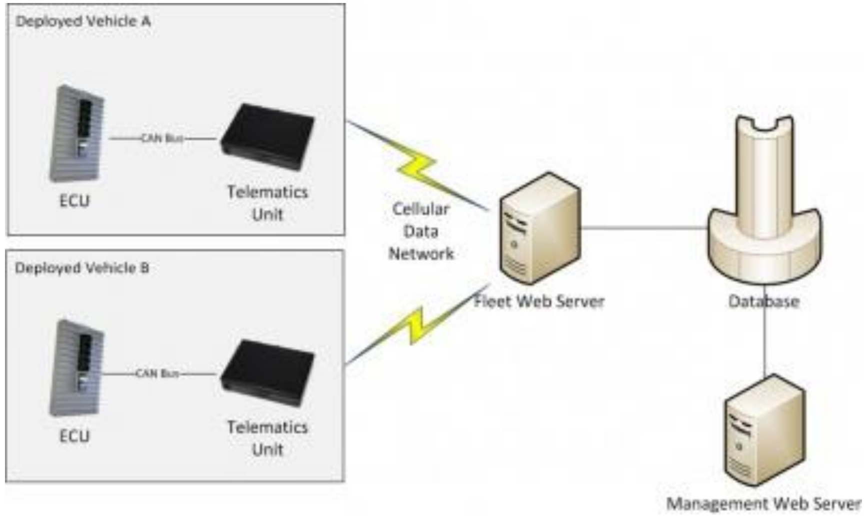
Technical Progress – CNG Hybrid Truck

- Cummins Westport Inc. Near-Zero ISL-G Engine
- Accumulated 1,264 miles in Nov/Dec 2019
- Data - shared with NREL and CALSTART for analysis.

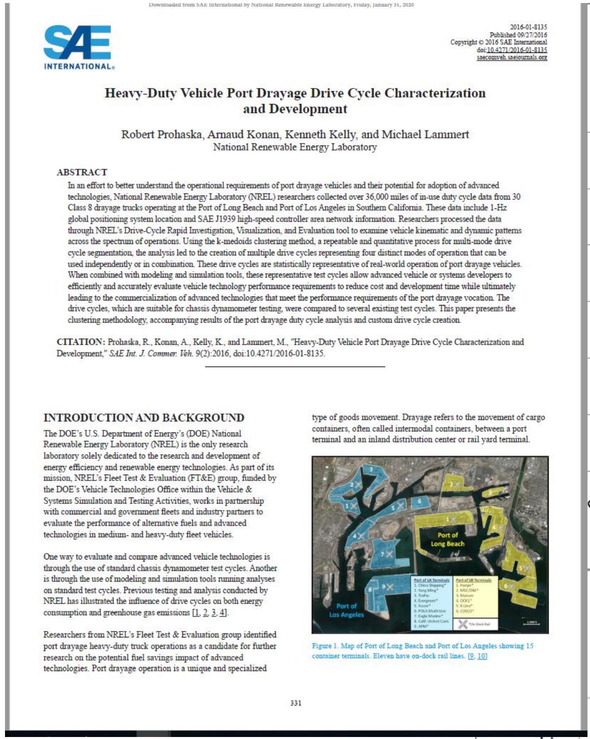
Parameter	Target	Measured
Range Total	150 miles	284 miles
Elec-Only	20 miles	26 miles
Top Speed	62 mph	65 mph

ZECT II – Data Channels

	Parameter or Variable	Units	Sample rate driving	Sample rate charging
1	Vehicle ID	n/a	1 Hz	1 Hz
2	Tractor weight or mass	kg or lb	1 Hz	1 Hz
3	Load (payload)	kg or lb	event	n/a
4	Timestamp	dd/mm/yyyy hh:mm:ss.x	1 Hz	1 Hz
5	Operation state	n/a	1 Hz	1 Hz
6	Shifter position (PRNDL)	n/a	1hz	n/a
7	Transmission gear state (if applicable)	n/a	1hz	n/a
8	Accelerator pedal position	%	1 Hz	n/a
9	Brake pedal on state or applied pressure	on/off or PSI	1 Hz	n/a
10	Vehicle speed	kph	1 Hz	n/a
11	Distance driven	km	1 Hz	n/a
12	GPS latitude	degrees, minutes	1 Hz	1 Hz
13	GPS longitude	degrees, minutes	1 Hz	1 Hz
14	GPS altitude	m	1 Hz	1 Hz
15	Battery current	DC A	1 Hz	1 Hz
16	Battery voltage	DC V	1 Hz	1 Hz
17	Battery pack SOC	%	1 Hz	1 Hz
18	Battery pack min cell voltage	V or mV	1 Hz	1 Hz
19	Battery pack max cell voltage	V or mV	1 Hz	1 Hz
20	Battery pack balance mode state	on/off	n/a	1 Hz
21	AC charging current	AC A	n/a	1 Hz
22	AC charging voltage	AC V	n/a	1 Hz
23	Ambient and Battery pack bulk temperature	deg C	1 Hz	1 Hz
24	Battery pack min cell temperature	deg C	1 Hz	1 Hz
25	Battery pack max cell temperature	deg C	1 Hz	1 Hz
26	Motor temperature	deg C	1 Hz	n/a
27	Power electronics/charger temperature	deg C	1 Hz	1 Hz
28	Motor speed	rpm	1 Hz	n/a
29	Motor torque	Nm	1 Hz	n/a
30	Motor power (electrical)	W	1 Hz	n/a
31	Air conditioner state	on/off	1 Hz	n/a
32	Air conditioner compressor power	W	1 Hz	n/a
33	Heater state	on/off	1 Hz	n/a



DATA analysis



2016-01-8135
Published 09/27/2016

doi:10.4271/2016-01-8135
saecomveh.saejournals.org

Heavy-Duty Vehicle Port Drayage Drive Cycle Characterization and Development

Robert Prohaska, Arnaud Konan, Kenneth Kelly, and Michael Lammert
National Renewable Energy Laboratory

ABSTRACT

In an effort to better understand the operational requirements of port drayage vehicles and their potential for adoption of advanced technologies, National Renewable Energy Laboratory (NREL) researchers collected over 36,000 miles of in-use duty cycle data from 30 Class 8 drayage trucks operating at the Port of Long Beach and Port of Los Angeles in Southern California. These data include 1-Hz global positioning system location and SAE J1939 high-speed controller area network information. Researchers processed the data through NREL's Drive-Cycle Rapid Investigation, Visualization, and Evaluation tool to examine vehicle kinematic and dynamic patterns across the spectrum of operations. Using the k-medoids clustering method, a repeatable and quantitative process for multi-mode drive cycle segmentation, the analysis led to the creation of multiple drive cycles representing four distinct modes of operation that can be used independently or in combination. These drive cycles are statistically representative of real-world operation of port drayage vehicles. When combined with modeling and simulation tools, these representative test cycles allow advanced vehicle or systems developers to efficiently and accurately evaluate vehicle technology performance requirements to reduce cost and development time while ultimately leading to the commercialization of advanced technologies that meet the performance requirements of the port drayage vocation. The drive cycles, which are suitable for chassis dynamometer testing, were compared to several existing test cycles. This paper presents the clustering methodology, accompanying results of the port drayage duty cycle analysis and custom drive cycle creation.

CITATION: Prohaska, R., Konan, A., Kelly, K., and Lammert, M., "Heavy-Duty Vehicle Port Drayage Drive Cycle Characterization and Development," *SAE Int. J. Commer. Veh.* 9(2):2016, doi:10.4271/2016-01-8135.

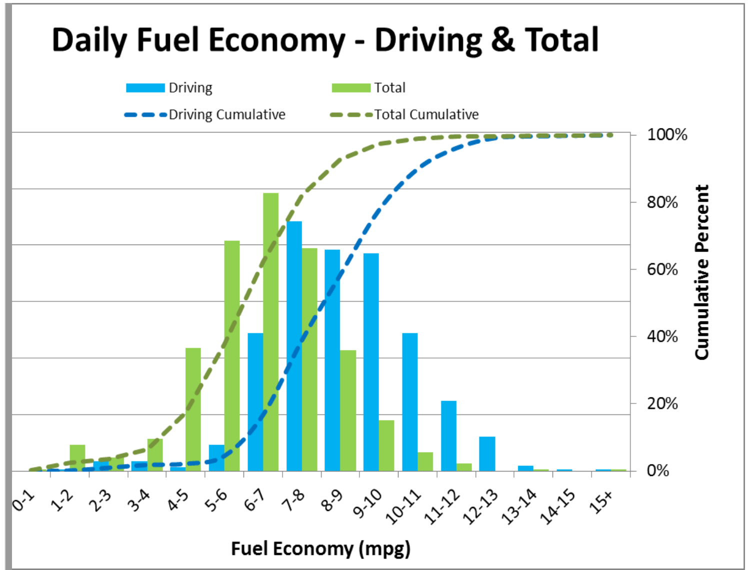
INTRODUCTION AND BACKGROUND

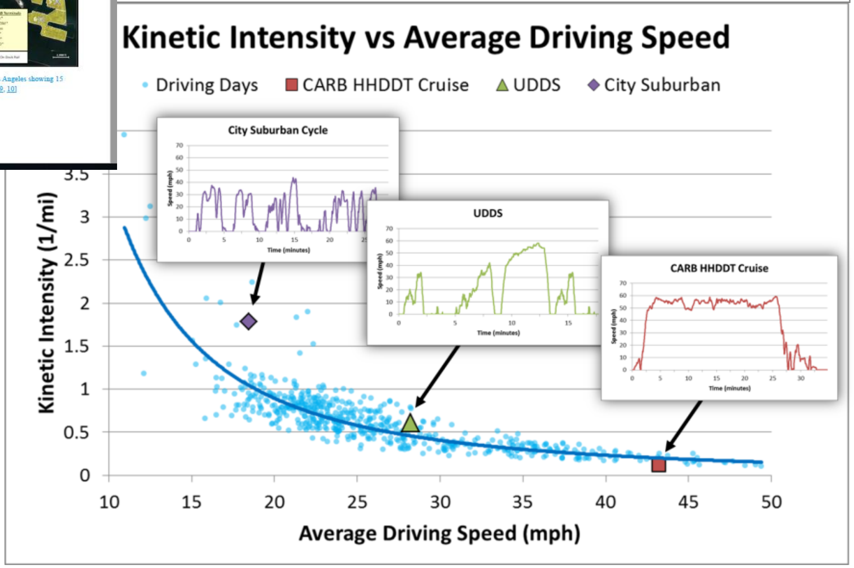
The DOE's U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) is the only research laboratory solely dedicated to the research and development of energy efficiency and renewable energy technologies. As part of its mission, NREL's Fleet Test & Evaluation (FT&E) group, funded by the DOE's Vehicle Technologies Office within the Vehicle & Systems Simulation and Testing Activities, works in partnership with commercial and government fleets and industry partners to evaluate the performance of alternative fuels and advanced technologies in medium- and heavy-duty fleet vehicles.

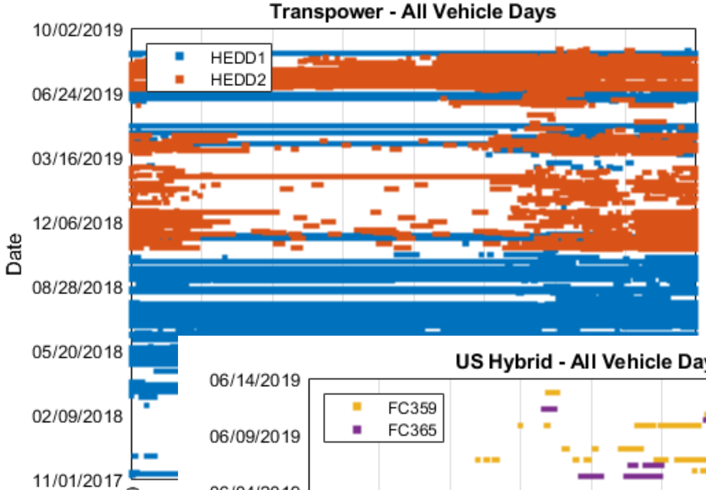
One way to evaluate and compare advanced vehicle technologies is through the use of standard chassis dynamometer test cycles. Another is through the use of modeling and simulation tools running analyses on standard test cycles. Previous testing and analysis conducted by NREL has illustrated the influence of drive cycles on both energy consumption and greenhouse gas emissions [1, 2, 3, 4].

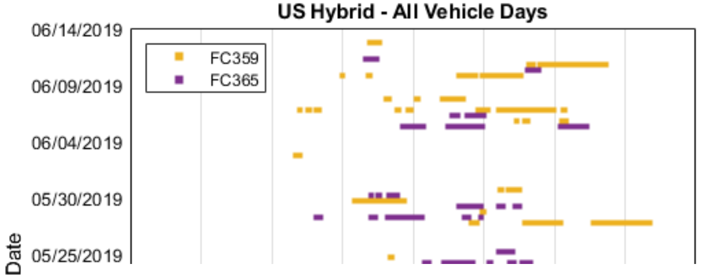
Researchers from NREL's Fleet Test & Evaluation group identified port drayage heavy-duty truck operations as a candidate for further research on the potential fuel savings impact of advanced technologies. Port drayage operation is a unique and specialized type of goods movement. Drayage refers to the movement of cargo containers, often called intermodal containers, between a port terminal and an inland distribution center or rail yard terminal.

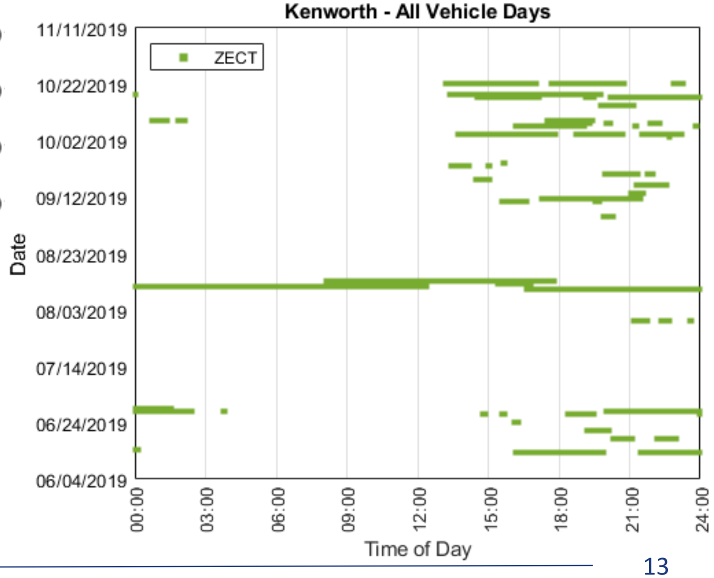
Figure 1. Map of Port of Long Beach and Port of Los Angeles showing 15 container terminals. Eleven have on-dock rail lines. [9, 10]











Remaining Challenges & Barriers

Fueling Infrastructure - Availability and location

- All temporary hydrogen fueling is in place and being used for the demonstration
- Permanent stations will be a challenge – South Coast AQMD is working with partners on a solution (Renewable hydrogen station, ZANZEFF project)

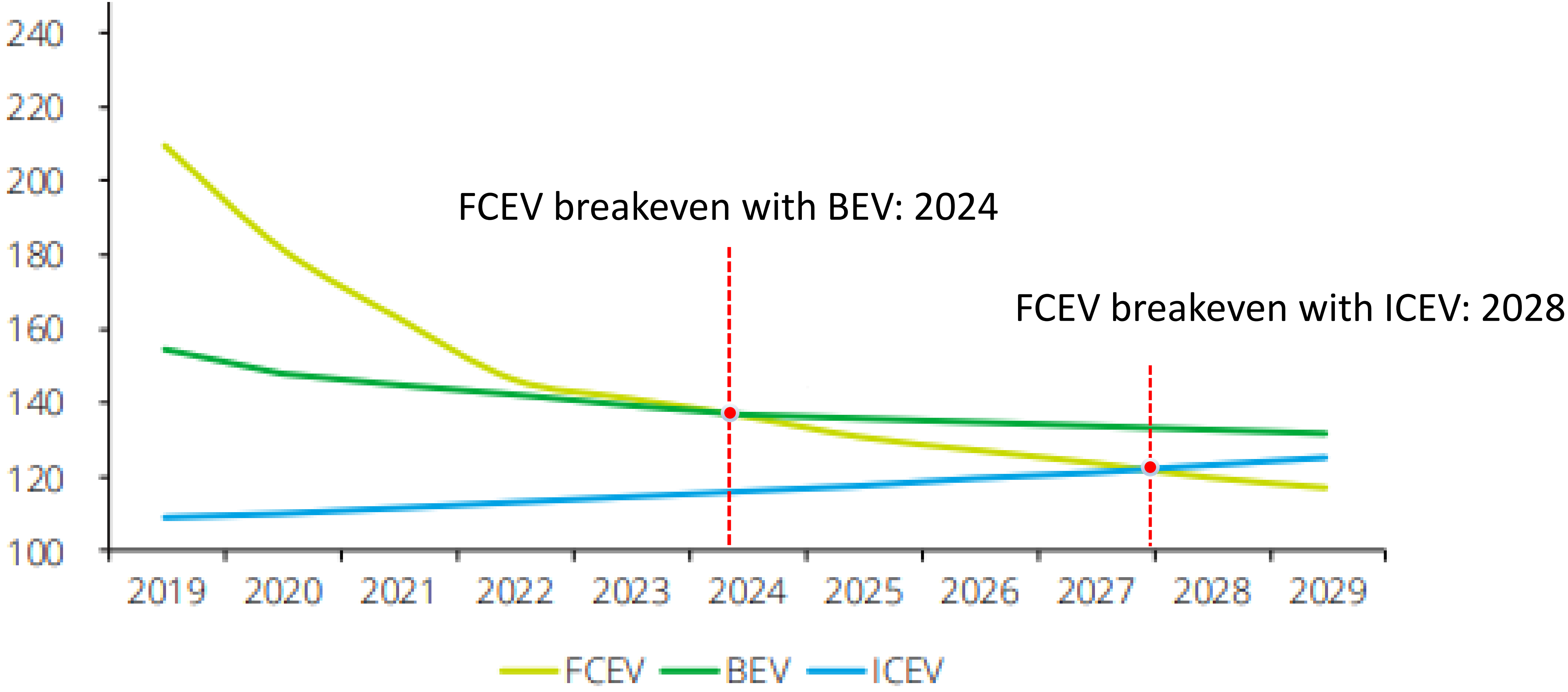
System Integration: Safe and efficient deployment of the technology

- Six of seven vehicle designs and integration are complete
- Design improvement and system optimization
- Analyze data collected and secure reliability

Costs and Application

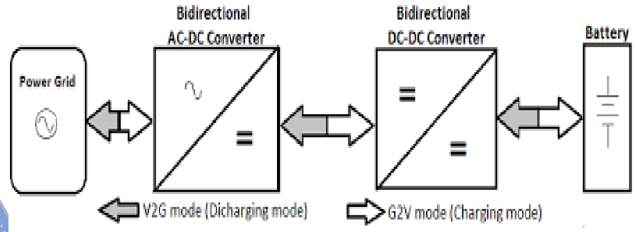
- Costs will remain a challenge for the near and mid term
- Penetration into mid or long range application

Total TCO /USD per 100km



https://info.ballard.com/hubfs/Other%20Reports/Deloitte%20Volume%201%20Powering%20the%20Future%20of%20Mobility.pdf

South Coast AQMD



Electric School Bus with V2G and V2B Demonstration Projects

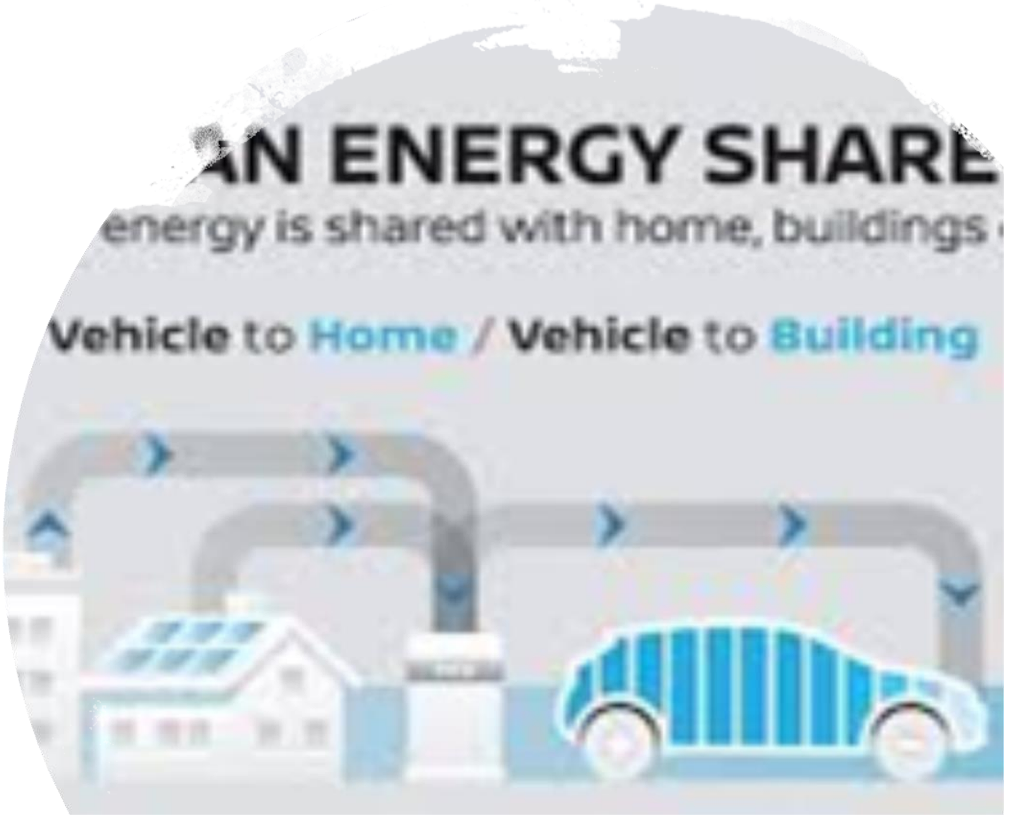
Mei Wang

Program Supervisor

Electric School Bus with V2G V2B Demonstration Projects

Project Concepts

- V2G is the ability of EVs to discharge the energy stored in their batteries back to the grid when the EVs are not in operation.
- V2B aggregate the energy from EVs aims to sustain the operation of building when unexpected outage
- Supply energy at times of peak demand and generate revenue to reduce the cost of ownership
- Utilize high-power inverter-charger (ICU) with bidirectional capability to recharge batteries and export power to grid or building
- School buses are large with room for batteries/energy storage and have significant non-operational time



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Electric School Bus with V2G V2B Demonstration Projects

Retrofit six diesel powered type C school buses

- Battery-powered electric drive
- V2G and V2B
- Onboard fast charger
- 70kW inverter charger – bidirectional

Project Partners:

- National Strategies, LLC
- Torrance Unified School District
- California Energy Commissions
- TransPower

South Coast AQMD

CALIFORNIA ENERGY COMMISSION

TORRANCE UNIFIED SCHOOL DISTRICT ESTABLISHED 1947

nsi

South Coast AQMD

Electric School Bus with V2G V2B Demonstration Projects

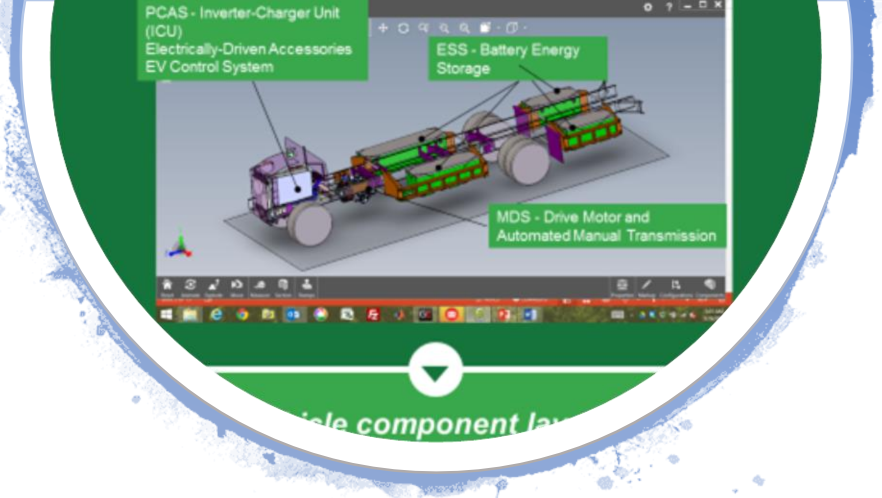
Torrance Unified School District

- 2 V2G buses with 115kW-hr energy storage
- Bidirectional inverters
- On-board chargers
- Utility interconnection
- Charge/discharge control system
- Charging infrastructure

South Coast AQMD

South Coast AQMD

Electric School Bus with V2G V2B Demonstration Projects

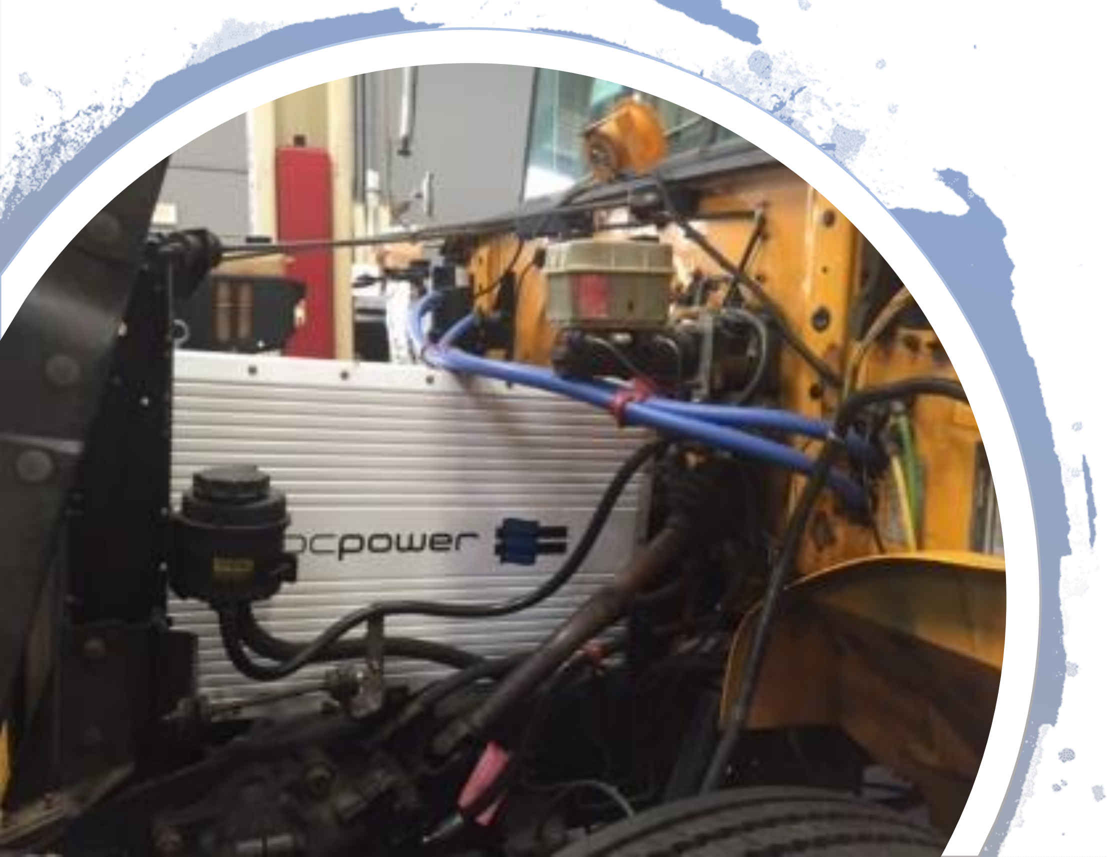


Project demonstrated:

- Conversion of type C school bused from diesel to electric drive
- Served as energy storage and generate revenues
- Frequency regulation to grid

Lessons learned:

- Retrofitting of 20-year-old school buses
- Reliability challenges – engineering interfaces
- SCE interconnectic



next project ›

Electric School Bus with V2G V2B Demonstration Projects

V2G School Bus Commercialization

Project Partners:

- Deportment of Energy
- South Coast AQMD
- Rialto Unified School District
- Blue Bird
- Vehicle subcontractors
  - Cummins Electrified Power
  - EPC Power
- NuVve
- National Renewable Energy Laboratory (NREL)
- National Strategies LLC

Electric School Bus with V2G V2B Demonstration Projects

Overall Objectives

- Create a electric school buses based on a competitive total cost of ownership
- Equip with V2G income-generating grid integration capabilities
- Advance the technical maturity of selected medium-duty electric drive components to achieve superior energy efficiency and reduce operating costs

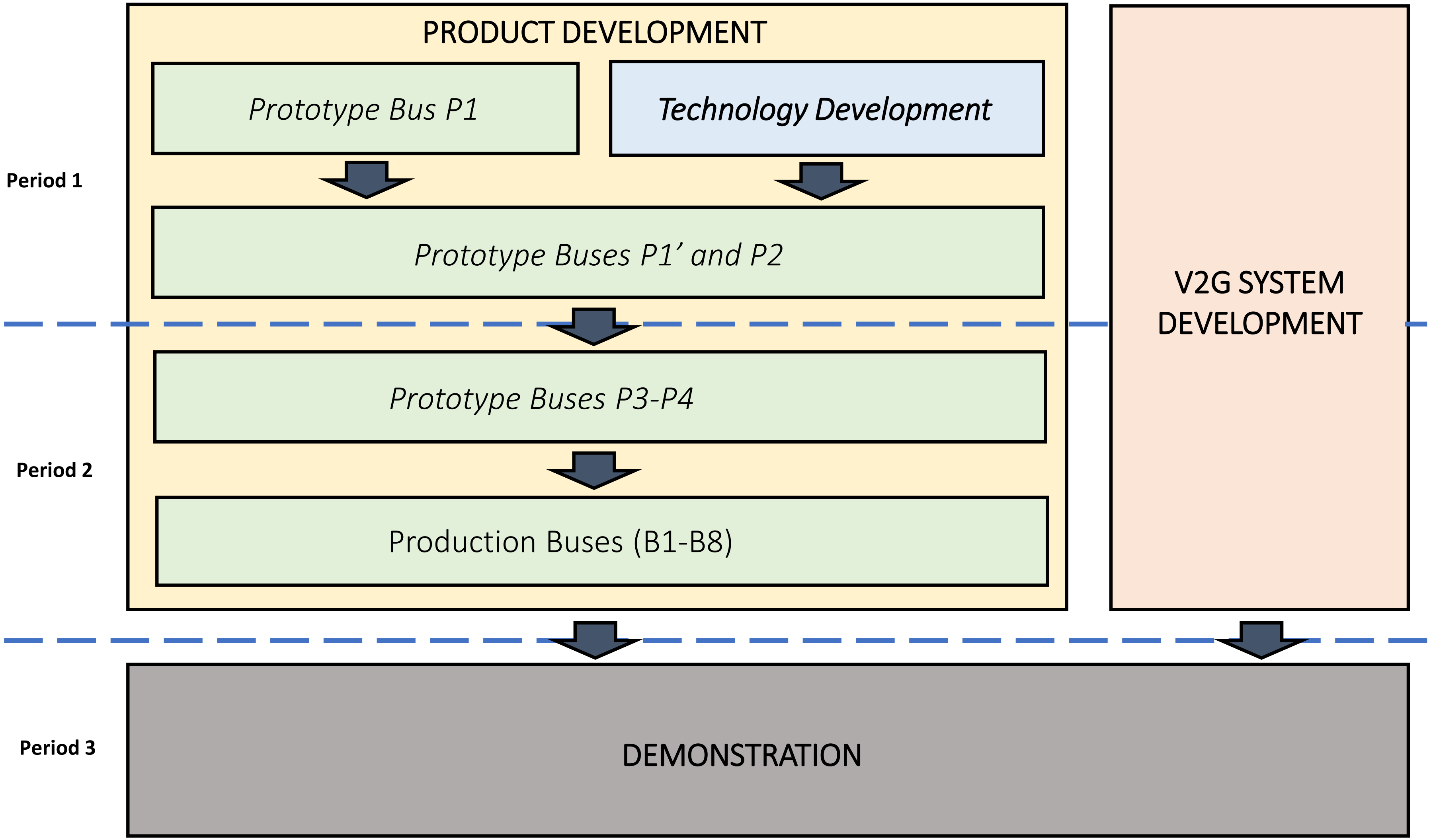
South Coast AQMD

Electric School Bus with V2G V2B Demonstration Projects

- Eight type C V2G school buses
- Deployed at Rialto Unified School District's new pupil transportation facility (currently under construction)
- Charge/discharge power capacity: 150 kW per bus
- "Full-strength V2G" = participate in wholesale ancillary services market

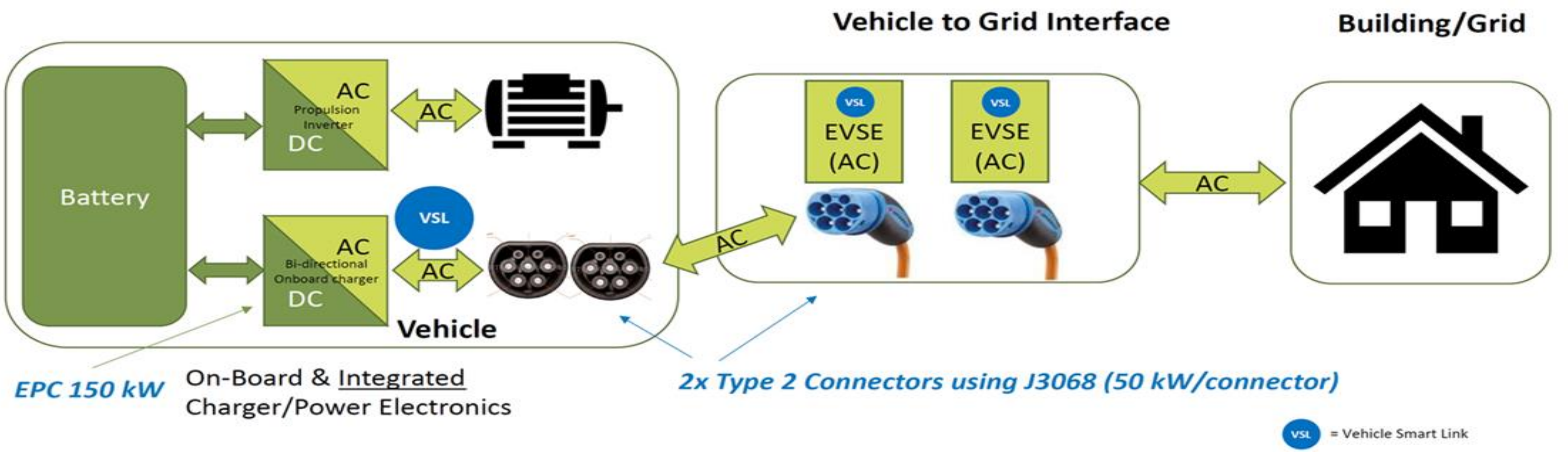
South Coast AQMD

Project Flow



Electric School Bus with V2G V2B Demonstration Projects

- Achieved energy efficiency of 1.32 kWh/mile for prototype bus P1' from the initial P1 benchmark of 1.53 kWh/mile
  - Goal of 1.10 kWh/mile (note: climate control is excluded from efficiency benchmark)
- Initiated process of adapting high-power inverter
- Weight Reduction – 620 lbs
  - Goal -1000 lbs reduction



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NEXT STEP

- Achieve energy efficiency of 1.10 kWh/mile
- Bidirectional inverter certification and package
- Obtain interconnection agreement with SCE
- Commission V2G charging stations
- Documenting total-cost-of-ownership
- Project under review by DOE and Blue Bird

Questions?

South Coast
AQMD

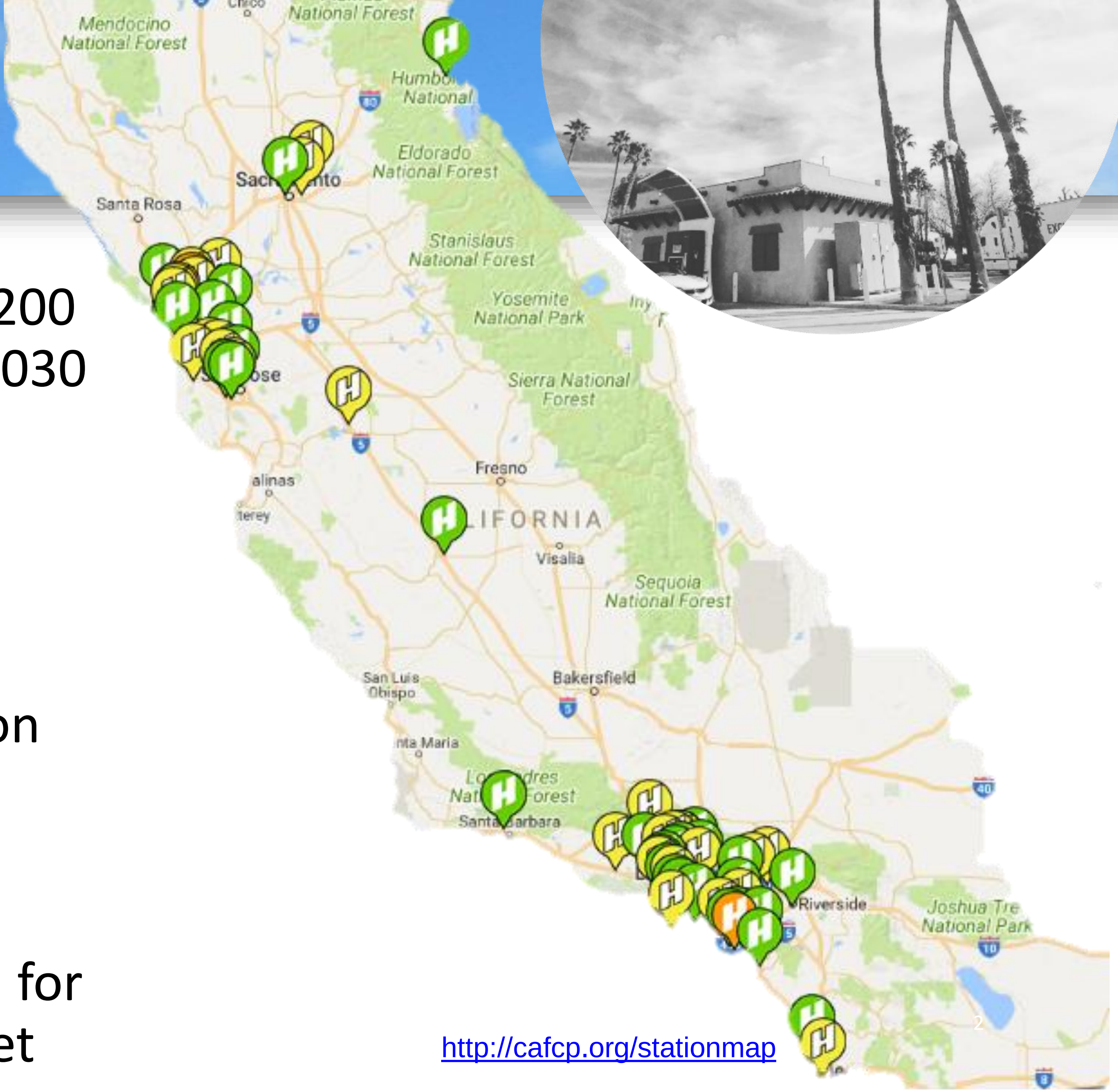
Clean Fuels Advisory Group Meeting
February 6, 2020

Hydrogen Infrastructure for Heavy-Duty Vehicles

Lisa Mirisola
Program Supervisor
Science and Technology Advancement
South Coast AQMD

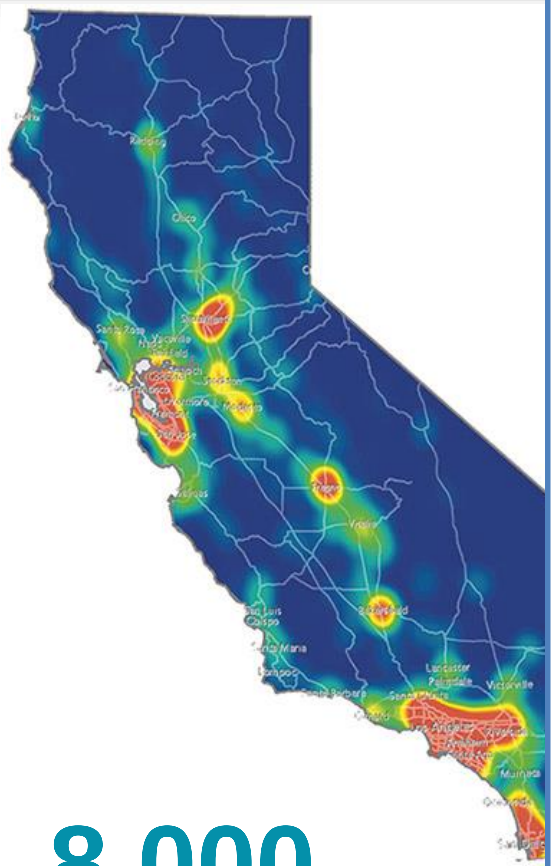
California Activities

- Executive Order B-48-18 targets 200 HRS by 2025 and 5MM ZEVs by 2030
- New H2 production facilities
- New heavy duty fuel cell truck projects
- Innovative Clean Transit regulation
- Low Carbon Fuel Standard Amendments
- CaFCP publishes new 2030 vision for a self-sustaining California market



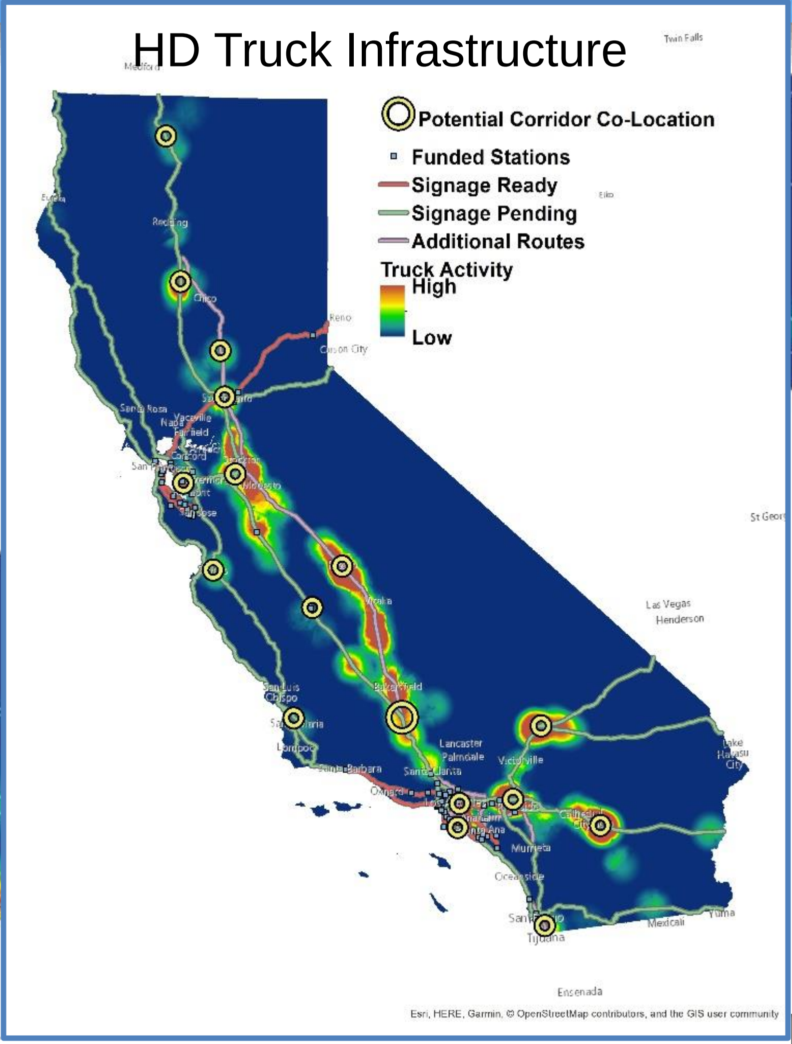
http://cafcp.org/stationmap

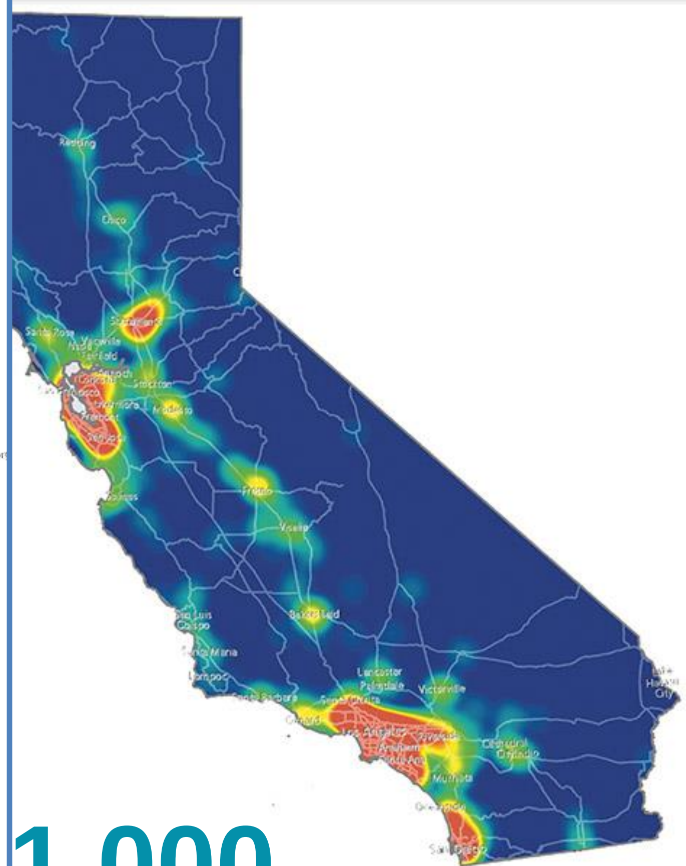
Image of a Successful Self-Sustaining Market



8,000

retail gas stations





1,000

retail H2 stations

Infrastructure Challenges

- Cost
- Supply Chain:
  H2 Production, distribution, parts
  (need multiple suppliers)
  Scale, skilled labor
- 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 issues

Hydrogen Fueling Industry

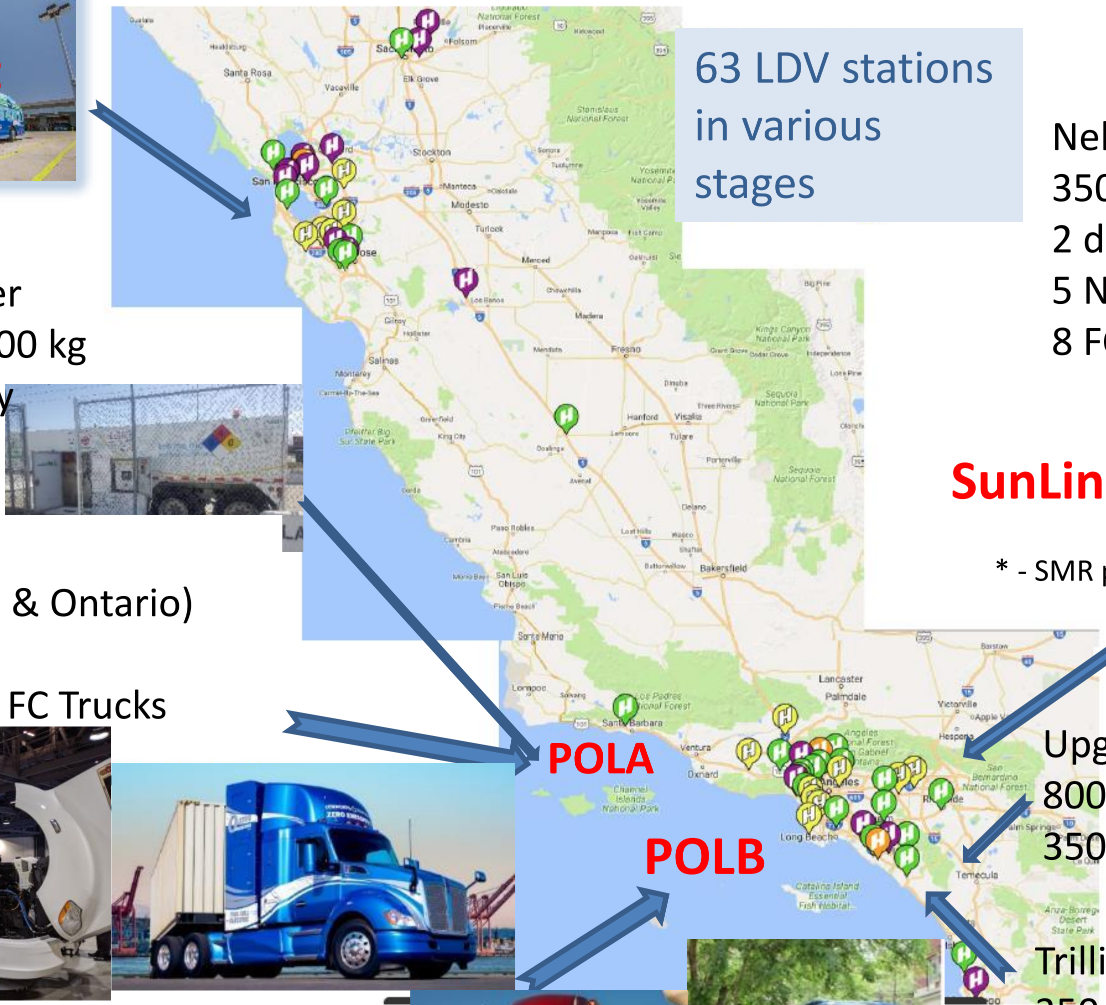
- High-flow Components Consortium
- Mercedes Heavy Duty
- Toyota Scale-Up
- Hyundai Scale-Up
- Cummins buys Hydrogenics
- Niche FCEV Markets Profitable
- IEA Study
- Deloitte Study
- McKinsey Study
- California GFO
- EU Innovation Fund
- RED II – Europe
- 400 mile range, 5 minute fueling

"Trucks have a challenge, long-haul trucks, that they will not greatly operate with a battery, not with the chemistry we have today," Schafer said at a CES briefing. "Our first application of Fuel cell will be in buses and trucks."

-Daimler R&D Chief, Markus Schafer, CES 2020

CA Hydrogen Stations

APCI Trailer
350 bar, 300 kg
10 fills/day



63 LDV stations in various stages

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

* - SMR production for 10+ years

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

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

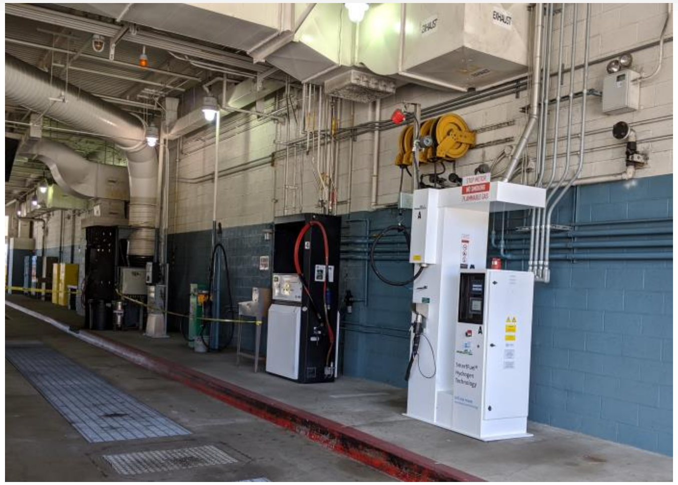
OCTA
Trillium, APCI LH2 delivery
350 bar, 1600 kg/day
10 New Flyer, 36 kg/bus,
6-10 min fill

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

(Photo: Toyota)

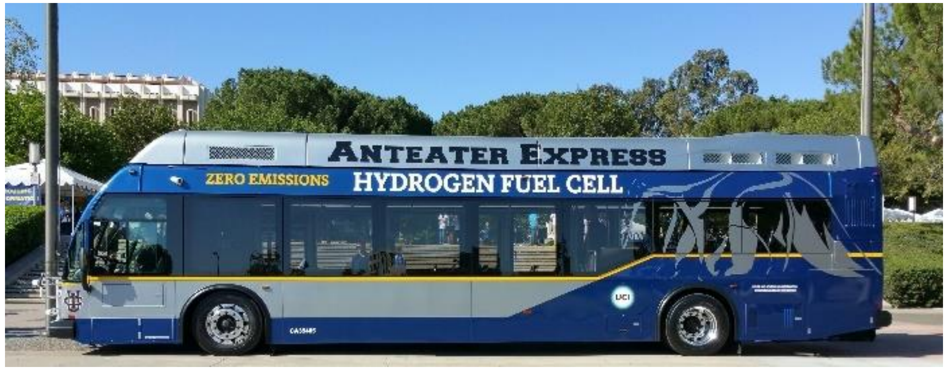
OCTA Liquid Hydrogen Fueling Station

- Trillium CNG with Air Products liquid hydrogen deliveries
- Hydrogen station event for partners January 31, 2020
- Fueling time 6 – 10 minutes/bus with 350 bar
- 280 kg peak back to back fills, 1,450 kg/day
- 10 New Flyer 40’ buses in operation
  85 kW Ballard fuel cell and 80 kWh Li-FePO4 batteries
- Each bus uses 35.6 kg/day to provide >300 miles range
- Infrared communication/grounding with TN1 receptacle on buses
- Compliant with SAE standards J2601-2 (2014), J2578, J2799, and J2719



UC Irvine Hydrogen Station Expansion

- UCI station has been operating at design capacity and is in urgent need of additional capacity to fuel cars and buses.
- Proposed expansion to 800 kg/day with liquid delivery, increased storage, and four fueling positions
- Public use will continue 24/7, with buses scheduled to refuel at night
- Co-funding approved & contracts executed
  - MSRC for up to $1M (PON 2018-02)
  - CEC $400k (ARFVTP)
  - SCAQMD $400k (Clean Fuels)



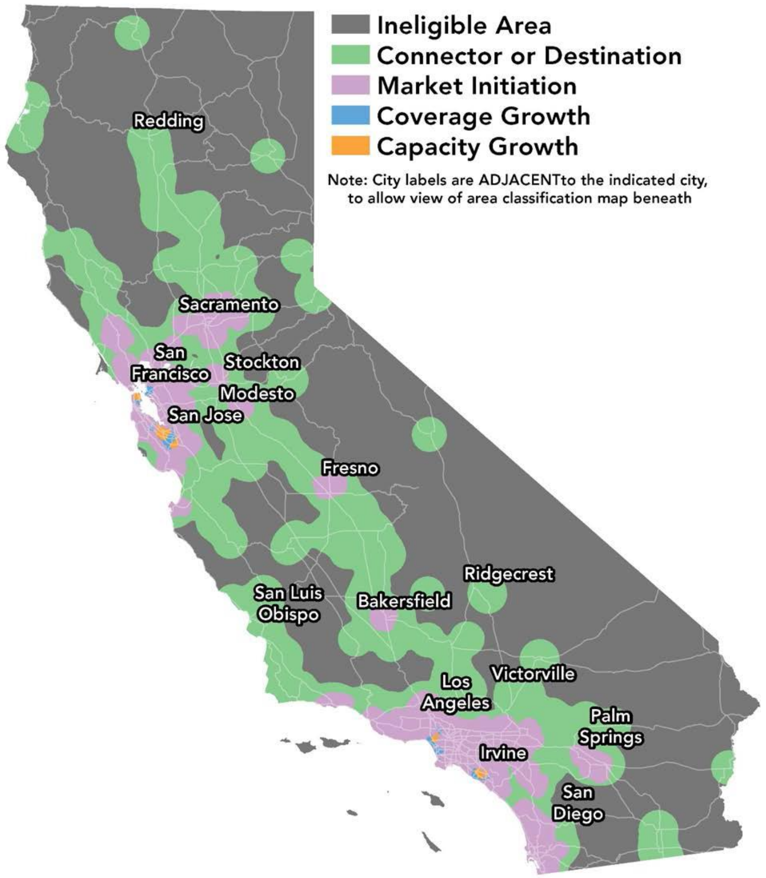
California Hydrogen Infrastructure Research Consortium

- 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 data
  - ➢ Hydrogen Contaminant Detection
  - ➢ Nozzle Freeze Lock
  - ➢ CA Hydrogen integration
  - ➢ Technical Assistance

Co-funding for Hydrogen Infrastructure

GFO-19-602 Hydrogen Refueling Infrastructure

- $45.7M currently available; up to $115.7M total
- New or upgraded retail hydrogen stations in eligible areas
- Minimum 50% match: cash or in-kind
- 40% renewable & qualifies for LCFS credit
- Encourage commercial vehicle and bus fleet usage, designed & managed to avoid conflicts with cars
- Deadline to submit applications: April 30, 2020
- Anticipated NOPA: June 2020
- Anticipated Business meeting: August 2020



- https://www.energy.ca.gov/solicitations/2019-12/gfo-19-602-hydrogen-refueling-infrastructure

Credit for Increased Infrastructure Investment

Click to save a picture to your desktop.

Potential LCFS Credit Revenue for Hydrogen

Fuel Production Technology	Feedstock	Example Carbon Intensity	Fuel Displacement Multiplier	Potential LCFS Credit Revenue
Steam Methane Reformation	Fossil natural gas	117.67 gCO2e/MJ	1.9	$1.57/DGE
	Biomethane from landfills	99.48 gCO2e/MJ	1.9	$2.03/DGE
	Biomethane from dairy/swine manure	-300 gCO2e/MJ	1.9	$12.24/DGE
Electrolysis	CA grid electricity	164.46 gCO2e/MJ	1.9	$0.37/DGE
	Zero-CI electricity	10.51 gCO2e/MJ	1.9	$4.30/DGE

CARB Note: assumes $190/credit, the average for June, 2019 23

https://ww3.arb.ca.gov/fuels/lcfs/electricity/zev_infrastructure/zev_infrastructure.htm

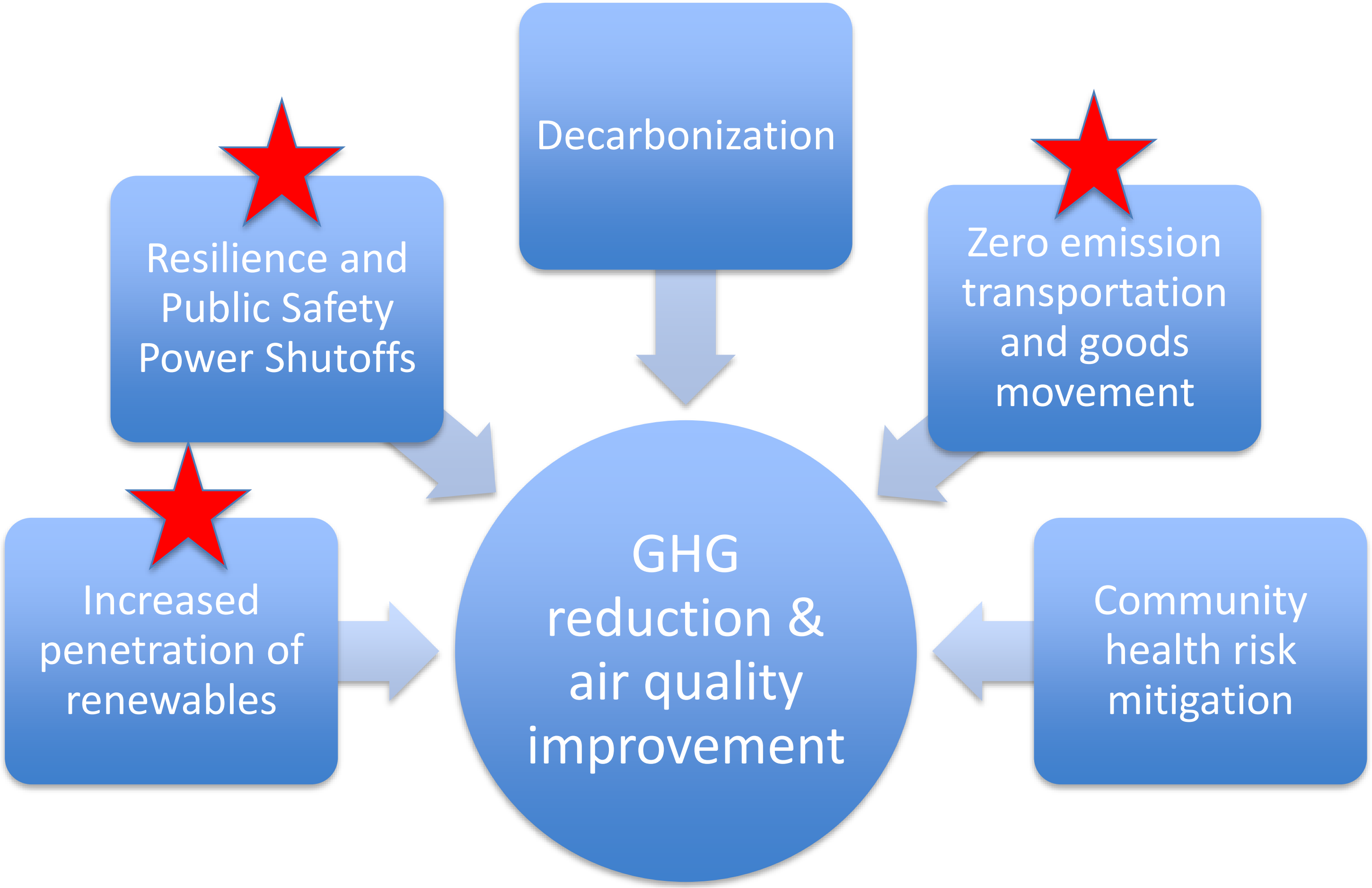
Infrastructure for ZE Heavy-Duty Vehicles - Microgrid

Technology Advancement Office
Air Quality Specialist

Seungbum Ha

Clean Fuels Program Advisory Retreat
Feb. 6, 2020

California Policy Priorities



Microgrid for Heavy-Duty Vehicle Deployment?

Charging 100 Electric drayage trucks:
- 50kW * 100 trucks = 5MW & 6 hours continuous charging (300kWh/truck)
- 150kW * 100 trucks = 15MW & 2 hours continuous charging
- 30MWh energy

Fueling 100 Hydrogen drayage trucks:
- 20 kg * 100 trucks = 2,000 kg of hydrogen everyday

Grid or hydrogen station can support cost-effectively?

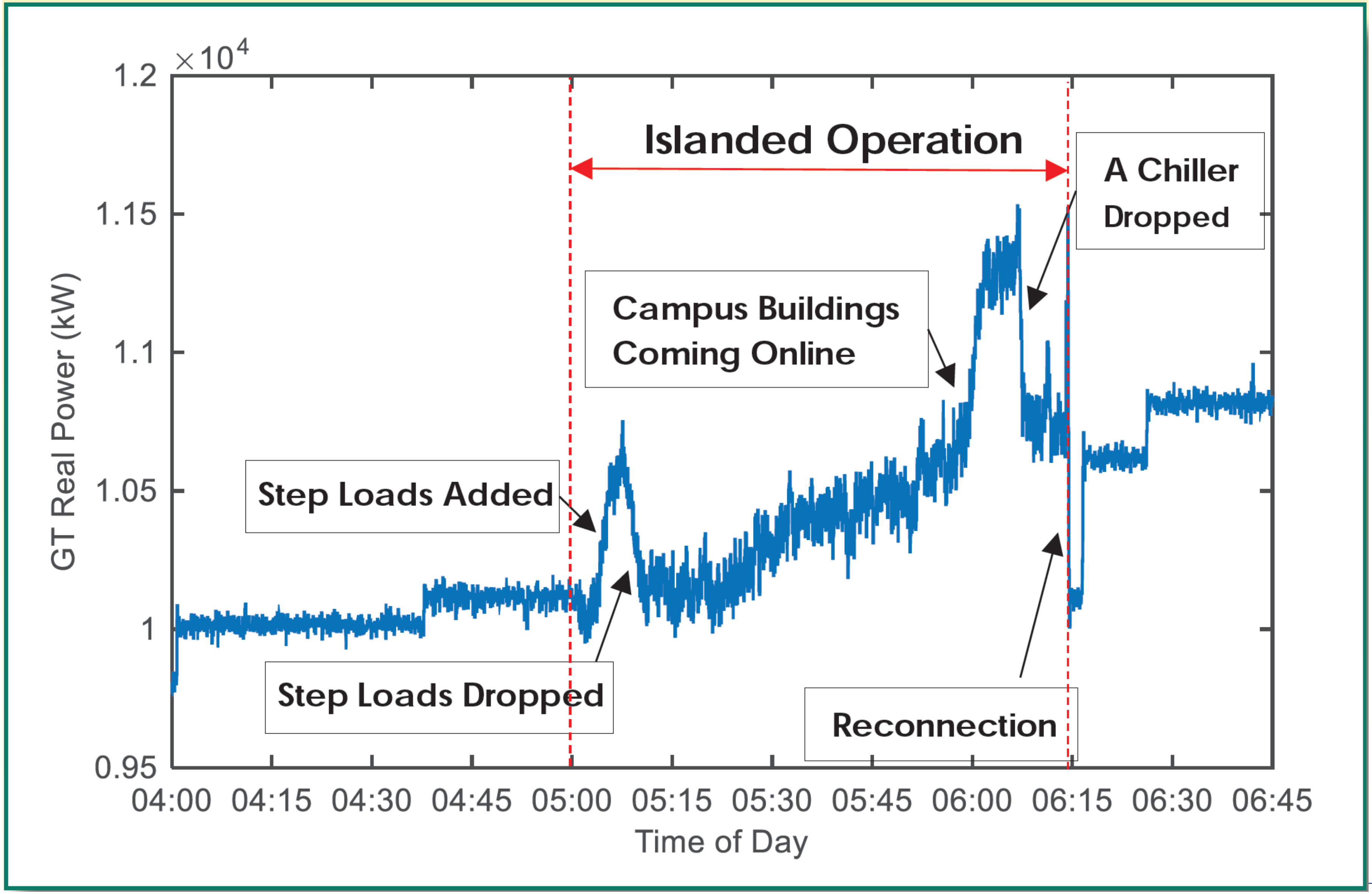
What if grid/station shut down?

Renewable energy?

Duck curve?

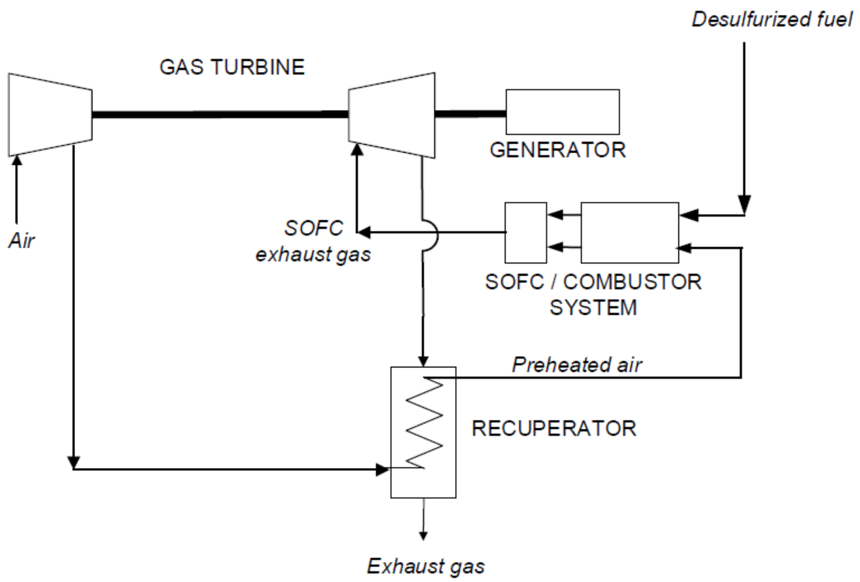
UCI Microgrid

Islanding of the UCI Microgrid



UC Irvine NFCRC, Jack Brower, Presentation

Fuel Cell-Gas Turbine Hybrid Technology



- Primary focus for stationary power generation
- Include natural gas, biogas and renewable hydrogen applications in the 1-10 megawatt range
- Potential for repowering locomotives and ocean going vessel power

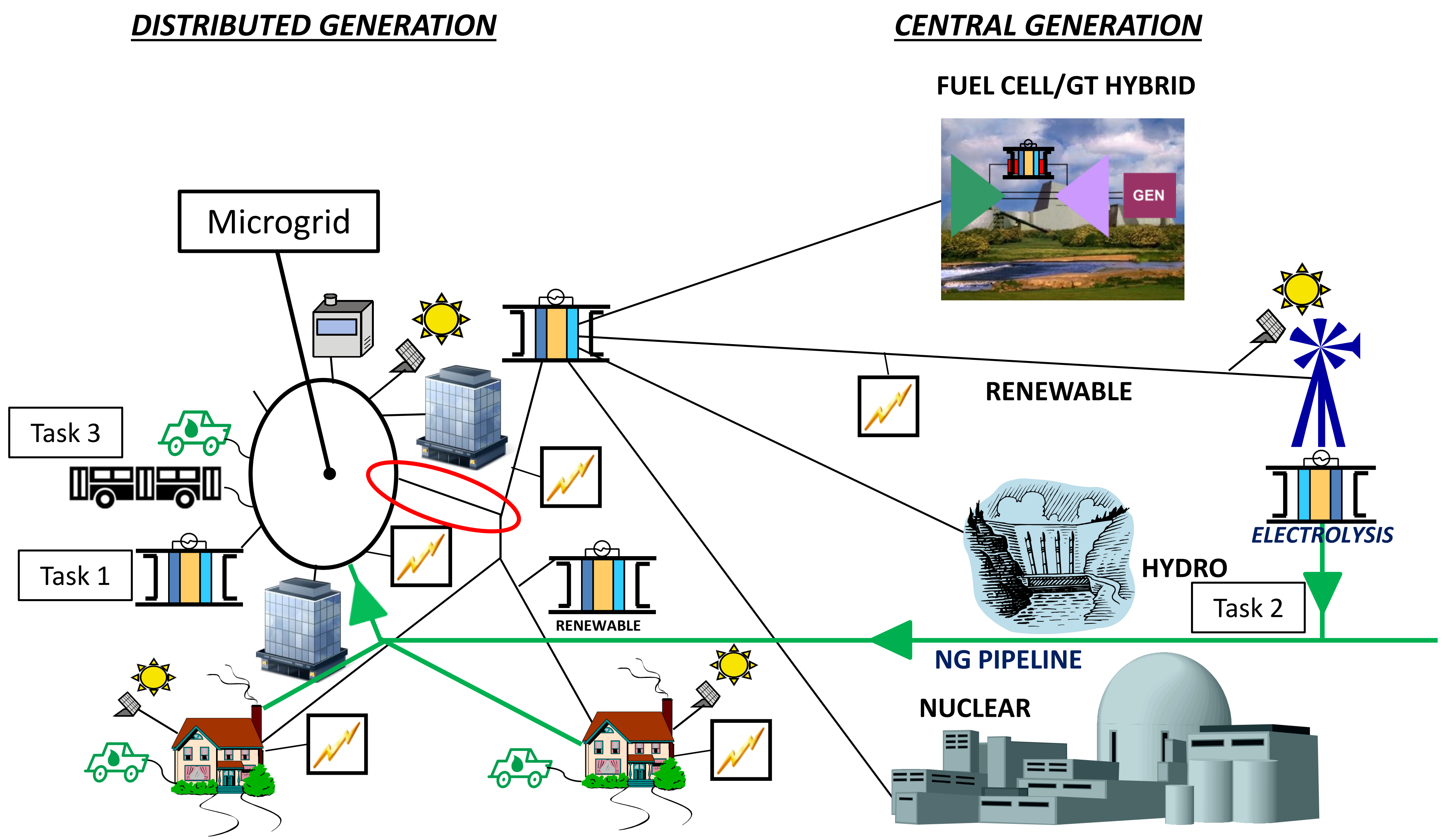
Optimal Operation Model for Renewable Electrolytic Fuel Production

- Optimize dispatch and operation of facilities
- Analyze electrolysis technology
- Develop a model to assess air quality impacts
- Hypothetic Scenarios
  - Renewable wind/solar electricity to hydrogen
  - CO_2 from an anaerobic digester combined with electrolytic H_2 to produce renewable methane
  - Up to 50 MW of solar electricity to generate renewable H_2 or methane using CO_2 from an anaerobic digester and inject into CNG pipeline

Air Quality and Greenhouse Gas Impacts of a Microgrid-Based Electricity System

- Fuel Cell Technology for Industrial and Petroleum Refinery Microgrids
  - Overall assessment of the criteria pollutant and GHG advantages of increased deployment of fuel cells in industrial and commercial applications, including petroleum refineries
- Comparative study on Environmental-Economic Impacts of Fuel Cell and Battery Electric Buses within a Microgrid
  - Conduct a comparison study of the operational and economic performance of a fuel cell and battery-electric buses
- Assess the Emission Impacts of Renewable Fuel Blending in the Natural Gas System
  - Evaluation of advantages and disadvantages of increased renewable fuel integration into the natural gas system

Microgrid system



Assess the Emission Impacts of Renewable Fuel Blending in the Natural Gas System

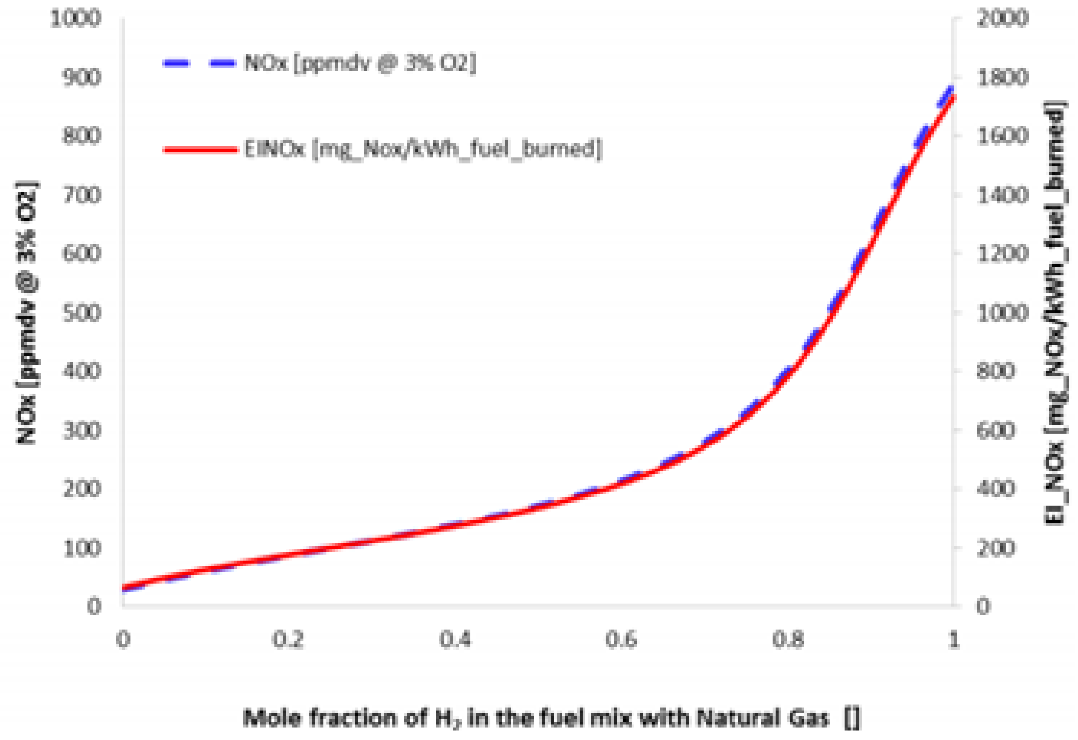
- The need for storage and transmission of renewable hydrogen generated via electrolysis and biomass/biogas pathways could support injection into the NG grid
- Combustion devices operating on NG will be impacted by transitions to NG/H2 blends, including changes in criteria pollutant emissions
- Emissions changes vary depending on combustion device and gas mixture composition
- Generally, NOx emissions from residential and commercial appliances decrease for H2 blends, but operability limits present challenges
- Emissions from NG boilers could increase or decrease depending on the burner technology, and could have the largest impact on air quality

Assess the Emission Impacts of Renewable Fuel Blending in the Natural Gas System

Impacts on emissions of NOx from industrial combustion burner – Radiant tube

Table 2. Summary of emissions for interchangeable mixtures (AGA)/3

Fuel Mixture	NO_x [ppmdv]	CO [ppmdv]
76% CH_4 - 24% H_2	↑266%	↓35%
94% CH_4 - 6% C_2H_6	=	↑4%
95% CH_4 - 5% C_3H_8	↑5%	↑ 4%
98% CH_4 - 2% CO_2	↓2%	↑2%



Assess the Emission Impacts of Renewable Fuel Blending in the Natural Gas System

Impacts on emissions of NOx from residential appliances

H_2 (Vol %)	0%	5%		10%		15%		20%		30%		40%		50%	
	NOx [ppm]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]	NOx [ppm]	NOx [Δ%]
Cookstove	109.90	88.80	19.20	89.50	18.56	88.20	19.75	85.30	22.38	87.60	20.29	86.10	21.66	84.30	23.29
Space Heater	100.90	103.50	-2.58	103.20	-2.28	103.20	-2.28	102.10	-1.19	99.90	0.99	96.70	4.16	--	--
Tankless WH 2 gal/min	37.50	34.70	7.47	33.00	12.00	31.50	16.00	29.90	20.27	--	--	--	--	--	--
Tankless WH 4 gal/min	17.90	16.30	8.94	16.30	8.94	14.80	17.32	13.50	24.58	--	--	--	--	--	--
Low-NO_x WH	10.90	9.50	12.84	--	--	--	--	--	--	--	--	--	--	--	--

Benefit of Microgrid

- Reduced emissions
  - Facilitate integration of zero-emission generation and energy storage through controls and optimal dispatch
  - Provide charging/fueling infrastructure for zero-emission vehicles
  - Increase the deployment of renewable generation and fuels

- Facilitate integration of zero-emission vehicles

- Increase reliability and resiliency – Islanding capability
  - Operation during grid outages
  - Serving critical load and facilities

SOUTHERN CALIFORNIA
EDISON®
Energy for What's Ahead®

SCE's Charge Ready Transport Program

Justin Bardin

Program Manager

SCE's Charge Ready Transport program provides infrastructure for fleet electrification

Launched May 2019

- Approved total program budget of **$356.4M**
- Achieve minimum **870 sites** with **8,490 electric vehicles** procured or converted
- **Covers cost of all infrastructure** needed up to charging station
- **Charging station rebates** available for **transit/school buses** and **sites in disadvantaged communities**

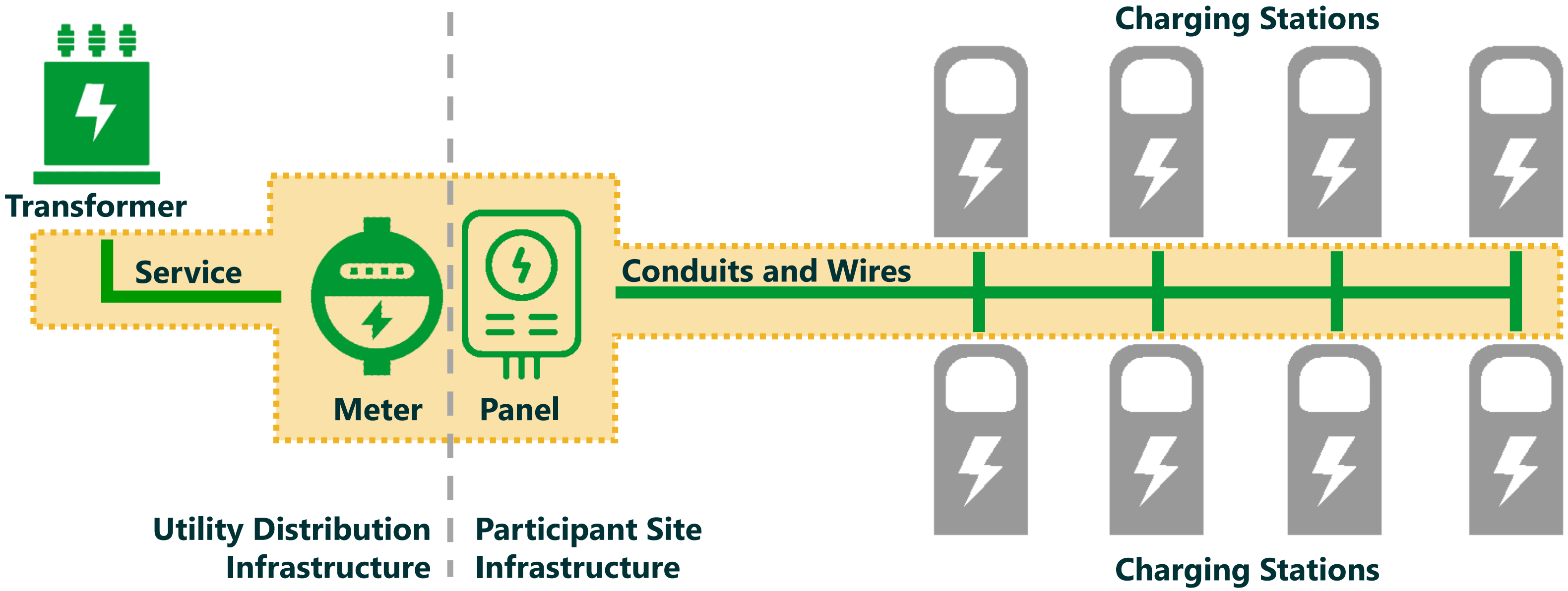
Apply	→	Reserve Funding	→	Permits	→	Design & Build	→	Rebate
www.SCE.com/CRT		**2-3 months**		**45 days**		**6-9 months**		**1 month**

Charge Ready Transport supports medium and heavy-duty electric vehicles

- Medium-Duty Vehicles
- Heavy-Duty Vehicles
- Forklifts
- School Buses
- Transit Buses
- Port Cargo Trucks
- Airport Ground Support Equipment
- Transportation Refrigeration Units (TRU)

SCE installs "make-ready" electrical infrastructure at no cost

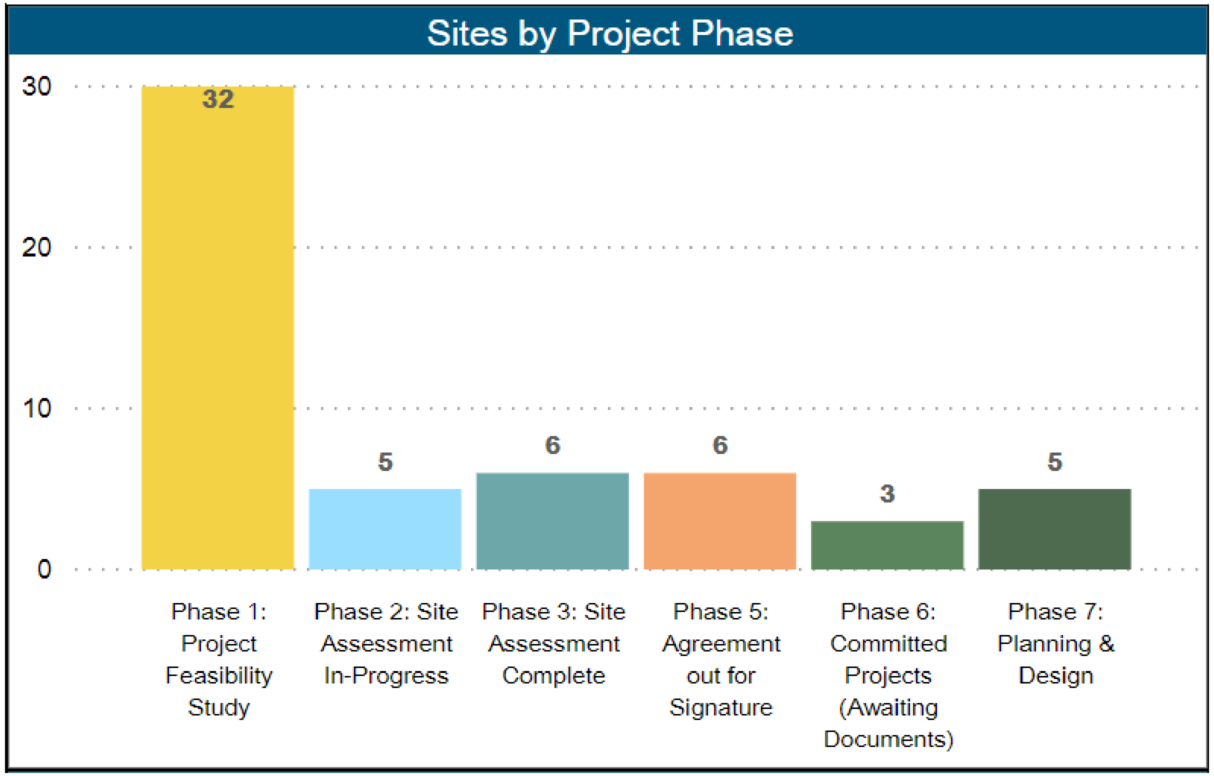
- Standalone charging station model



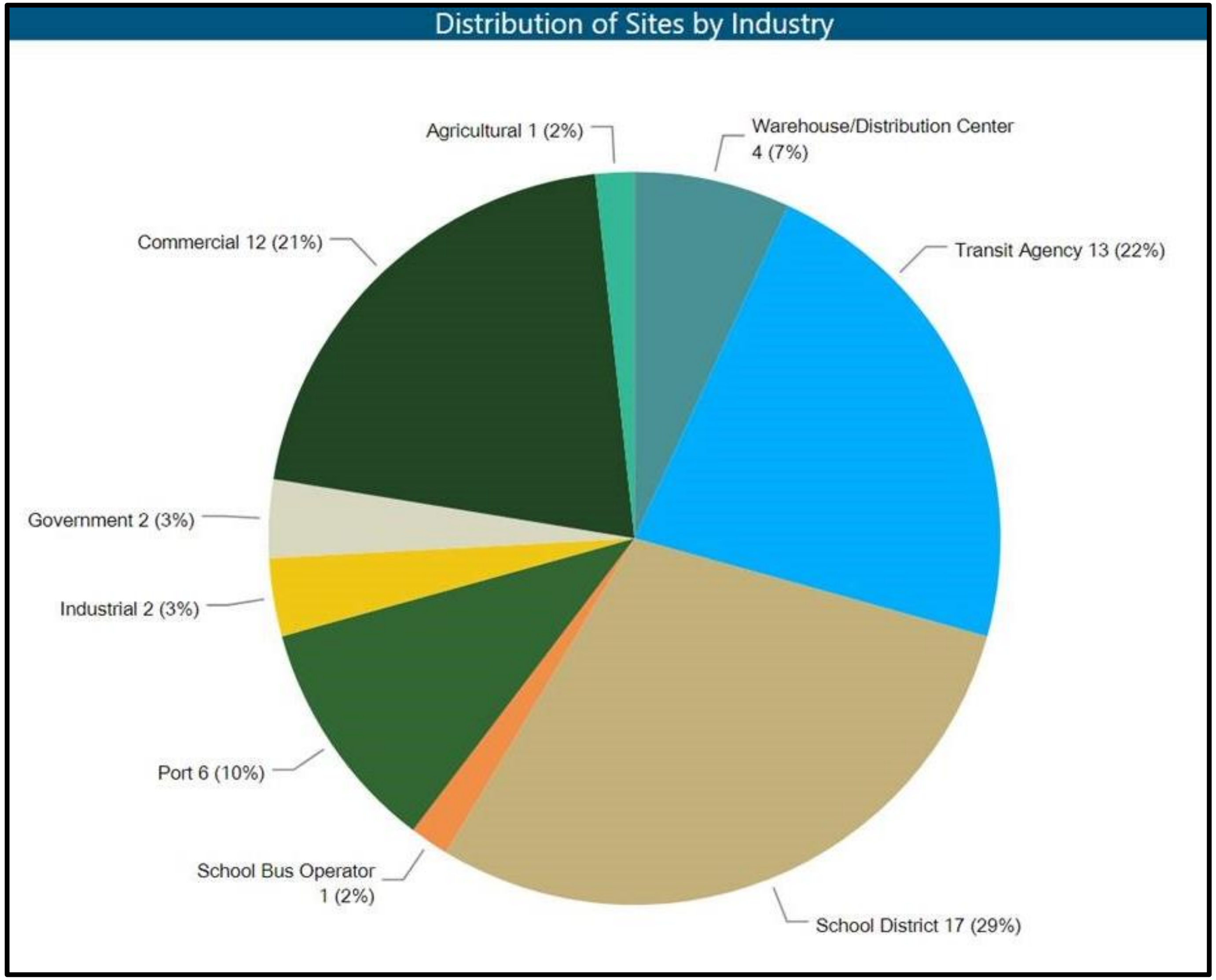
Program covers costs associated with service drop, meter, panel, and circuit dedicated to EV charging. Make-ready ends at interconnection point with customer charging equipment providing AC service.

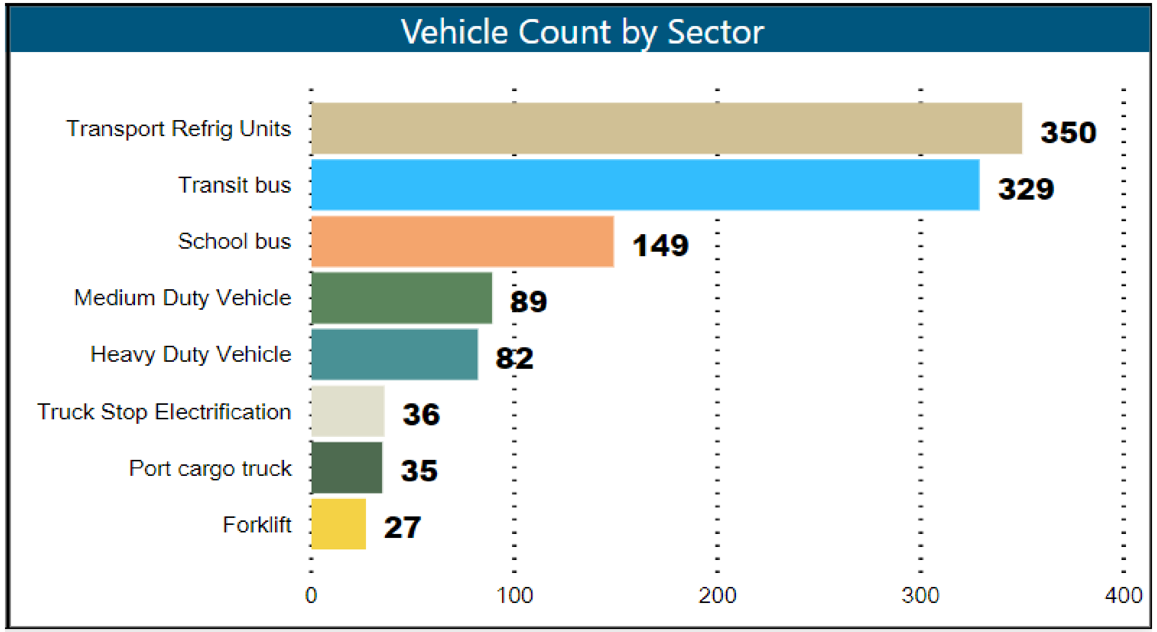
Current Progress

- SCE is currently working with **57** sites that can support up to **1,097** MDHD electric vehicles



Site Characteristics





Beyond CRT, SCE's role is to improve availability, affordability, & awareness

Availability Infrastructure necessary to fuel EVs	**Affordability** Low cost in comparison to traditional vehicles	**Awareness** Customer understanding of benefits of EVs
❑ Build out capitalized charging infrastructure for: • Passenger vehicles at workplaces, apartments, and public locations • Commercial freight vehicles • Transit buses	❑ Provide charging station rebates for commercial & residential ❑ Provide new and used vehicle rebates (Low Carbon Fuel Standard) ❑ Invest in customer-side infrastructure ❑ Offer special rates for EV charging	❑ Provide market education and outreach programs ❑ Run broad and targeted advertising ❑ Provide fleet customer support and advisory services

SCE's New EV Rates

- Available for all MDHD electrification sites – not just CRT
- **Zero demand charges until 2024**
- Encouraging off-peak charging – higher energy rates on-peak (4-9 PM)
- EV rates available for separately-metered charging installation

Calendar Year	2019-2023	2024	2025	2026	2027	2028	2029+
% of Final Demand Charges	0%	16.67%	33.33%	50%	66.7%	83.33%	100%

Next Steps

- Continue customer outreach through marketing campaigns, conferences, etc.

- Develop resources and tools to educate customers about the advantages of fleet electrification and aid in their planning process (e.g. Fueling Cost Calculator)

- Continue to improve application and construction process for CRT sites

Appendix

Energy for What's Ahead®

SOUTHERN CALIFORNIA EDISON®

Charge Ready Transport Program Activity Flow

A — Funding Request
Applicant determines

1. Program Enrollment Application
2. EV Acquisition Plans

B — Funds Reservation
2-3 months

3. Application Screening & Prioritization
4. Project Site Evaluation
5. Conceptual Infrastructure Design
6. Program Participation Agreement

Optional participant program termination at no additional cost prior to this point

C — Pre-Construction Commitments
45 days

7. Proof of Electric Vehicle Acquisition
8. Proof of Charging Equipment Acquisition
9. Rebate Assignment

D — Design & Build Phase
6-9 months

SCE Builds Infrastructure

10. SCE Performs Detailed Site Design Work
11. Grant Final Easement
12. SCE to Request & Secure Permits
13. Construct Infrastructure
14. Participant Installs Charging Equipment

Customer Builds Make-Ready

15. Participant Performs Detailed Site Design Work
16. Grant Final Easement
17. Participant Requests & Secures Permits
18. Construct Make-Ready Infrastructure
19. Participant Installs Charging Equipment

E — Issue Rebates
1 month

20. Charging Equipment Installation Verification
21. Review Documentation & Issue Rebates
22. Complete Program Surveys

F — Compliance Verification
10 year duration

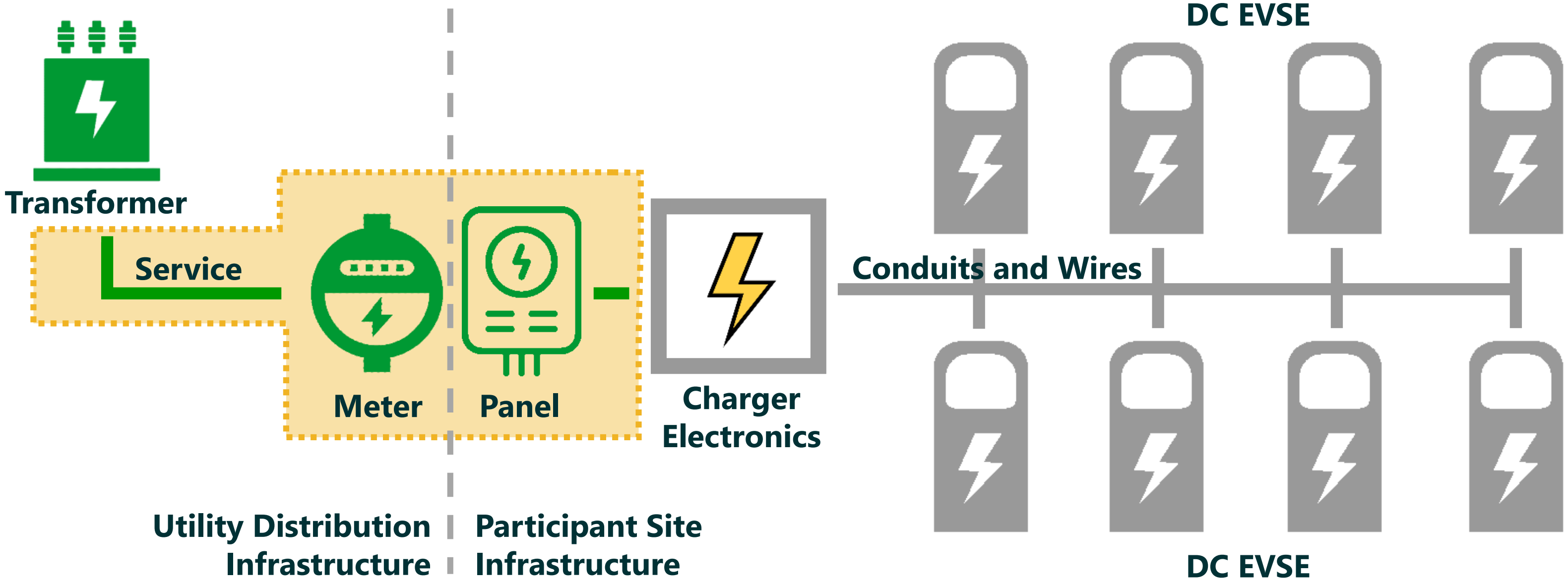
23. Completion of Planned EV Acquisitions
24. Compliance with 10-Yr Operation of Charging Equipment
25. Compliance with 5-Yr Port Level Data Sharing Commitment

LEGEND

- Approximate Timeline
- Program Participant
- SCE

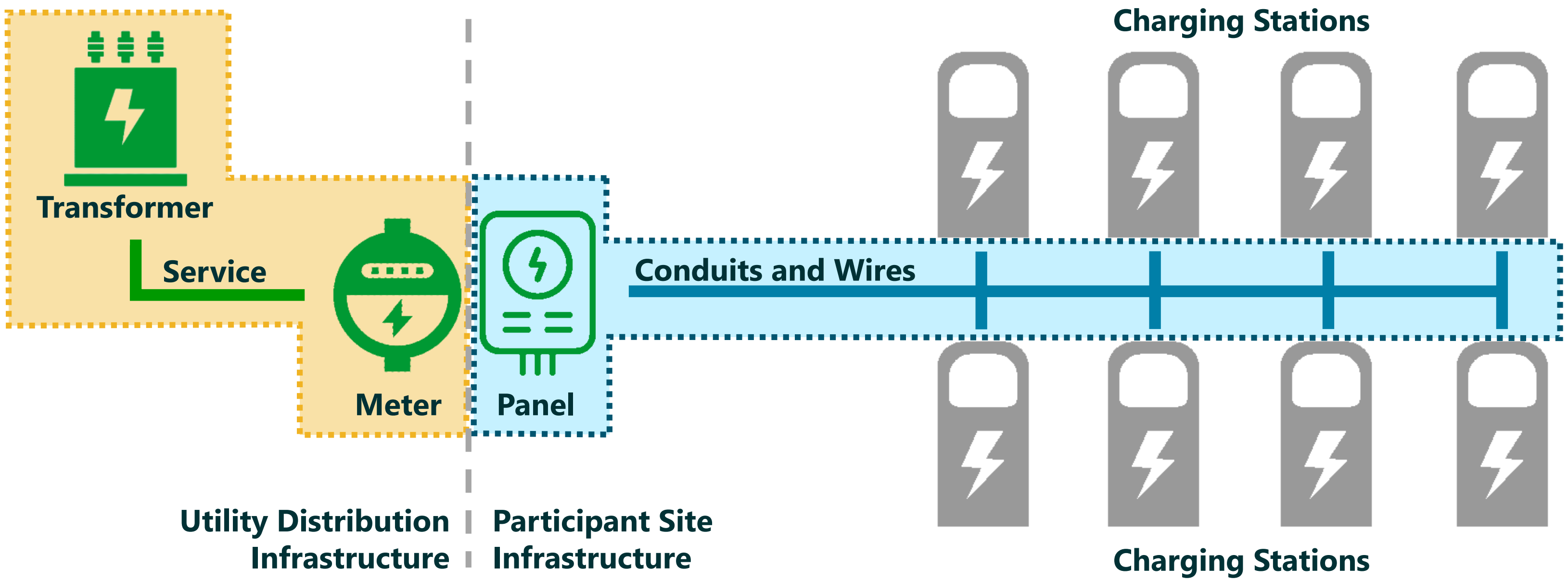
Defining Make-Ready Infrastructure

- Centralized charger electronics with modular DC power distribution



Program covers costs associated with service drop, meter, panel, and circuit dedicated to EV charging. Make-ready ends at interconnection point with customer charging equipment providing AC service.

Make-Ready Infrastructure (Customer-Built)



Program covers costs associated with service drop and meter. SCE infrastructure ends at interconnection point with customer-provided panel.

Customer will provide panel and construct all conduits and wires leading to interconnection point with charging equipment.