



Advanced Clean Truck Workgroup Meeting

February 25, 2019

Agenda

- Market segment analysis
- Fleet total cost of ownership
- Infrastructure needs
- Next steps/general discussion



Zero Emission Vehicle (ZEV) Market Segment Analysis

ZEV Market Segment Analysis

- Initial EMA market segment assessment for 87 truck categories
- Four main categories plus miscellaneous (green, yellow, red designations)
 - Weight
 - Daily range
 - Access to infrastructure
 - Space for batteries, fuel cell and tank placement
 - Other miscellaneous factors
- Overall 1-5 suitability score for each truck segment
- Helps identify vehicle types and uses that are easier to electrify
- Reflects today's technology

CARB's Adjustments

- Removed double counting between four main segments and miscellaneous categories
- Revisited weight and range categories
 - No changes for space constraints and infrastructure
 - Truck segment description left unchanged
- Segment suitability scored on a quantitative basis
- Added a fuel cell electric vehicle (FCEV) assessment
- Detailed spreadsheet on website for comment¹

Truck Segment Spreadsheet

Market Segment	Class	Total CA Sales	Battery-Electric Suitability Factors			
			Loading	Routes/Range	Infrastructure/ Charging	Battery Space Constraints
H-D Van - Contractor	2B-3	11854	Heavy	50-150 miles per day, High route variability	Some central dispatch, many go with driver o/n	Constrained
H-D Van - Shuttle	2B-3	1116	Light	50-300 miles per day, Medium route variability	Centralized, but 24/7 operation	Open
H-D Van - Refrigerated	2B-3	70	Heavy	200-300 miles per day. Refrigeration reduces range, High route variability	Centralized, at night	Constrained
Pickup Truck - 4WD Off Road	2B-3	5000	Light to moderate	Variable--expect some will have long distance routes.	Variable--off road usage will likely be away from EV grid. Off-highway usage and extended operation will make charging impossible for extended offroad operation.	Constrained
Box Truck - Pickup & Delivery (Fixed Light <100 Miles per Day)	4-7	3075	Light	Variable <100 miles per day	Centralized	Open
Box Truck - Pickup & Delivery (Medium to Heavy Load >100 Miles per Day)	4-7	1538	Medium to heavy	Variable >100 miles per day	Centralized	Open
Box Truck - Pickup & Delivery (Medium to Heavy Load >200 Miles per Day)	4-7	1538	Medium to heavy	Variable >200 miles per day	Centralized or remote	Open
Regional Tractor - Medium Haul	8	400	Variable, up to 80K GCW	Variable, 100-300 miles per day	Centralized, at night. Multiple shift operations impact charging times	Constrained, short wheelbase
Port Drayage	8	120	Heavy	Variable, 100-500 miles per day	Variable / Centralized, depending on owner. Multiple shift operations impact charging times	Constrained - short wheelbase
Refuse, Rear Packer, Residential Service	8	133	Start light, end day at max load	Fixed, 75 miles per day. Occasional long routes	Centralized, at night	Constrained

Battery Electric Vehicle (BEV) Range

- Revisited high mileage or route variability concerns
- EMFAC, Cal-VIUS 2018, VIUS 2002, and other data sources, show most straight trucks average less than 100 miles per day
- During initial deployments, ZEV's expected to make up a fraction of any one fleet
 - Conventional trucks can cover variable routes or intermittent needs until the technology further develops

Weight and Payload

- AB 2061 (2018) increases the upper weight limit of a zero- or near-zero emission vehicle by 2,000 lb.
 - Eliminates weight concerns for most Class 2B-7 vehicles
 - Reduces concerns for local or regional Class 8 vehicles
- Can also maintain same payload by moving up a weight class
 - Still issue with shifting from Class 6 to 7 due to commercial driver license requirements

FCEV Assessment

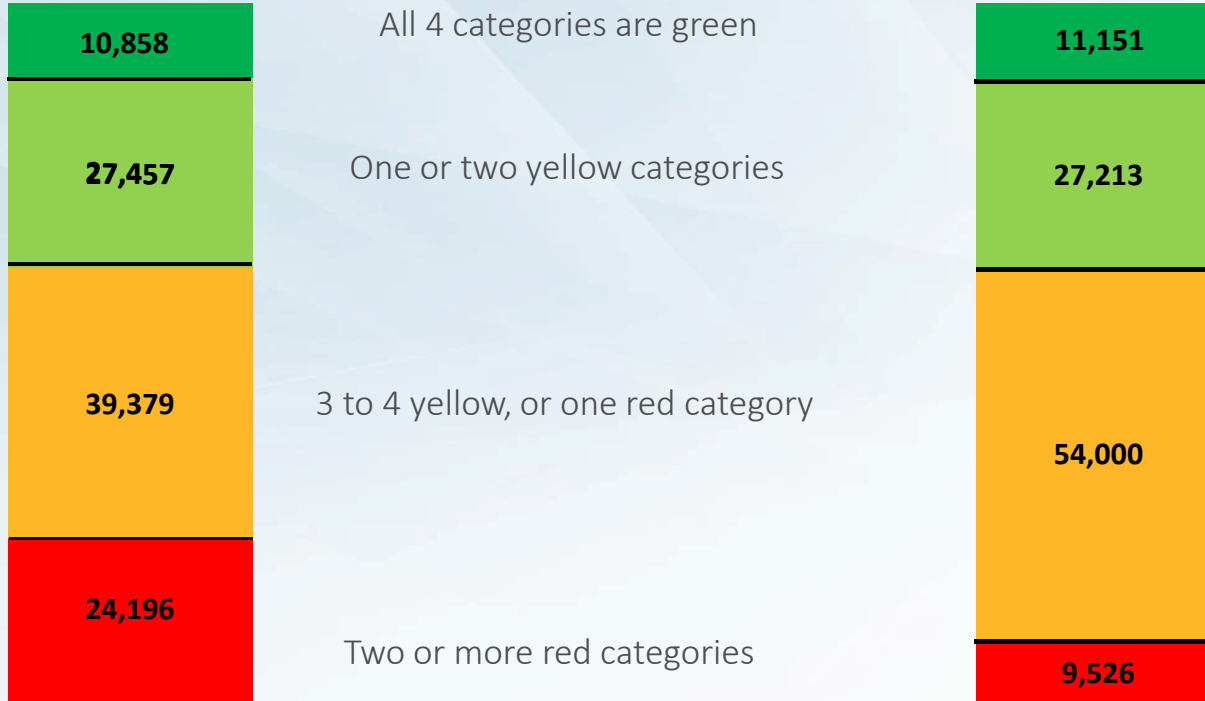
- Adjusted BEV assessment with some basic differences
- Range limitation category
 - Changed to green for all segments assuming same range as diesel
- Infrastructure access category
 - Centralized fueling – green
 - Class 2B-3 potential to use retail passenger car fueling – yellow
 - Up to 10 kg hydrogen storage tank
 - Class 4-8 assumed no access to retail fueling - red

CARB Market Assessment Results

California Annual Truck Sales

BEV

FCEV



Truck Segment Results by Weight Class For Annual California Sales

Battery Electric

Class	Score 1	Score 1.1-2	All other vehicles	Percent of total sales scored 1 or 2
2B-3	2,353	19,192	53,352	29%
4-7	7,436	6,555	5,422	72%
8	1,069	1,710	4,801	37%
Total	10,858	27,457	63,575	37.6%

Fuel Cell Electric

Class	Score 1	Score 1.1-2	All other vehicles	Percent of total sales scored 1 or 2
2B-3	2,472	19,573	52,852	29%
4-7	7,610	6,484	5,319	73%
8	1,069	1,156	5,355	29%
Total	11,151	27,213	63,526	37.7%

ZEV Truck Segment Summary

Reflecting Today's Market

- Class 4-7: ~70% of sales suitable for electrification
- Class 2B-3 and Class 8 have suitable vehicles for electrification, but currently represent a smaller portion of total sales
 - High pickups sales assumed to be challenging
 - Tractor assessment for regional use requires further study
- Little difference between battery-electric and hydrogen fuel-cell when assuming no public refueling network
- Does not reflect future outlook

Wide Range of ZEV Class 4-7 Vehicles



School Bus

Manufacturers: 3 today, 2 coming
50-150 mi. range



Cutaway Shuttle

Manufacturers: 3 today
100-130 mi. range



Delivery Vans

Manufacturers: 5 today, 2 coming
80-120 mi. range



Cabover Chassis

Manufacturers: 1 today, 2 coming
100-150 mi. range



Conventional Chassis

Manufacturers: 1 today, 2 coming
100-200 mi. range

Several Class 2B-3 and Class 8 Vehicles



Tractor Trailer

Manufacturers: 1 today, 5 coming
150-500 mi. range



Refuse/Straight Trucks

Manufacturers: 2 today, 2 coming
80-130 mi. range



Terminal Trucks

Manufacturers: 3 today
~60-80 miles per charge



Cargo/Passenger Van

Manufacturers: 2 today, 1 coming
50-150 mi. range



Heavy-duty Pickup/Utility

Manufacturers: 1 coming
120-200 mi. range

Outlook for the Future

- Several manufacturers targeting categories assessed as more challenging
- Battery density improvements
 - Decrease weight and space constraints, or
 - Enable greater range
- Innovative designs reduce barriers
 - Skate board platforms
 - Composite bodies, e-axles
 - Same or better payload than diesel today
- Fueling/charging network development can address infrastructure concerns





Fleet Total Cost of Ownership Draft Discussion Document

Vehicle Total Cost of Ownership (TCO)

- Diesel, BEV, and FCEV in 2018, 2024, and 2030
 - Class 3 passenger van
 - Class 6 walk-in stepvan
 - Class 8 regional day cab tractor
- Draft discussion document for comment on methodology and key assumptions



Total Cost of Ownership Analysis

- Vehicle capital costs
 - Vehicle price
 - Taxes
 - Financing costs
- Fuel costs
 - Dispensed fuel cost
 - LCFS credit revenue
- Other expenses
 - Maintenance cost
 - Midlife costs
 - Vehicle registration
 - Residual values at the end of analysis period
- Charging infrastructure costs

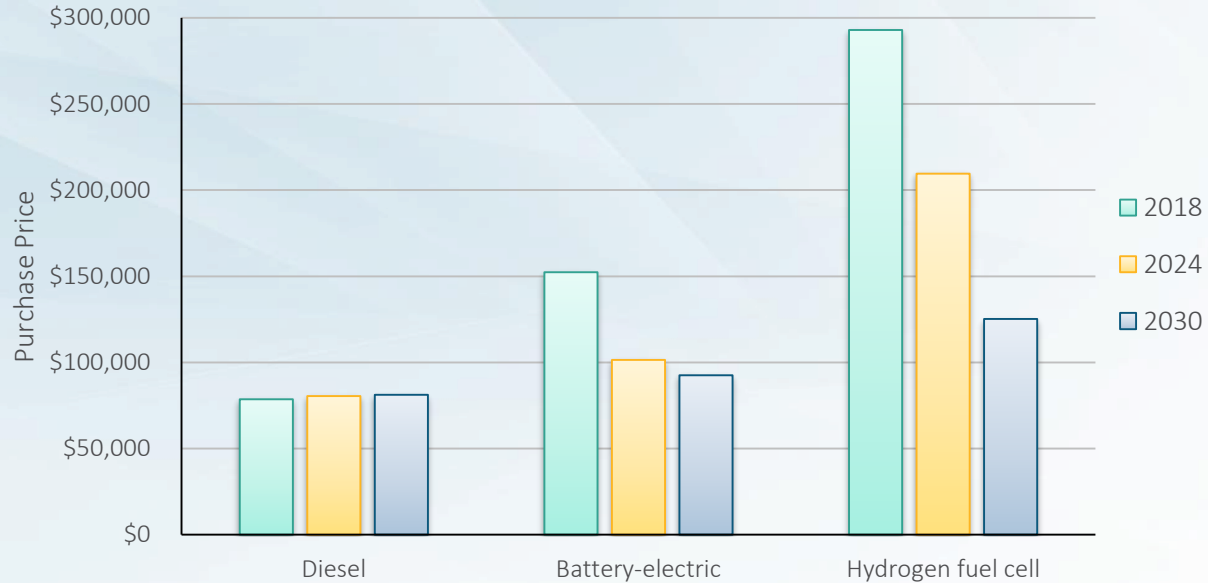
Vehicle Mileage and Analysis Period

- 12 year economic life assumed for all vehicles
 - Lower bound on how long a vehicle stays in operation
 - From DMV and EMFAC, most vehicles can last 20+ years
- Annual Miles – Based on EMFAC and a CALHeat report
 - Passenger van – 15,000 miles/yr
 - Stepvan – 24,000 miles/yr
 - Regional Tractor – 54,000 miles/yr
- Daily miles – assuming 300 days of operation

Vehicle Capital Cost

- Diesel truck prices
 - Manufacturer websites and online truck marketplaces for new and used
- Zero emission truck prices
 - Diesel glider plus component cost estimate
 - Battery costs
 - Bloomberg light-duty battery cost projections with a five-year delay
 - Suggestion from last workgroup meeting
 - BEV Component costs¹
 - FCEV component costs²
 - Retail price assumes 10% profit margin
- Taxes and financing costs included

Example – Stepvan Purchase Price



Fuel Costs and Efficiency

- Fuel Cost
 - Diesel – Energy Information Administration - Annual Energy Outlook 2018 with higher cost of Low Carbon Fuel Standard (LCFS)
 - Electricity – CARB Battery-electric Truck and Bus Charging Calculator
 - Hydrogen – Email from Trillium
- Fuel Economy/Efficiency
 - Diesel truck – GHG Phase 2 calculated fuel economy
 - BEV – in-use data from available studies
 - FCEV – Class 2B-3 – 2.5x more efficient than diesel, Class 4-8 – 1.9x more efficient than diesel
 - Diesel fuel economy decreases significantly in urban operation and not modeled for van or tractor (plan to include in future updates)

Electricity Costs

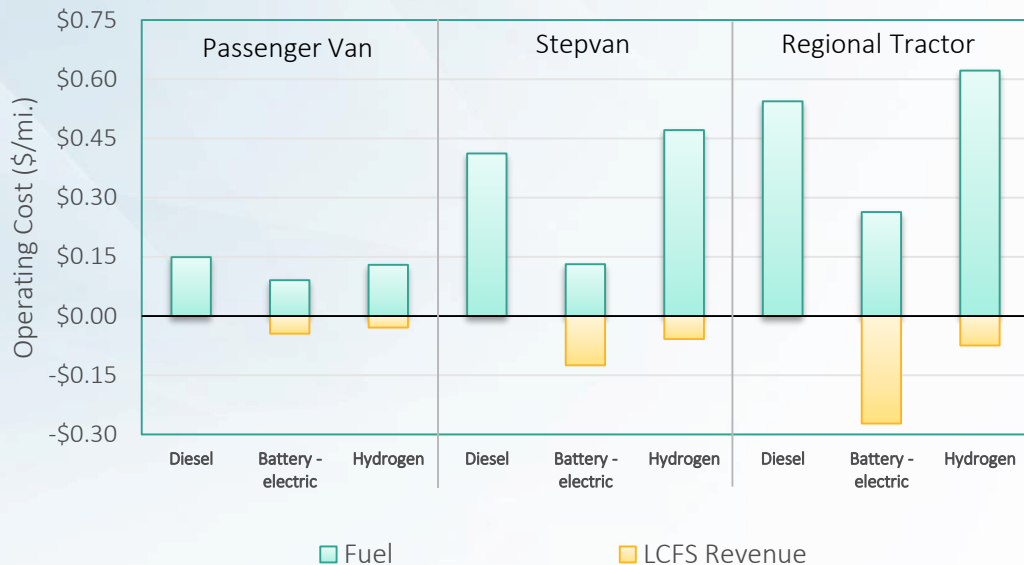
- Assumes 20 vehicles charged overnight in yard
- Determined with the Battery-electric Truck and Bus Charging Calculator
 - Energy charges
 - Demand charges
 - Fixed fees
 - 90% charging efficiency

	Passenger van (\$/kWh)	Delivery van (\$/kWh)	Regional tractor (\$/kWh)
LADWP	\$0.10	\$0.10	\$0.10
PG&E	\$0.15	\$0.14	\$0.13
SMUD	\$0.14	\$0.11	\$0.11
SDG&E	\$0.21	\$0.20	\$0.19
SCE	\$0.13	\$0.12	\$0.11
Statewide Average	\$0.14	\$0.13	\$0.12

Fuel Cost and LCFS Revenue

- Analysis based on LCFS at \$125/credit
 - Actual LCFS value higher credit at ~\$190 today
- Electricity cost for depot charging eliminated
- Assumes hydrogen near parity with diesel by 2024 with low volume

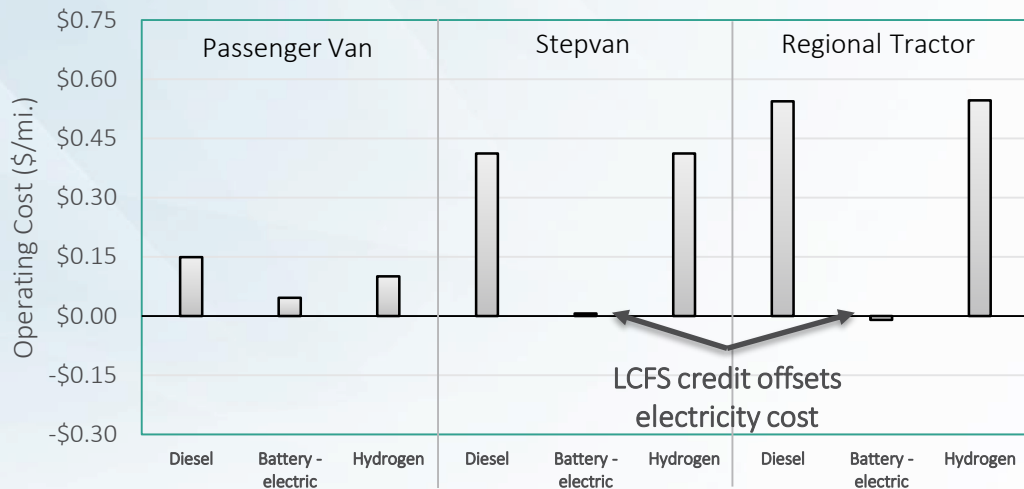
2024 Operating Cost per Mile Comparison



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2024 Operating Cost per Mile Comparison



□ Total Cost per Mile

Other Costs

- Maintenance
 - Diesel – based on in-use data
 - BEV – 25% maintenance reduction
 - FCEV – same as diesel
- Residual value at end of operating life
 - Diesel – For sale price by truck age using TruckPaper
 - BEV – Assumes 50% of diesel
 - FCEV – Assumes 25% of diesel

Other Costs (Continued)

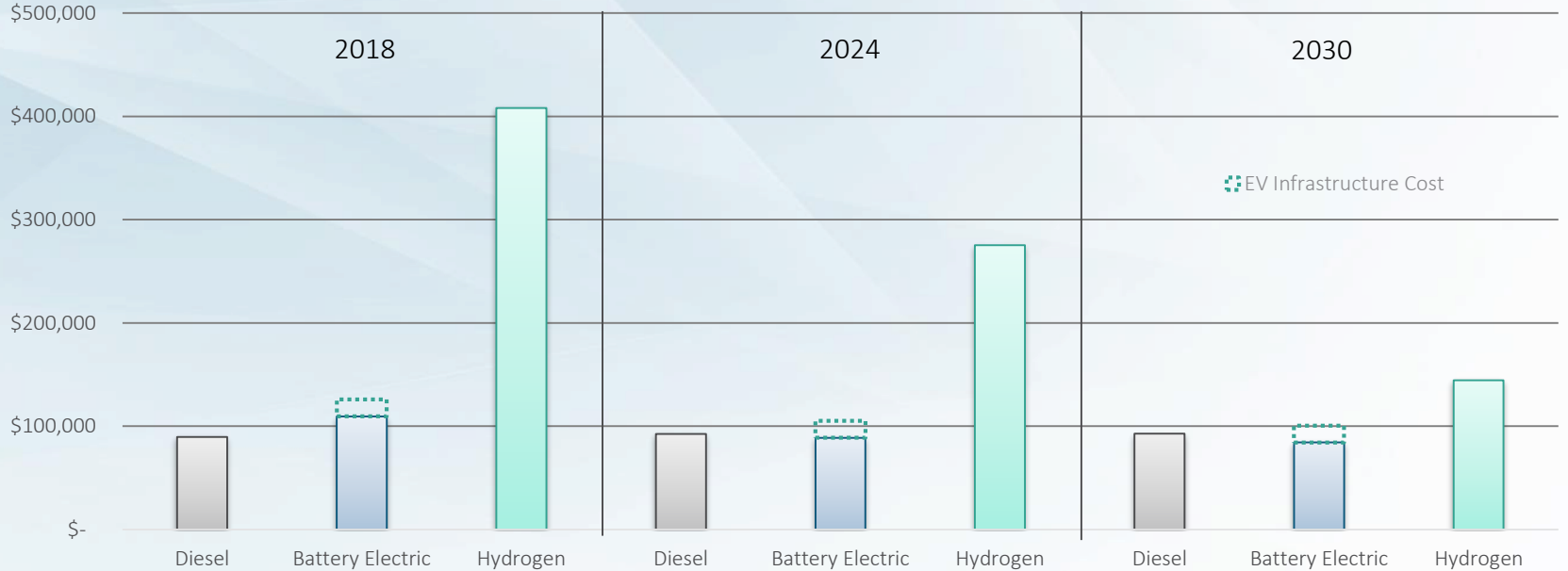
- Registration fees
 - Fee structure different for diesel and ZEV
 - ZEVs generally pay less
- Midlife costs
 - Diesel – no rebuild assumed due to lower mileage assumptions
 - BEV – no battery replacement for passenger van or delivery van, assumed to be necessary for regional haul tractor
 - FCEV – stack refurbishment included for all vehicles

Infrastructure Costs

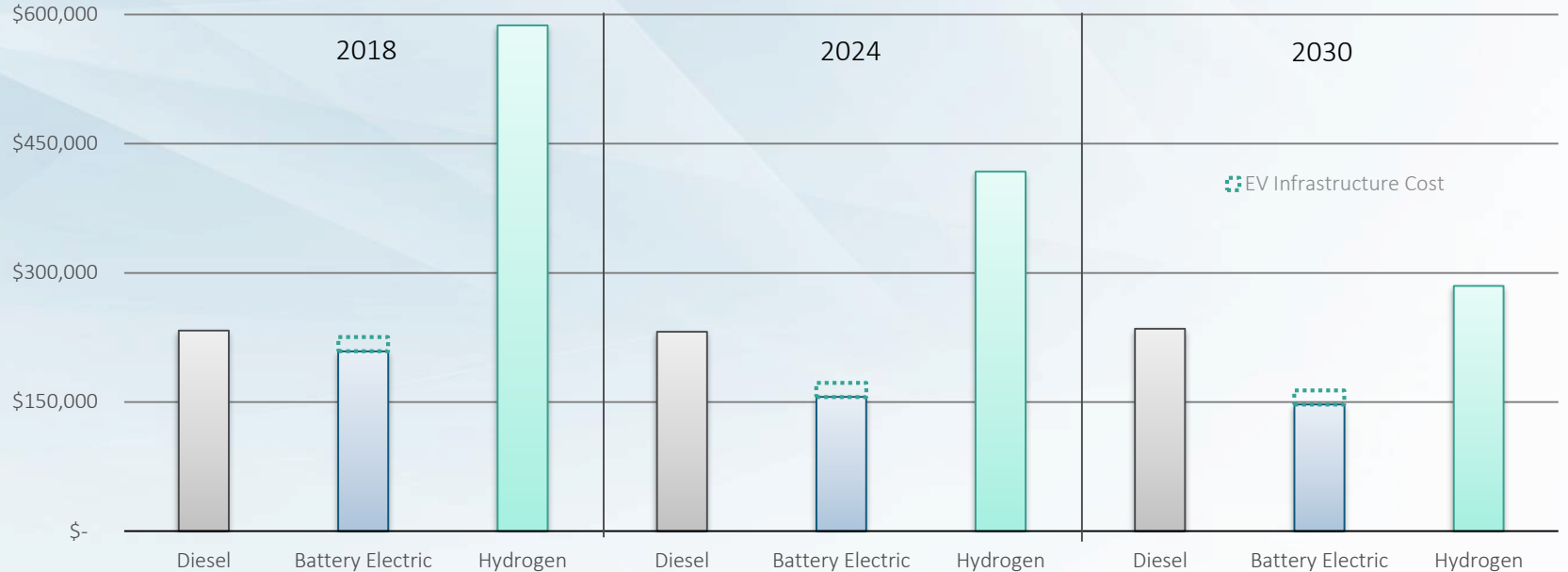
- Diesel and hydrogen infrastructure costs factored into fuel costs
- BEV: Overnight depot charger installed cost
 - 19 kW charger costs based on PG&E and SCE SB350 applications
 - 100 kW charger based on transit bus data
- Costs spread over a 20 year period

	Passenger van	Stepvan	Regional Tractor
Charger info.	19 kW AC	19 kW AC	100 kW DC
Charger Cost	\$5,000	\$5,000	\$50,000
Infrastructure Upgrade	\$20,000	\$20,000	\$55,000

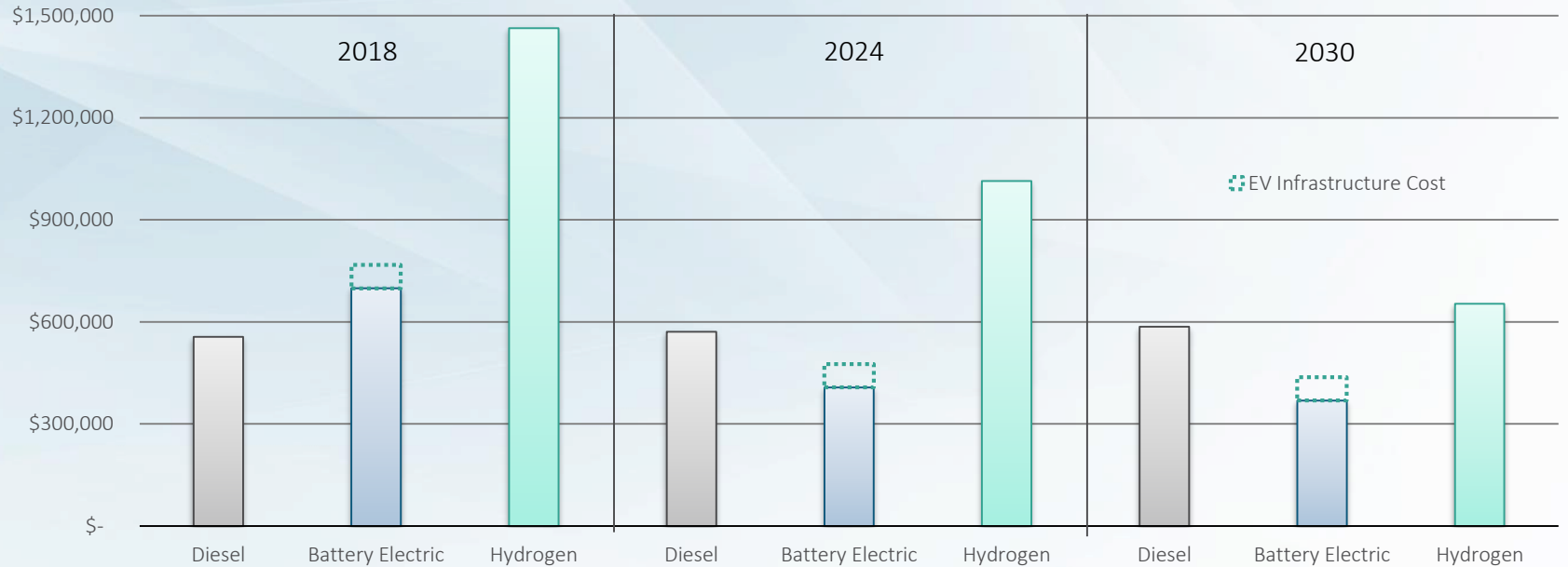
Passenger Van TCO



Stepvan TCO

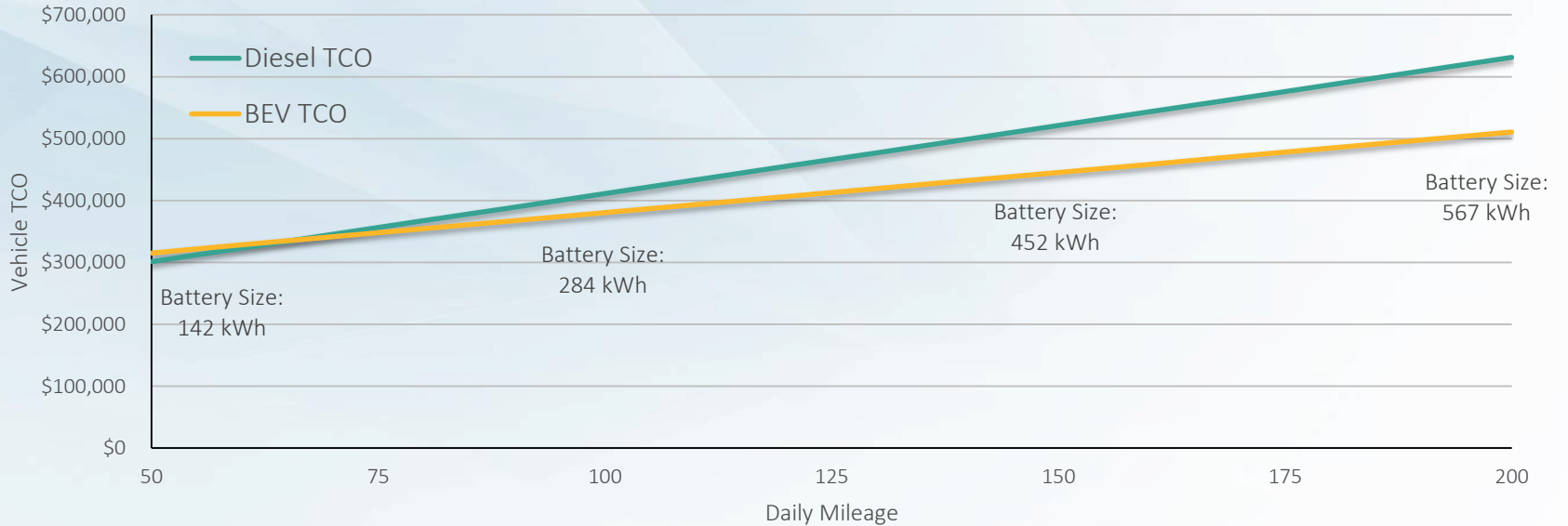


Regional Tractor TCO



BEV TCO vs Diesel Improves with Higher Daily Miles

2024 Regional Tractor



TCO Summary

- By 2024, BEVs likely to have TCO parity with diesel in a wide range of applications
 - Vehicles need to be placed where suitable
 - Better TCO opportunity for higher mileage/fuel use operations
 - LCFS credits likely to offset most electricity costs
 - Higher capital costs (vehicle/infrastructure) still an issue
- By 2030, hydrogen may approach TCO parity with diesel
 - Dependent on hydrogen station throughput and placement
 - May happen quicker if costs decline faster than assumed
 - Higher vehicle capital costs still an issue



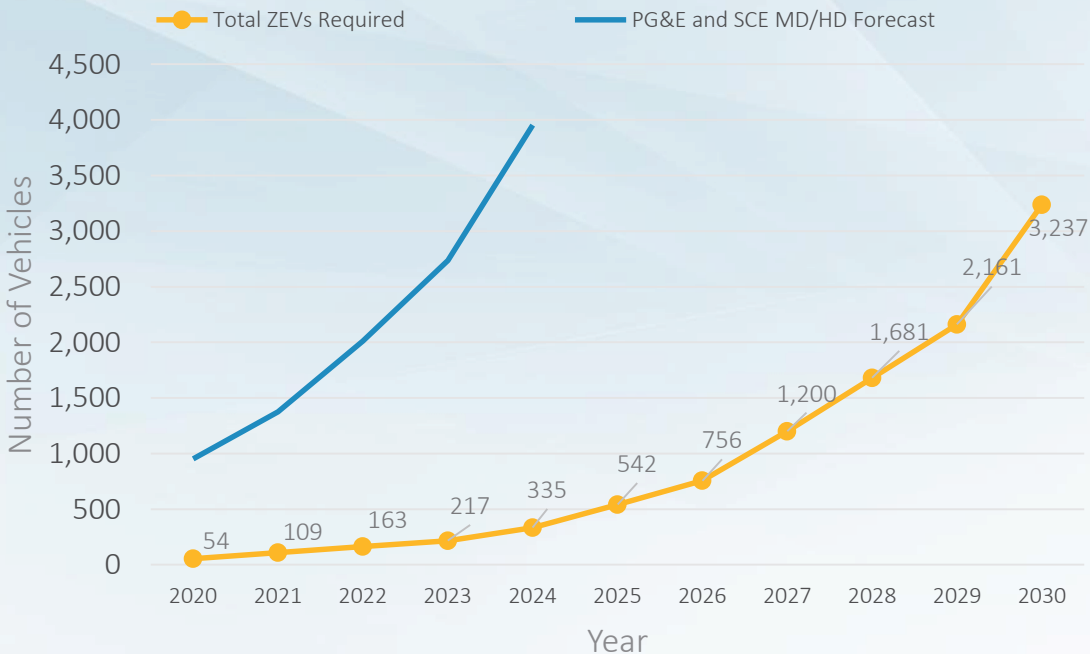
Infrastructure Needs

Infrastructure Support

- Challenges to address
 - Planning, availability, and lead time
 - Access to refueling and standardization
 - Cost and scalability
- California has committed to support transportation electrification in medium- and heavy-duty
 - Southern California Edison – \$343 million
 - Pacific Gas and Electric - \$236 million
 - San Diego Gas and Electric - \$151 million (pending)

Projected Infrastructure and Needs

HD ZEV Requirements vs. Utility ZEV Support



- CPUC approved infrastructure plans exceed rule requirements
 - Innovative Clean Transit
 - AB739 – State fleet purchases
 - Zero Emission Airport Shuttle (proposed)

Infrastructure Discussion

- California utility programs (SB 350)
- Hydrogen production and station buildout