Multi-State MHDV MOU

Market Readiness Materials and Findings

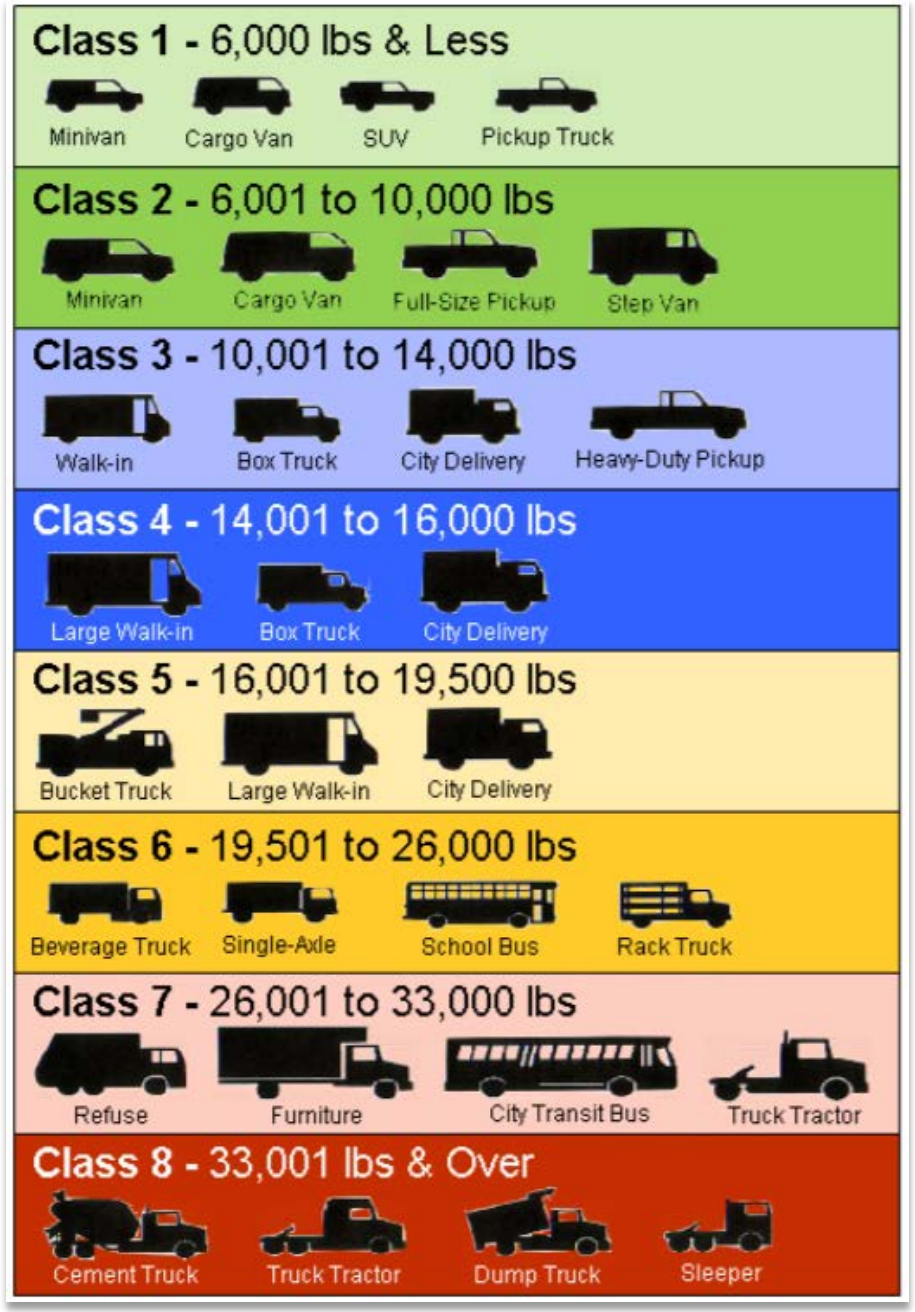
Overview of Key Considerations and Findings

Availability/Product & Fleet Announcements	• Multiple models for a variety of applications are currently available in each weight class with a significant number of additional new models coming to market this year • By 2023, nearly 150 models are projected to be commercially available across all classes	Slides 3-6
TCO Cost Parity (including infrastructure costs)	• By 2030, commonly used applications in every weight class will achieve cost parity without government subsidies, most before 2025	Slides 7-17
Cold Weather Impacts	• Very little available information, most analysis for buses operating in warmer climates • Recent study found significant loss of range in freezing and below freezing temperatures; for temperature drops from 50-60° F to 22-32°F: loss in range of 37.8% for BEVs and 23.1% for FCEBs	Slides 18-19
Advanced Clean Trucks Rule Interim Targets	Key interim targets revised as follows: In 2025: 7% sales target for classes 2b-3, 11% for classes 4-8, 7% for class 7-8 tractors In 2030: 30% sales target for classes 2b-3, 50% for classes 4-8, 30% for class 7-8 tractors In 2035: 55% sales target for classes 2b-3, 75% for classes 4-8, 40% for class 7-8 tractors	Slide 20

Estimating Vehicle Sales Needed to Meet Various Interim Sales Targets	• State registration data is likely the best way to estimate the number of vehicles needed to meet different sales targets. However, national sales data, along with a proxy to estimate each state's proportional share, can be used to provide a rough estimate.
	• For instance, a ballpark estimate can be calculated by assuming the potential MOU states account for 25.8% of national MHDV sales market based on their proportional share of registered class 3-8 vehicles:
	  • A 2030 25% sales target would require collective MHD ZEV sales of roughly 102,426
	  • A 2030 30% sales target would require collective MHD ZEV sales of roughly 122,911
	  • A 2030 35% sales target would require collective MHD ZEV sales of roughly 163,882
		Slides 21-23

Truck Classifications

- Vehicle classes are based on gross vehicle weight rating (GVWR).
- Class 2 is subdivided into:
  - Class 2a vehicles with a GVWR of 6,001-8,500 lbs.; and
  - Class 2b vehicles with a GVWR of 8,501-10,000 lbs.
- MHDVs consist of classes 2b-8.



Source: U.S. Department of Energy

Medium- and Heavy-Duty ZEV Inventory

- Some recently announced battery electric pickup trucks are expected to be classified as 2b or 3 based on GVWR (e.g., Ford F-150 Electric, Tesla Cybertruck, Rivian R1T)
- Vehicle availability will likely be impacted by the COVID-19 pandemic because some OEMs temporarily shut down manufacturing operations and/or shifted their production lines to manufacture medical equipment

Sources: Global Commercial Vehicle Drive to Zero, Zero-Emission Technology Inventory Tool, and OEM websites.

MHD ZEV Model Availability Through 2023

Vehicle Type	Weight Class(es)	Now	2020	2021	2022	2023
Cargo Van	2b, 3, 4, 5	4	3	1	1	-
Step Van	3, 4, 5, 6	4	6	1	-	-
MD Pickup &Truck	2b, 3, 4, 5, 6, 7*, 8*	12	25	9	1	2
HD Truck	7, 8	5	4	4	2	4
Yard Tractor	8	3	4	-	-	-
Shuttle Bus	2b, 3, 5, 6, 7	13	5	-	-	1
Transit Bus	7	24	1	-	-	1
Other	4, 6, 8	5	5	-	-	-

* *Some MD trucks can be sorted in Class 7 or 8 based on the vehicle's total operating weight.*

For a detailed compilation of product offerings that are currently available and coming to market through 2023 as well as OEM product announcements, please see appendices to this slide deck.

Noteworthy Fleet Orders and Announcements

- Dec. 2017 - PepsiCo orders 100 Tesla Semis
- Dec. 2017 - UPS orders 125 Tesla Semis
- May 2018 - Anheuser-Busch orders 800 Nikola fuel cell semi-trucks
- Aug. 2018 - Zeem Solutions orders 50 Lightning Systems ZEV class 6 trucks
- Nov. 2018 - FedEx orders 1,000 Chanje electric delivery vehicles
- Sept. 2019 - Amazon orders 100,000 Rivian electric delivery trucks
- Jan. 2020 - UPS orders 10,000 Arrival electric delivery vans

Public Sector MHD ZEV Fleet Targets

Seattle Refuse Truck

Electric Buses in NYC

California:

- 15% of new vehicles with GVWR of 19,000 lbs. or more must be ZEV beginning in 2025; increasing to 30% in 2030
- Only ZEV transit bus purchases allowed after 2029; entire transit fleet must be zero emission by 2040
- 100% ZEV purchases of private/public fixed route airport shuttle buses required by 2040

Connecticut:

- 30% of transit bus purchases required to be zero emission by 2030

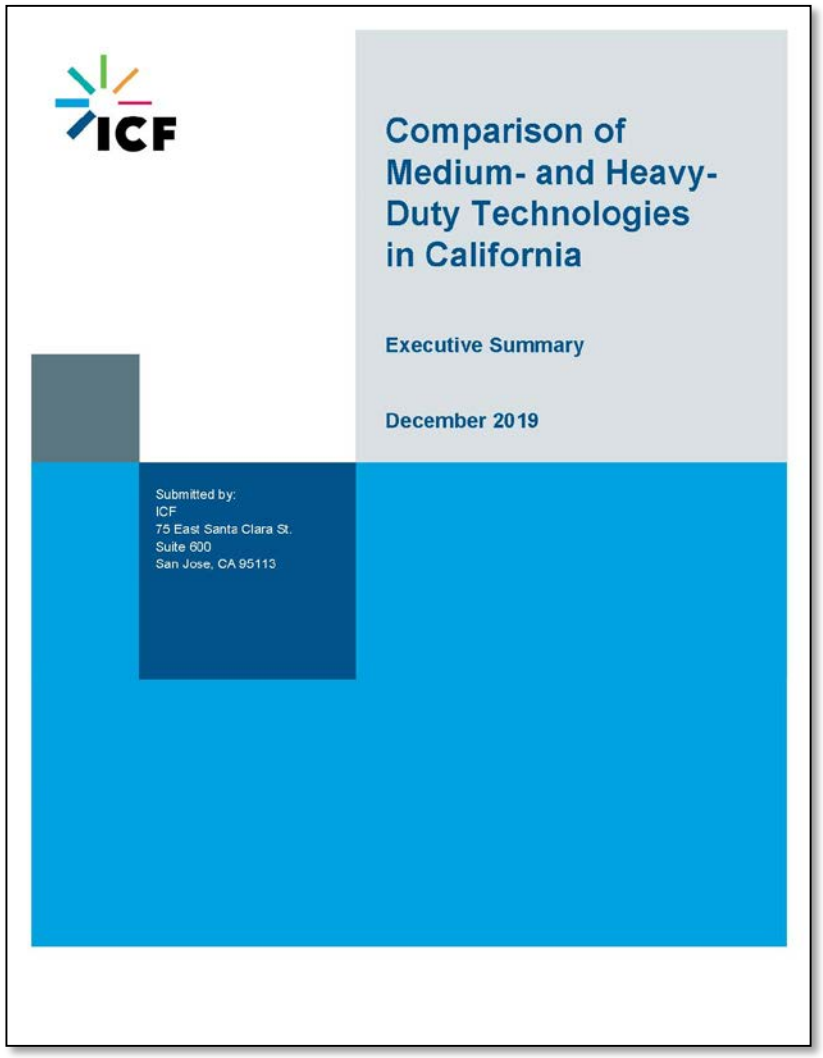
New Jersey:

- 10% of new NJ Transit bus purchases required to be electric by 2024, 50% by 2026, 100% by 2032

NYC:

- Entire city fleet required to be zero emission by 2040

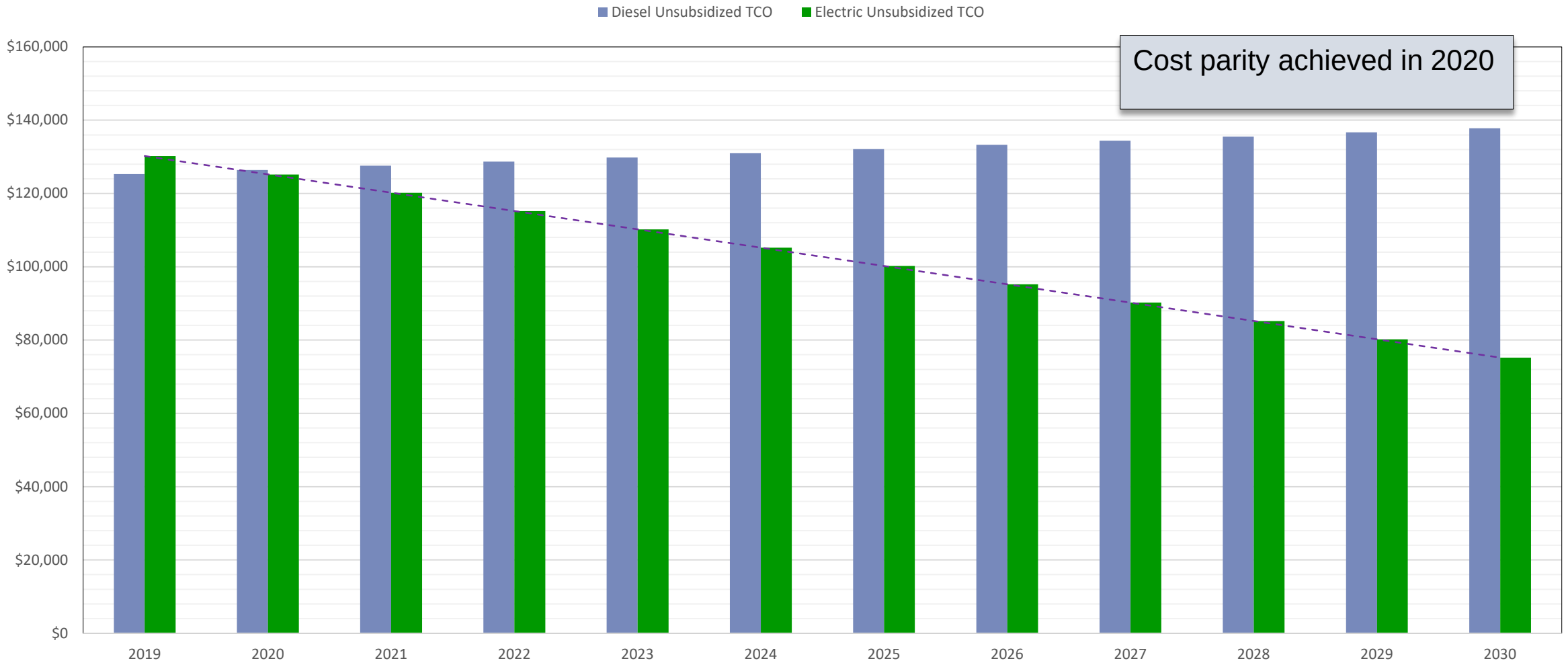
Projected TCO Cost Parity Without Government Subsidies



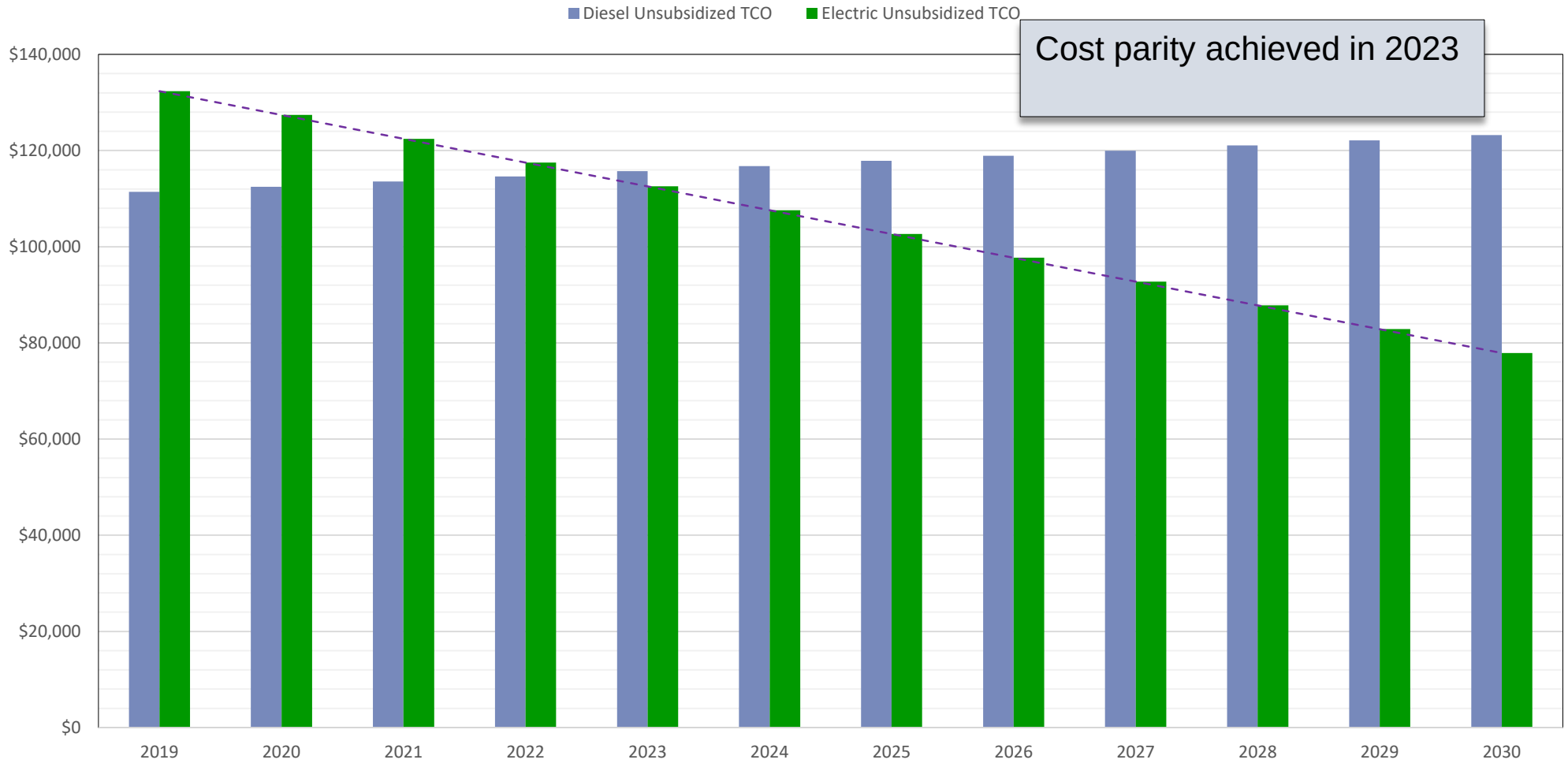
- Analysis performed by ICF for NRDC and CalETC to inform Advanced Clean Trucks Rulemaking
- The data reflected in the following slides include infrastructure costs and do not take any government subsidies into account
- Results projected favorable TCO for battery electric vehicles over diesel and hydrogen fuel cell vehicles in nearly all classes in the decade leading up to 2030 without government subsidies
- Class 2b-8 MHDVs will generally be cost competitive with diesel vehicles well before 2030

https://caletc.com/comparison-of-medium-and-heavy-duty-technologies-in-california/

Class 2b Van TCO Parity



Class 3 Walk-in/Delivery TCO Parity

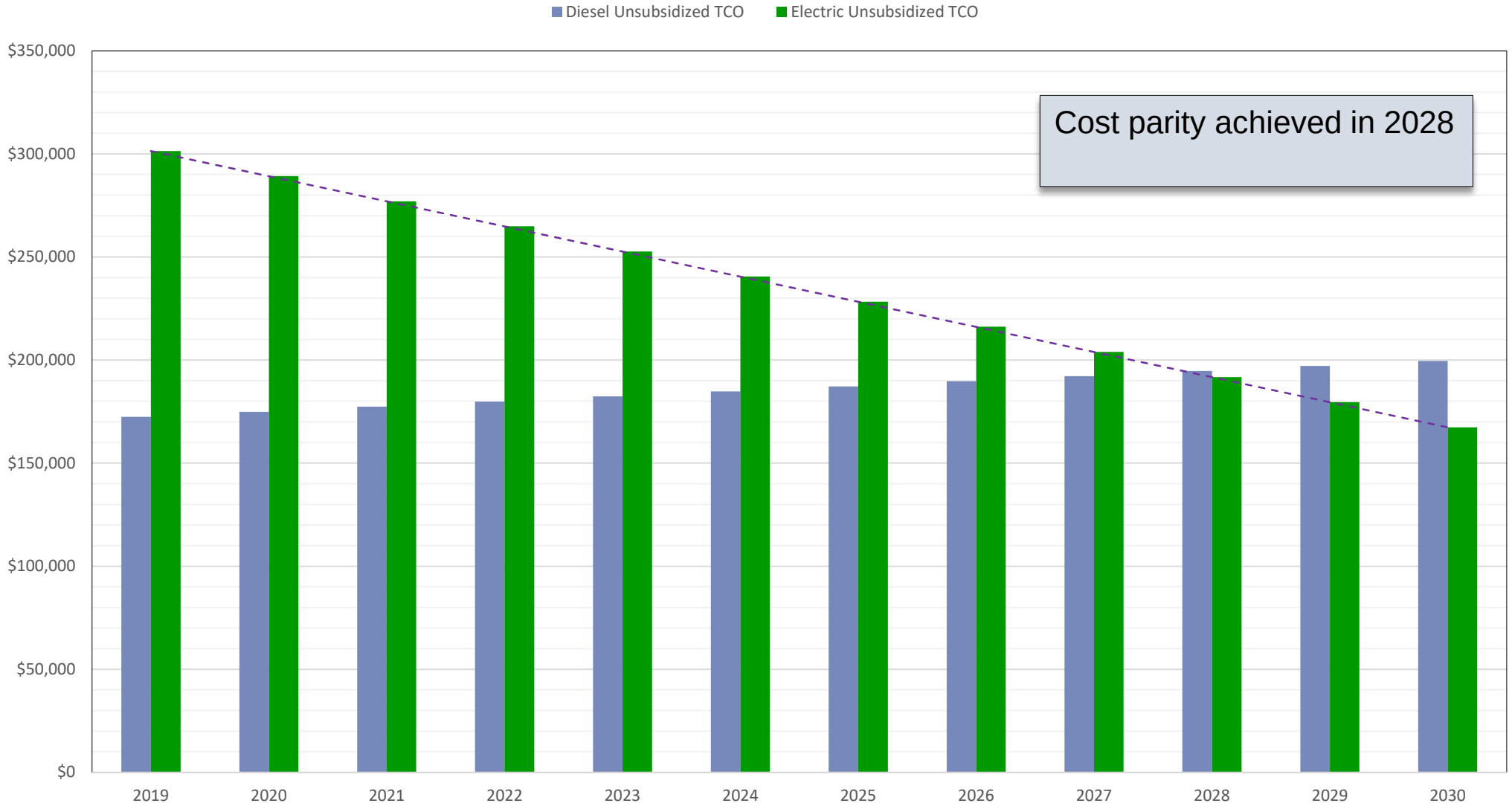


Class 4/5 Delivery TCO Parity

Class 4/5 Shuttle/Vans TCO Parity

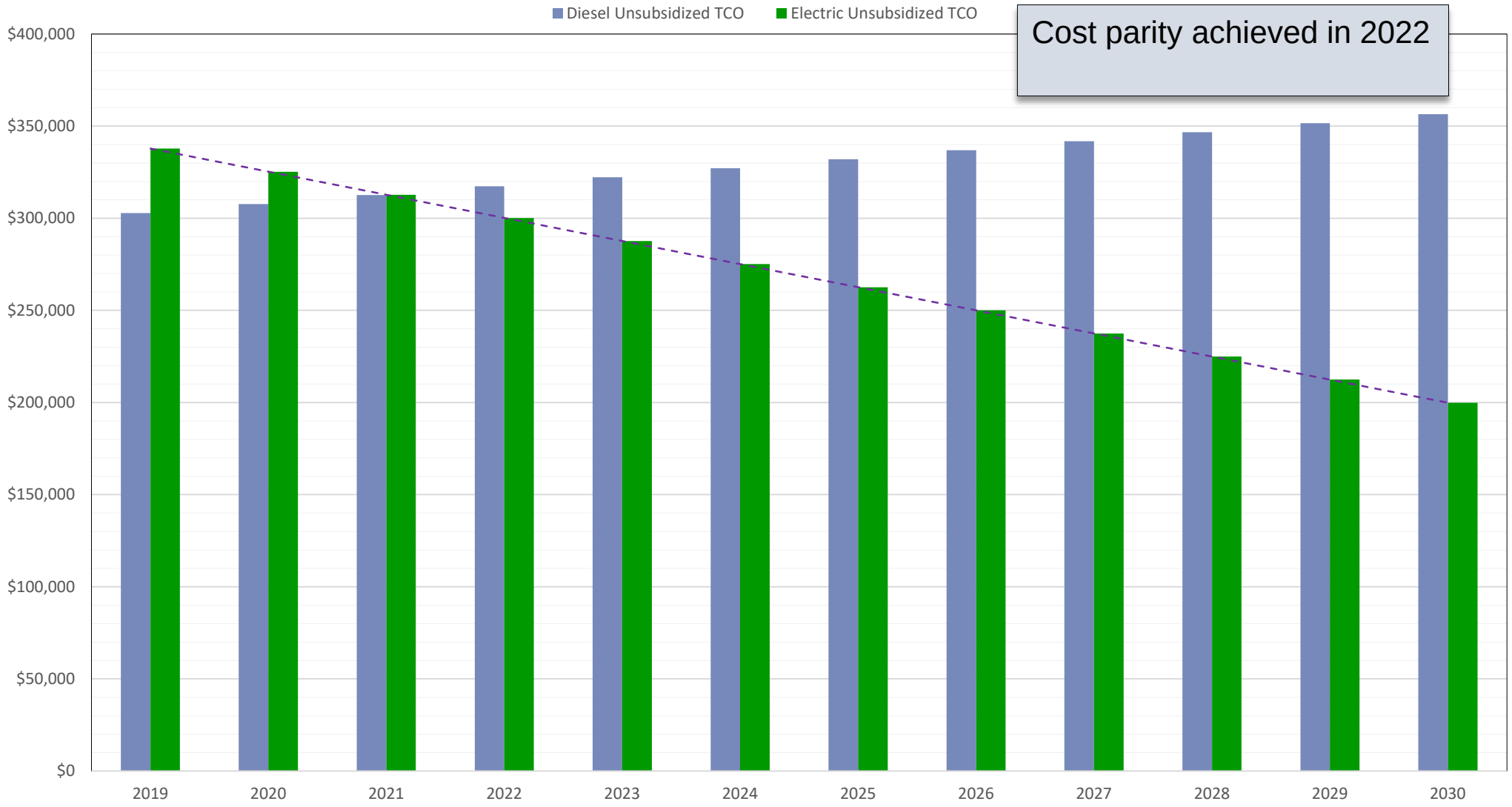
Class 6 Urban Delivery TCO Parity

Class 6 Regional Haul TCO Parity

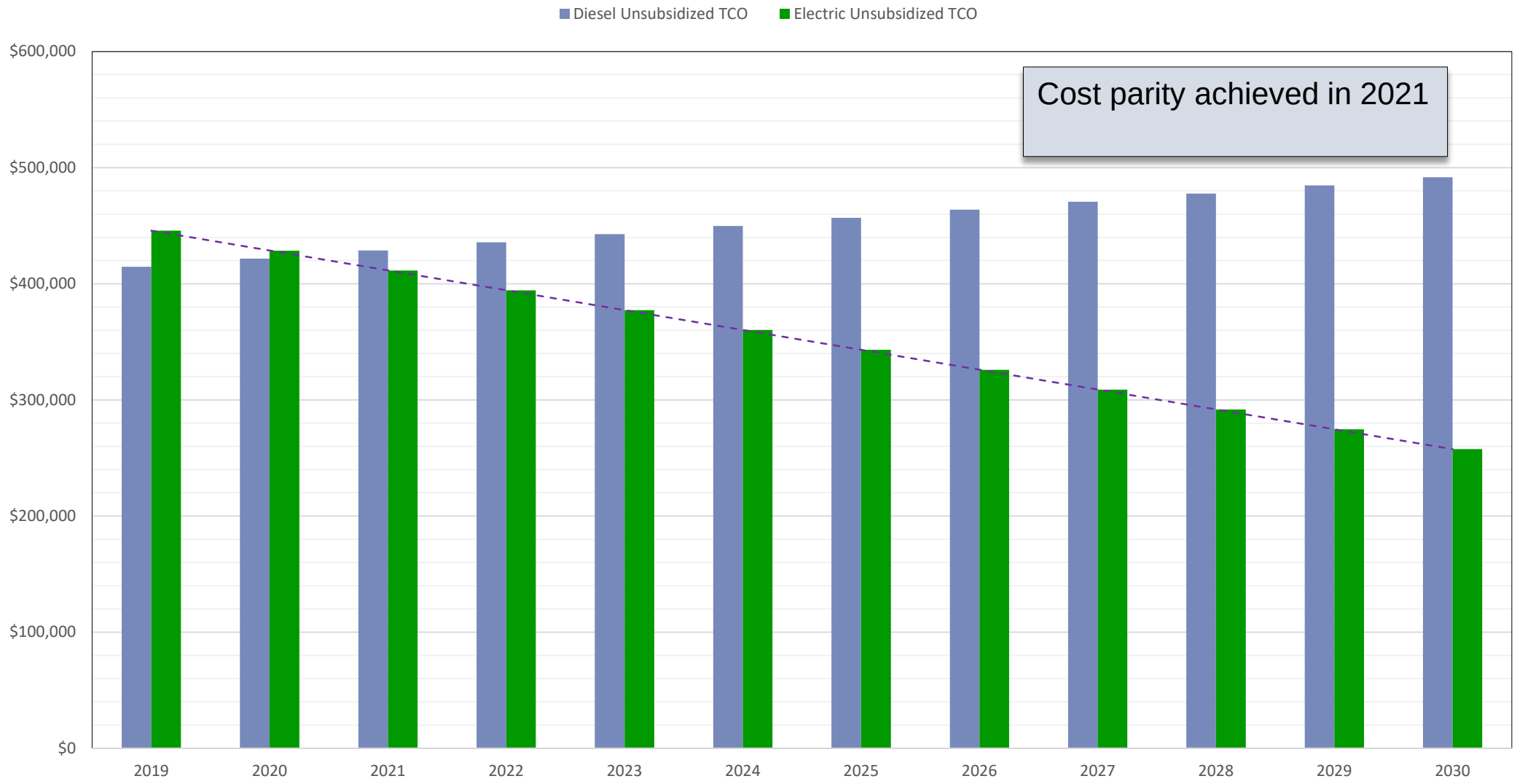


Class 8 Drayage TCO Parity

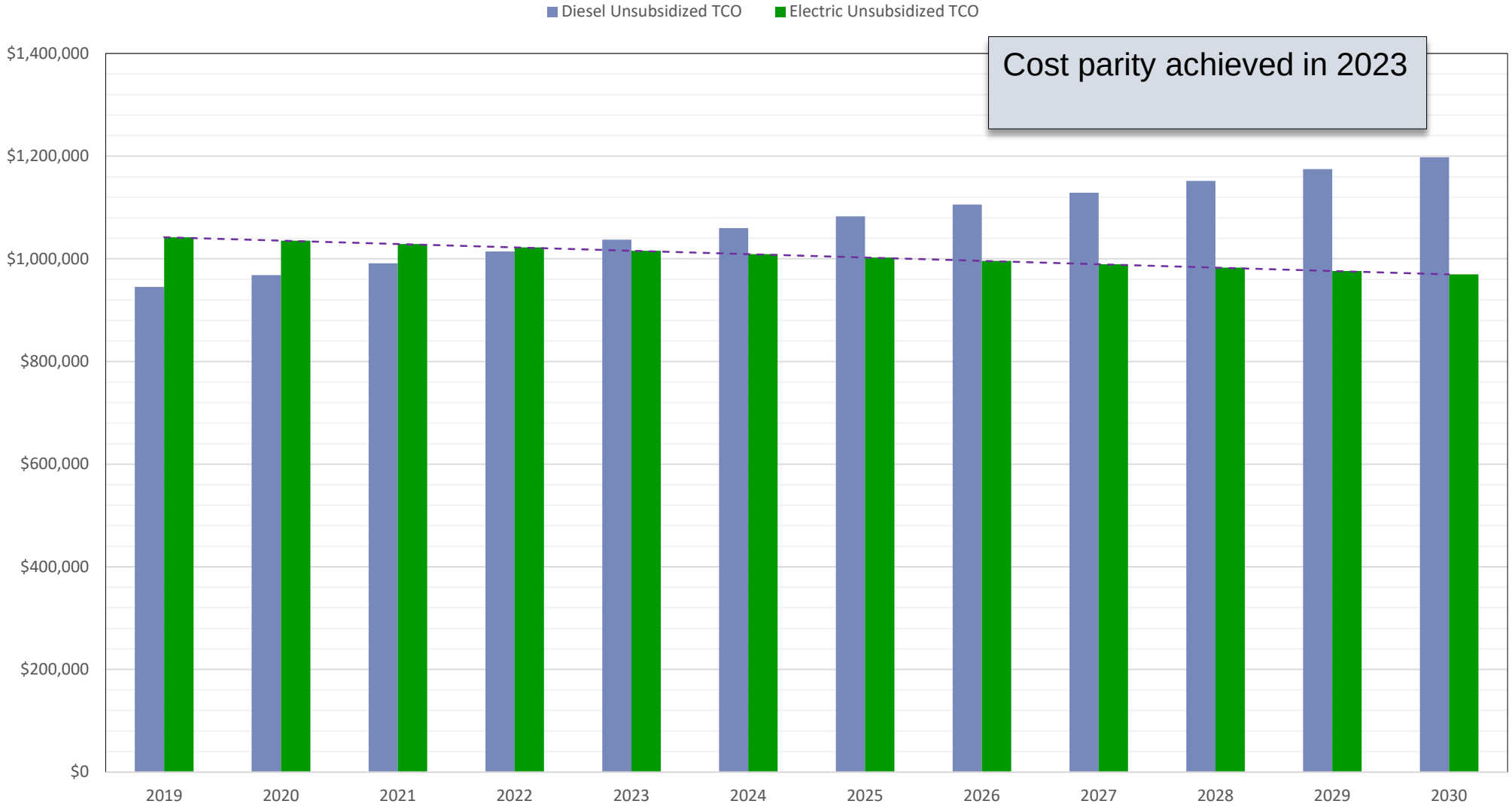
Class 8 Short Haul TCO Parity



Class 8 Tractor TCO Parity



Class 7 Transit Bus TCO Parity



Cold Weather Impacts on Range

An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Range for Battery Electric and Fuel Cell Electric Buses

Prepared by:

THE MIDWEST HYDROGEN CENTER OF EXCELLENCE
A Key Initiative of the Renewable Hydrogen Fuel Cell Collaborative

cte

Maxine Goodman Levin College of Urban Affairs

Cleveland State University/MHCoE:
Mark Henning*
Andrew Thomas*

CTE:
Alison Smyth**

In collaboration with:

SARTA

*Mark Henning (m.d.henning@csuohio.edu) and Andrew R. Thomas (a.r.thomas99@csuohio.edu) are with the Midwest Hydrogen Center of Excellence (http://www.midwesthydrogen.org/mhcoe/) and the Energy Policy Center at the Levin College of Urban Affairs, Cleveland State University, Cleveland, Ohio. *See* http://levin.urban.csuohio.edu/epc/.
**Alison Smyth (Alison@cte.tv) is with the Center for Transportation and the Environment. *See:* https://cte.tv/.

https://cte.tv/wp-content/uploads/2019/12/Four-Season-Analysis.pdf

- Limited information on cold weather impacts available; this study is the most useful
- November 2019 analysis comparing changes in ambient temperatures to BEB and FCEB transit bus fuel efficiency and vehicle range based on data from 6 transit agencies in range of climate conditions
- Other factors affecting fuel efficiency not accounted for: topography, ice/snow/rain, driver performance, number of stops
- Study not attempting to demonstrate causation, only establish association between fuel economy/range and ambient temperatures
- Participating transit agencies: Thousand Palms CA, District of Columbia, Canton OH, Duluth MN, Victoria, BC, Oslo Norway
- Based on daily data, not monthly averages

Cold Weather Impacts on Range

Estimated Mean Range in Miles per ZEB at Selected Ambient Temperatures

ZEB Type	Agency	Ambient Temperature (F)							
		10°	*20°*	*Freezing*	*40°*	*50°*	*60°*	*70°*	*80°*
Fuel Cell Electric Bus (FCEB)	BC Transit (Victoria, BC)	N/A	162	185	204	230	258	246	240
	Ruter (Oslo, Norway)	96	107	125	139	164	162	159	156
	SARTA (Canton, OH)	194	207	224	237	253	270	247	227
	SunLine (Thousand Palms, CA)	N/A	N/A	N/A	293	294	294	277	258
	Average range for FCEBs[1]	**166**	**171**	**180**	**201**	**233**	**253**	**250**	**246**
Battery Electric Bus (BEB)	DDOT (Washington, DC)	60	69	90	106	131	162	165	145
	Duluth Transit (Duluth, MN)	123	132	143	151	163	167	165	N/A
	Average range for BEBs[2]	**111**	**117**	**119**	**122**	**142**	**164**	**165**	**145**

FCEBs

- For each 1° decrease in temperature below 65°F, an increase in fuel consumption of between 0.57% – 1.28%
- For each 1° increase in temperatures above 65°F, increase in fuel consumption of between 0.29% - 0.90%

- **For temperature drops from 50-60° to 22-32°F, loss in range for FCEBs was 23.1%**

BEBs

- For each 1° decrease in temperature below 65°F, an increase in fuel consumption of between 0.33% - 2.20%
- For each 1° increase in temperatures above 65°F, increase in fuel consumption of between 0.71% – 1.41%

- **For temperature drops from 50-60° to 22-32°F, loss in range for BEBs was 37.8%**

Advanced Clean Trucks Rule

Revised Manufacturer ZEV Sales Requirements for Final Rule

Model Year (MY)	Class 2b-3	Class 4-8	Class 7-8 Tractors
2024	**5%**	**9%**	**5%**
2025	**7%**	**11%**	**7%**
2026	**10%**	**13%**	**10%**
2027	**15%**	**20%**	**15%**
2028	**20%**	**30%**	**20%**
2029	**25%**	**40%**	**25%**
2030	**30%**	**50%**	**30%**
2031	**35%**	**55%**	**35%**
2032	**40%**	**60%**	**40%**
2033	**45%**	**65%**	**40%**
2034	**50%**	**70%**	**40%**
2035 and beyond	**55%**	**75%**	**40%**

Establishing a Baseline for Sales

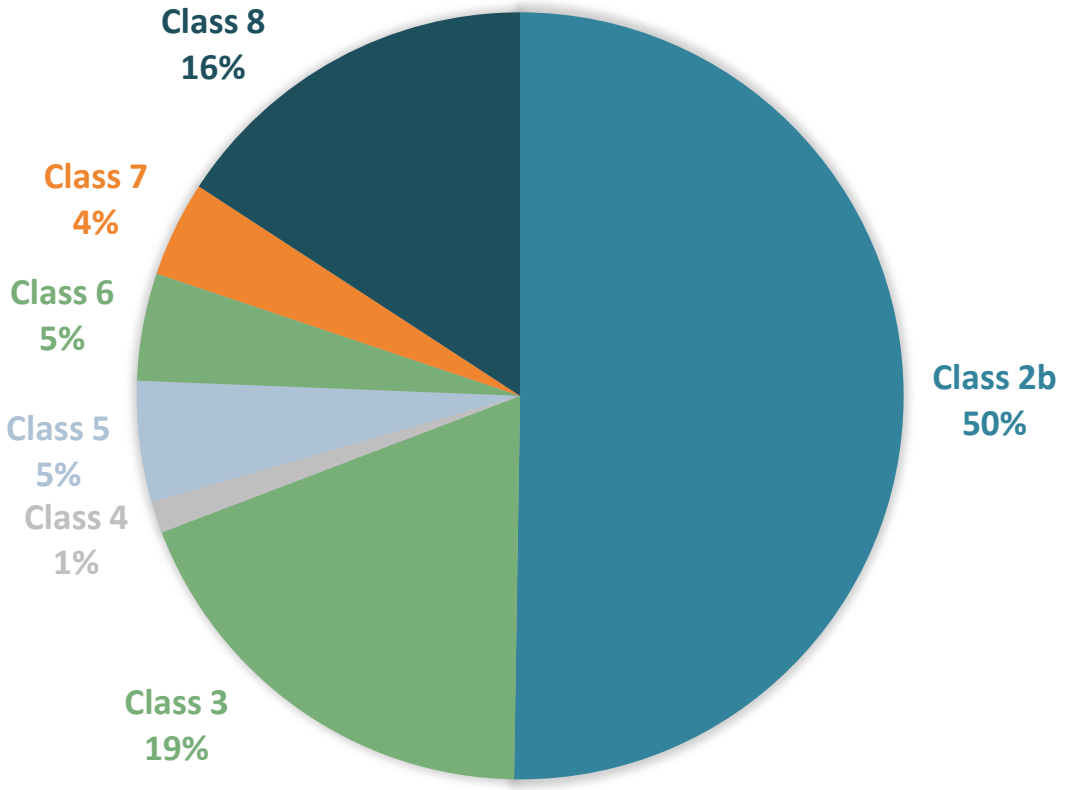
- In 2018, national new retail sales of Class 2b-Class 8 vehicles totaled roughly 1,588,000.
- Class 2b vehicles dominated sales (50%), followed by Class 3 (19%) and Class 8 (16%).

Source: Transportation Energy Data Book: Edition 38 (Jan. 2020), available at https://tedb.ornl.gov/; Class 2b vehicles sales extrapolated based on Energy Information Administration, *Annual Energy Outlook 2019.*

New U.S. Retail Sales in 2018 by Vehicle Class

Class 2b	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	**Total**
798000	301000	21000	81000	72000	64000	251000	**1,588,000**

MHDV Market Share by Vehicle Class



Estimates for Individual States

To get a rough ballpark estimate of the numbers of new vehicle sales needed in individual states to meet different sales targets in 2030, simply multiply total retail sales by proposed sales target by preferred proxy for proportional state share.

Using Maryland as an example:

1,588,000 (total retail sales) x 0.30 (30% sales target) x 0.016 (% all vehicles registered in Maryland) = 7,622.

Proxies for estimating proportional state share of national retail sales of new MHDVs

STATE	% US Population	% All Vehicles Registered	% Class 3-8 Vehicles Registered
California	11.94	11.2	9.8
New York	5.81	4	4.2
New Jersey	2.67	2.3	2
Washington	2.33	2.6	2.6
Massachusetts	2.09	1.9	1.8
Maryland	1.82	1.6	1.4
Oregon	1.29	1.4	1.5
Connecticut	1.07	1.1	1
Hawaii	0.42	0.5	0.5
Maine	0.4	0.4	0.4
Rhode Island	0.32	0.3	0.3
District of Columbia	0.22	0.1	0.1
Vermont	0.19	0.2	0.2
TOTAL	30.57	27.6	25.8

Source for % US Population (based on 2017 census data: https://worldpopulationreview.com/states/
Source for % Vehicles Registered (based on 2015 registration data): https://www.fhwa.dot.gov/policyinformation/
Source for % Class 3-8 Vehicles Registered (based on 2018 registration data: https://www.fhwa.dot.gov/policyinformation/statistics/2018/mv1.cfm

What do different sales targets mean collectively for potential MOU states?

2030 MHD ZEV Sales Target	Collective # of MHD ZEVs to Meet Sales Target in Potential MOU States	MHD ZEV Sales to Meet Target as % of National MHDV Sales
20%	81,941 - 97,186	5.2% - 6.1%
25%	102,426 - 121,482	6.5% - 7.7%
30%	122,911 - 145,778	7.7% - 9.2%
40%	163,882 - 194,371	10.3% - 12.2%
50%	204,852 - 242,964	12.9% - 15.3%

Assumes the following: (1) national new retail sales of Class 2b-8 Vehicles in 2030 is 1,588,000 (same as 2018); (2) CA, CT, DC, HI, ME, MD, MA, NJ, NY, OR, RI, VT, and WA sign the MOU; and (3) these states collectively account for 25.8% of Class 3-8 vehicle registrations, which is used to calculate the lower range, and 30.6% of US population, which is used to calculate the higher range.