Transit Zero Emission Vehicle Roadmap

November 2021

Photo Credit: CDOT

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Introduction

The Transit Zero Emission Vehicle (ZEV) Roadmap is a comprehensive and adaptable guide for transit agencies, key stakeholders, and the State of Colorado to implement the transit zero emission strategies contained within the Colorado Electric Vehicle Plan (2020 EV Plan) and bring clean transit options to all Coloradans. The Transit ZEV Roadmap provides a transit electrification strategy for the State of Colorado to stage, support, and incentivize transit agencies to transition toward technologies that achieve the greatest fuel economy, maximize greenhouse gas (GHG) and other emissions benefits, and set the stage for a zero-emission future.

The 2020 EV Plan commits the Colorado Department of Transportation (CDOT), the Colorado Energy Office (CEO), and the Regional Air Quality Council (RAQC) to work with transit agencies, electric utilities, and other stakeholders to establish timelines, identify strategies, and dedicate sufficient resources to achieve ZEV transit goals. A number of other supporting actions are identified in the 2020 EV Plan to address the unique needs of rural transit agencies, account for equity in state programs and grants, and consider the viability of hydrogen fuel cell electric vehicles (FCEVs) for transit service.

The State of Colorado recognizes that the transit sector faces unique challenges and opportunities in transitioning to ZEVs and installing/constructing the charging and fueling infrastructure necessary to support them. Transit agencies provide essential mobility services to diverse and sometimes vulnerable populations across a wide range of geographies, climates, and routes, so a one-size-fits-all approach will not be possible.

The transition to ZEVs will likely occur first in agencies that employ a greater percentage of full-size transit buses, whereas agencies that rely more on vans and cutaways to serve longer routes and/or operate demand-response service may not have the option to transition their fleets for several more years. Every transit agency is different and should leverage state and local subject matter experts and experience to determine when and how to address fleet transition. The Transit ZEV Roadmap highlights and provides resources to support Colorado transit agencies on the path to ZEV fleet conversion.

While transportation electrification across all sectors is a priority for the State of Colorado, it should be noted that all transit service provides GHG and emission reduction benefits by reducing vehicle miles traveled and providing lower per capita emissions for riders who might otherwise drive to their destinations. Transitioning transit vehicles to zero emissions can augment these existing benefits while also exposing a broader segment of the population to zero emission vehicles, improving the rider experience, pioneering large fleet electrification in the public sector, and potentially reducing total cost of ownership (TCO) over the life of the vehicle.

Transit Vehicle Defined:

A vehicle operated by transit agencies that carry passengers or public riders. For the purposes of this report, transit vehicles do not include school buses, charter or intercity bus transportation or intercity passenger rail transportation.

Zero Emission Vehicle (ZEV) Defined:

A vehicle that produces zero or near-zero exhaust emission of any criteria pollutant (or precursor pollutant) or greenhouse gas under at least one operational mode. Eligible ZEVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs).

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Colorado ZEV Policy & Planning

In 2019, Colorado HB 19-1261 established statewide goals to reduce 2025 GHG emissions by at least 26 percent, 2030 GHG emissions by at least 50 percent, and 2050 GHG emissions by at least 90 percent, all relative to the baseline levels of statewide GHG emissions that existed in 2005.

The 2020 EV Plan, adopted in April 2020, identified several specific programs, strategies, and targets for achieving these goals through the widespread electrification of Colorado's transportation system. In addition to a high-level goal of full electrification of the light-duty sector and an interim target of 940,000 electric vehicles (EVs) on the road by 2030, it also included several recommended actions specific to the transit sector.

The 2020 EV Plan established a goal of transitioning 100 percent of transit vehicles in the state to ZEVs no later than 2050 and set an interim target of at least 1,000 transit ZEVs by 2030, which includes rubber-tired conventionally fueled transit buses, cutaways, vans, minivans, and automobiles. Widespread adoption of ZEVs is considered among the most impactful strategies for achieving the 2050 GHG emission reduction goals.

Key Elements of the Transit ZEV Roadmap

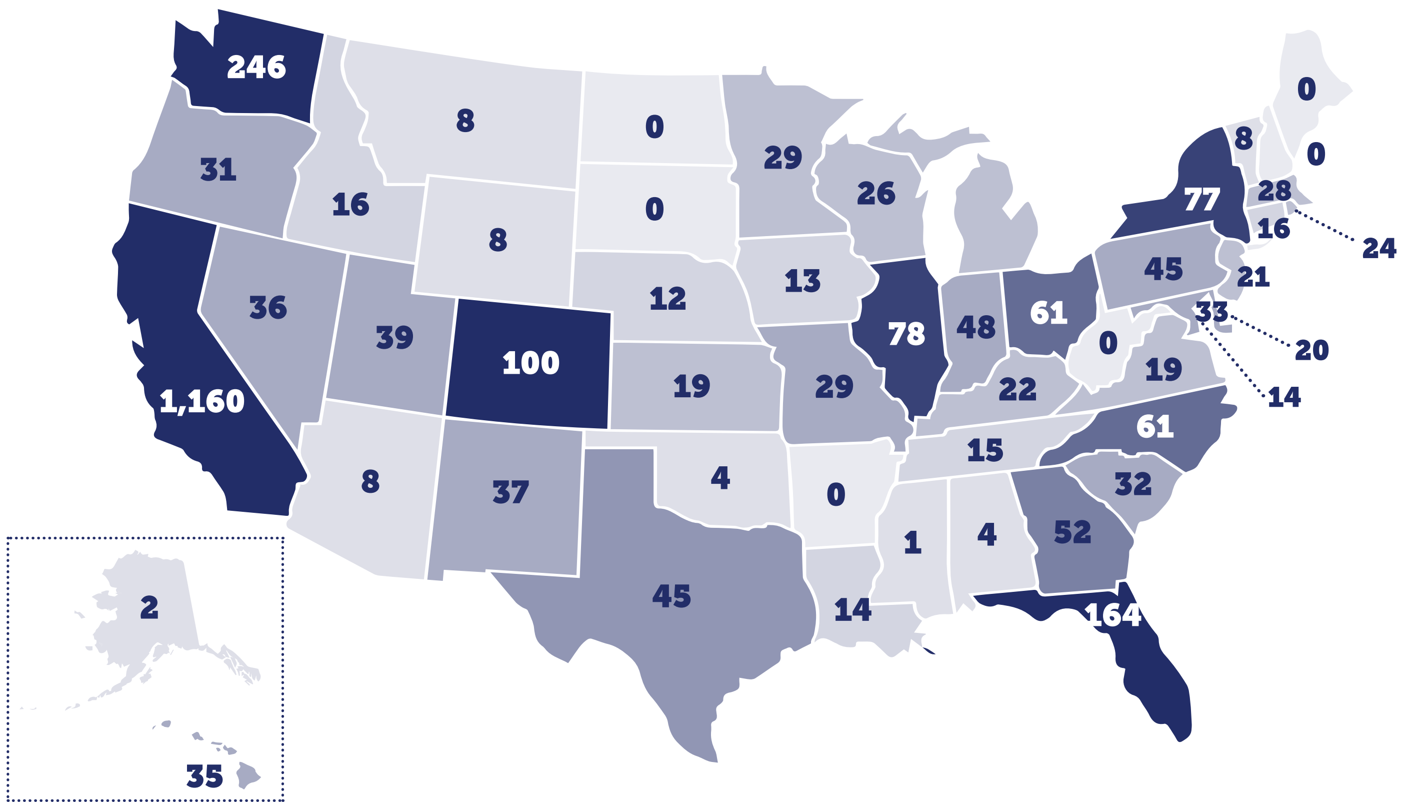
- **Collecting data and conducting research and analysis** to inform the current state of Colorado's transit fleet, understand the current state of the national transit ZEV market, identify transit ZEV conversion barriers and opportunities, and determine and document complementary utility actions and policies needed to advance the transition of Colorado's transit fleet to ZEVs.
- **Conducting outreach and engagement with transit agencies and utilities** to understand current ZEV plans, issues, opportunities and potential strategies the State could implement to support the transit ZEV transition.
- **Engaging with transit agencies and utilities** to support the transition of 1,000 transit vehicles to ZEV by 2030 and a 100 percent fleet transition by 2050.
- **Crafting a comprehensive Transit ZEV Roadmap** that integrates findings and strategies from complementary planning efforts and provides statewide transit and utility decision-makers with the direction and tools to facilitate and manage the ZEV transition while continuing to deliver quality transit service to the traveling public.

Photo Credit: CDOT

National Transit ZEV Trends

The transition to ZEVs presents several challenges and barriers to realizing the full financial and environmental benefits of the next generation of transit vehicles. There is increasing national experience transitioning transit fleets to ZEVs, as shown on Figure 1.

Figure 1: 2020 ZEV Transit Buses Deployed, On Order, or Soon to be on Order in the US[1]



Transit agencies must adapt to and embrace new vehicle standards, products and changing mobility needs. In addition to contemplating ZEV fleet adoption, many transit agencies are simultaneously evaluating service and technology changes including integration of mobility-on-demand and mobility-as-a-service options. Remaining on the cutting edge of new transit technology and ZEV planning should be evaluated at the local level with awareness and context of national trends and best practices.

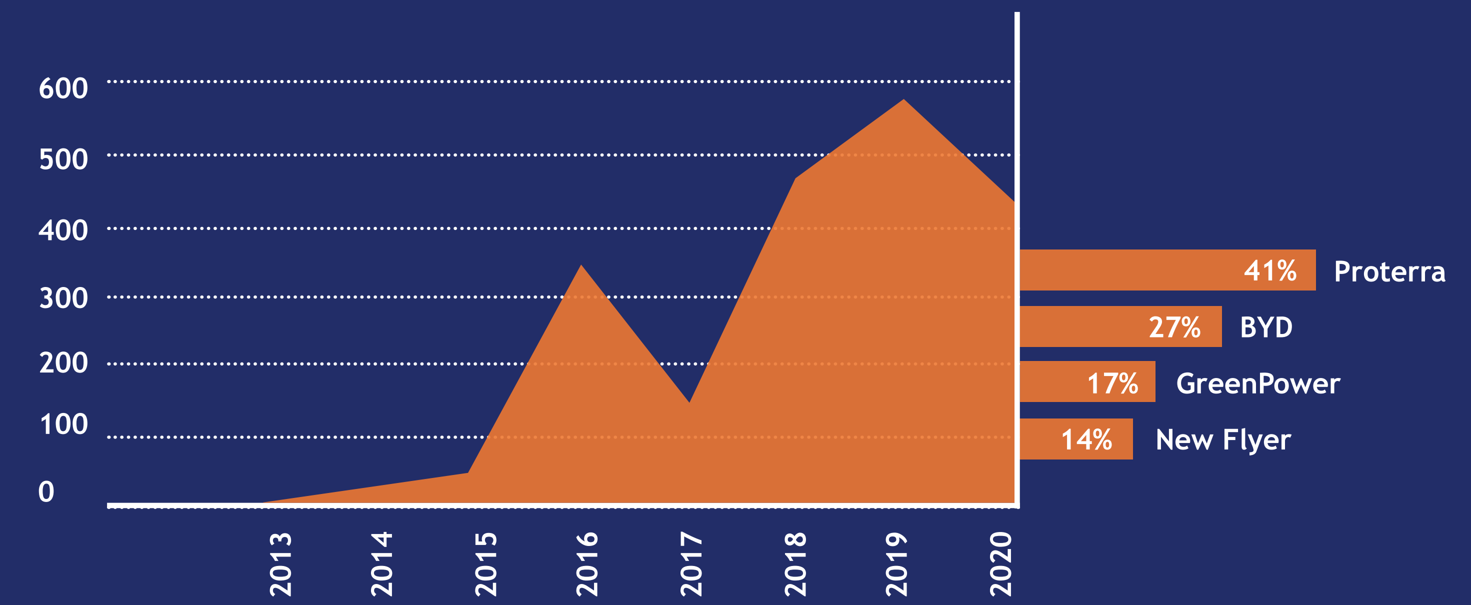
Vehicle Availability

Full-sized electric buses have been commercially available and their use has been increasing for over a decade. At the beginning of 2020, approximately 180 transit agencies were operating over 850 electric transit buses throughout the US with an additional 1,000 vehicles on order for delivery by 2022.[2]

Decreasing battery and electricity costs have contributed to the growth of the battery electric ZEV market. Proterra has dominated the North American ZEV bus market but faces competition from GreenPower, New Flyer, and BYD. The traditional transit vehicle original equipment manufacturers (OEMs) - New Flyer, Gillig, and Nova Bus - have collaborated with zero-emission powertrain suppliers to develop battery electric models and retain their market share.[3]

Figure 2 provides a summary of zero emission bus sales in North America. Appendix A provides detailed information about the state of transit ZEV model availability.

Figure 2. North American Zero Emission Bus Sales (2013-2020)[4]



Manufacturers that initially focused on full-size electric transit buses are pivoting to integrate medium- and small-size cutaway vehicles into their portfolios to meet the growing demand for offerings in this market segment. Given the various needs and service delivery models across Colorado, additional ZEV types will support faster adoption of ZEVs as cutaway vehicles make up approximately 25 percent of Colorado's existing transit fleet. In Colorado, vehicles must be able to operate with extended ranges to serve rural areas and must be able to operate successfully in areas with cold climates and steep grades. ZEV deployment should occur as proven vehicle models are available to meet current and future transit needs.

Barriers to ZEV Fleet Adoption

A comprehensive literature review identified the following barriers to ZEV fleet adoption. These barriers provided context to inform the development of strategies for the Transit ZEV Roadmap for the State, transit agencies, and other stakeholders to support a 100 percent transition of Colorado's transit fleet to ZEVs by 2050.

Knowledge Barriers

Lack of understanding of the technical, planning, financial, and governance factors critical to successful ZEV implementation.

- Lack of access to sufficient, reliable, and up-to-date information to conduct a thorough assessment of the feasibility of adopting a ZEV fleet
- Changes to operational characteristics and maintenance requirements of ZEV vehicles, including training for drivers, technicians, and other staff
- Need for new infrastructure planning processes and tools to evaluate the transition to a ZEV fleet
- Need for modified vehicle replacement and procurement processes
- Need for new implementation strategies for maintaining and operating a ZEV fleet
- Design challenges associated with increased space requirements for installing ZEV charging and fueling infrastructure
- Lack of understanding of how energy needs and costs vary by vehicle deployment size (i.e., can a 10 vehicle pilot be readily scaled to accommodate a 50+ vehicle deployment?)

Technological Barriers

Currently available ZEV transit models cannot meet the range of all transit service needs.

- Battery technology advancement necessary to improve vehicle range and the ability to operate in environments with varying grades and temperatures
- Required complementary evolution of the electric grid to accommodate charging
- Limited hydrogen fuel availability and affordability - The Colorado Hydrogen Roadmap is critical to understanding the full impact of this barrier

Financial Barriers

Some Colorado transit agencies report that the cost of transit ZEVs can be as much as double that of internal combustion engine vehicles. Significant financial barriers arise when combined with costly infrastructure upgrades and transit agency training required to develop electric rates collaboratively with utility companies.

- High upfront costs associated with ZEV options relative to traditional transit vehicle options
- Need for more options for financing higher capital costs associated with ZEVs, including mechanisms for accounting for total cost of ownership (TCO) vs. upfront capital costs
- High capital costs associated with required grid infrastructure upgrades and charging equipment
- Lack of familiarity with energy vs. demand charges and impacts on operating costs and/or availability of ZEV charging rates
- The higher purchase price of ZEVs may force transit agencies to re-evaluate budgets to decide whether to prioritize capital investment in higher cost vehicles at the expense of the operating budget

Institutional Barriers

Transit agency and utility service territories cover diverse and dynamic geographic areas. Colorado utilities and transit agencies have varying levels of experience and inconsistent processes for coordinating across jurisdictional boundaries to meet service planning and transmission/distribution planning needs.

- Need for unprecedented coordination between transit agencies and utilities
- Range of experience coordinating across jurisdictional boundaries to meet transit service planning and electrical grid transmission/distribution planning needs
- Need for supporting transit electric infrastructure to be integrated into transmission and distribution system planning
- Need for regulatory agencies to develop processes to expedite infrastructure investments
- Need to address the limitations of FTA useful life thresholds to accommodate early replacement of non-ZEVs with ZEVs

Fleet Electrification Readiness

Transit agency fleets that have accomplished successful ZEV transitions are charcterized by the following actions. Appendix A includes several case studies, lessons learned, and additional information on fleet electrification readiness strategies from previous ZEV deployments.

Conduct a fleet-wide assessment to develop short- and long-term ZEV transition goals

- Plan for incremental deployment/demonstration projects to verify how well different ZEV options meet the range of fleet needs and to refine ZEV charging and maintenance schedules
- Identify representative routes to model energy and vehicle range requirements
- Evaluate impacts of unique geographic and service characteristics to identify necessary strategies to prevent service quality impacts

Leverage long-term planning goals to maximize use of available funding

- Long-term utility infrastructure sizing strategies (make-ready investments such as upsizing transformer pads or laying additional conduit) add minor additional costs to earlier deployments but will reduce overall long-term costs

Develop phased plans to upgrade/retrofit maintenance facilities and bus depots

- Assess installation, space, and power requirements for short- and long-term fueling infrastructure needs
- Ensure clear communication with new vendors to reduce costs associated with incremental retrofitting
- Evaluate and plan for land purchases to house current and future transit fleets
- (For battery electric buses): Upgrade/retrofit bus yards to accommodate additional equipment and evaluate the potential to use gantries for overhead depot charging or cord management
- (For fuel-cell electric buses): Evaluate opportunities to retrofit existing fuel storage and compressed natural gas (CNG) fueling stations for compressed hydrogen fuel

Consult early and often with electric utilities to plan for electric infrastructure needs, review rate schedules, and collaborate to develop mutually beneficial incentives or pilot programs

- Review reliability reports to understand the frequency and types of outages that have occurred and develop resiliency plans with utilities
- Work with utility companies early to determine if an agency's long-term plans are possible given the electrical capacity available where existing facilities are located

Provide proactive training for operations and maintenance staff

- Consult with labor unions to ensure needed accommodations are implemented in the deployment plan

Involve diverse stakeholders early in the planning and transition process

- **Internal Stakeholders to include:** Operations and planning, maintenance and engineering, training, facilities, finance and procurement, IT, sustainability manager, contract operators, board or executive leadership, and public information officers
- **External Stakeholders to include:** Governmental agencies, electric utilities, labor unions, environmental justice representatives, surrounding communities and other interest groups

Photo Credit: RTD Flickr

Transit Storage & Maintenance Facility Needs

Key installation activities before acquiring a large battery electric bus (BEB) fleet include onsite installation of charging equipment, installation of power distribution to connect to local utility service, and capability to draw required power from the grid. Phased infrastructure investment and implementation is recommended to complement BEB fleet deployment and expansion.[5] A phased approach can minimize implementation costs and allow transit agencies to test feasibility and identify infrastructure and facility upgrades that best meet the needs of each deployment.

For smaller BEB deployments, charging requirements can be met with scaled-down implementation efforts and equipment. For example, equipment such as plug-in pedestal chargers and minimal infrastructure investment may be adequate for these smaller deployments. Larger charging infrastructure systems may be needed to support larger BEB fleets. Depending on the size of the fleet and the limitations of the facility, plug-in charging may not be practical. Some agencies prefer to use overhead pantograph or reel dispensers attached to the roof structure or gantry when larger BEB fleets are used.[6]

High voltage systems and hydrogen gas can be dangerous, but so can gasoline or diesel fuel. BEBs and FCEVs present different safety risks requiring mitigation strategies that differ from diesel and gasoline fueled vehicles. Ensuring continued safe operation of transit vehicles will require ZEV-specific facility design and staff training.

Maintenance Costs

Most transit agencies have limited experience maintaining ZEVs over multi-year periods. However, studies and evaluations conducted to date indicate that BEBs are projected to incur significantly lower maintenance costs as maintenance staff and vehicle operators become more familiar with ZEVs. Proterra estimates that electric buses can provide up to $50,000 annually in fuel and maintenance cost savings, and New Flyer reports lifetime fuel and maintenance savings of up to $525,000.[7]

An analysis by the California Air Resources Board found that a 2016 electric bus can save $458,000 in fuel and maintenance costs over time compared to a diesel bus, $336,000 compared to a natural gas bus, and $331,000 compared to a diesel hybrid bus.[8] Many ZEV fleets in operation today do not have experience with midlife engine overhauls and battery or fuel cell replacements that may be necessary over the lifetime of a ZEV. Early procurement contracting and demonstration negotiations with OEMs should explore mechanisms for transit agencies to share the risk of these unknown costs with the manufacturers. Information sharing among Colorado transit agencies can inform state-specific projections for maintenance costs.

Photo Credit: Breck Free Ride

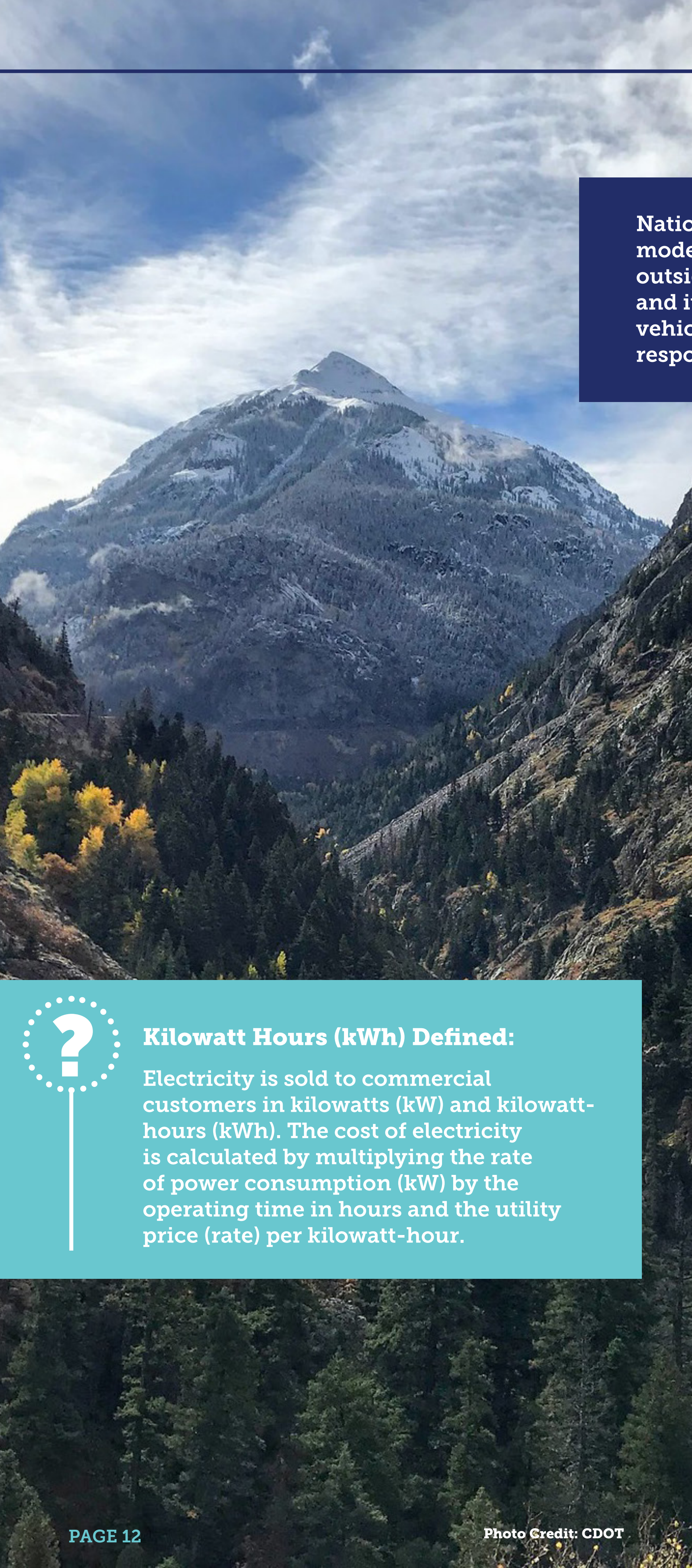
Zero Emission Vehicle Options & Model Availability

Fuel cell systems largely dominated the early ZEV transit market. However, the lack of extensive hydrogen fueling infrastructure has resulted in the majority of ZEV transit deployments using BEBs.[9] Decreasing battery and renewable electricity costs have contributed to the growth of the battery electric ZEV market and the pursuit of clean transit vehicle options.

Model availability and procurement and delivery times may vary by manufacturer and could be significantly impacted by nationwide efforts to transition transit fleets to ZEVs. Table 1 provides a complete list of existing model availability by manufacturer.[10]

Table 1: Existing ZEV Model Availability by Manufacturer

ZEV Manufacturer	Product Type	In Use/Procured by Colorado Transit Agency?
APS Systems[11]	Conversion to BEB or mix of battery and alternative fuels	No
AVASS Group[12]	BEB manufacturing Conversion to BEB	No
Build Your Dreams (BYD)[13]	BEB manufacturing	RTD
GreenPower Motor Company[14]	BEB, electric traction motors, and battery management systems	No
GILLIG[15]	Hybrid-electric, BEB	Town of Vail[16]
Lightning eMotors[17]	Conversion to BEB	City of Boulder (Via)[18]
Motiv Power Systems[19]	Conversion to BEB	Town of Estes Park[20]
New Flyer Industries[21]	BEB and Fuel Cell	RFTA[22]
Novabus[23]	BEB manufacturing	No
Phoenix Motorcars[24]	Conversion to BEB	No
Proterra[25]	BEB manufacturing	Town of Avon[26], ECO Transit Summit Stage[27], Town of Breckenridge[28] City of Boulder (Via), Mountain Metro Transit
Van Hool[29]	Fuel Cell	No
ENC/El Dorado[30]	Fuel Cell	No



National market trends such as transit vehicle model availability reflect forces largely outside the control of the State of Colorado and its transit agencies – statewide ZEV vehicle adoption will require flexibility to respond to market opportunities.

Market Readiness

ZEV transit purchase cost parity depends on the reduction of many of the technological, economic, and knowledge-based barriers to ZEV fleet adoption.

The largest drivers of purchase cost parity for BEBs are advancements in battery technology and a decline in battery costs. Historic lithium-ion battery cost trends indicate that battery costs decrease by 18 percent every time demand doubles. The price of lithium-ion battery packs has fallen by 24 percent since 2016 and 79 percent since 2010 and is projected to reach a cost of $96/kWh by 2025 and $70/kWh by 2030.[31]

As shown in Table 2, lithium-based NMC and LFP are expected to remain the go-to battery choice in the near term. However, major advancements in battery technology and increased range are projected to coincide with the rise of lithium sulfur battery technology post-2022.[32]

Kilowatt Hours (kWh) Defined:

Electricity is sold to commercial customers in kilowatts (kW) and kilowatt-hours (kWh). The cost of electricity is calculated by multiplying the rate of power consumption (kW) by the operating time in hours and the utility price (rate) per kilowatt-hour.

Photo Credit: CDOT

Table 2. Future Battery Chemistries in EVs - 2017-2030

		2017	2020	2025	2030
Li-ion (LFP, LMO, NMC)	Energy Density	110-220 Wh/kg	> 300 Wh/kg		
	Pack Cost	$500>>>$150 kWh	$150>>>$80/kWh		
	Lifecycle	30-1,500 cycles	> 1,500 cycles		
Lithium Titanate Oxide	Energy Density	30-80 Wh/kg	> 150 Wh/kg		
	Pack Cost	$1,000>>>$400 kWh	$400>>>$140/kWh		
	Lifecycle	3,000 cycles	~ 7,000 cycles		
Lithium Sulfur	Energy Density		500-600 Wh/kg (theoretical)	400 Wh/kg (practical)	
	Pack Cost		$500-$350/kWh	$350-$150/kWh	
	Lifecycle		500-1,000 cycles	> 1,500 cycles	
Solid State Li	Energy Density		400 Wh/L	600 Wh/L	
	Pack Cost		$500 - $400/kWh	$250-$150/kWh	
	Lifecycle		> 10,000 cycles		

Source: Frost & Sullivan

Total Cost of Ownership (TCO)

Formalizing the transit ZEV procurement processes can provide increased price transparency, strengthen statewide buying power, and reduce the level of effort required for transit agencies to evaluate ZEV options.

Evaluating the transit ZEV transition using purchase price parity alone has the potential to ignore some of the primary benefits of ZEV options over diesel options that lie in the reduced fuel and maintenance costs that accrue over time. Conducting a TCO evaluation can identify when the fuel and maintenance cost savings could offset the higher purchase costs. The primary factors impacting a TCO comparison are:

- Electricity, CNG, gasoline, diesel and hydrogen fuel prices
- Annual vehicle miles traveled (VMT)
- Access to fueling infrastructure, installation and capital equipment costs, electric rate design options, and fueling/charging strategies

There is a strong inverse relationship between the TCO and annual VMT; as VMT increases, the reduced operations and maintenance costs associated with ZEV options allow the ZEVs to be cost-competitive with their diesel counterparts. Due to the range limitations of the battery technology, focusing early deployment of BEBs on routes that are shorter in length and those with high ridership may result in high cost efficiency per passenger and per mile. Examples in Colorado include RTD's 16th Street Mall Ride and the HOP in Boulder.

There is an opportunity to develop complementary policies to emphasize the importance of environmental benefits of ZEVs (e.g., changing procurement processes to include an evaluation of environmental impacts). Colorado should include the environmental and societal costs of tailpipe emissions into procurement processes.

Workforce Readiness

Leveraging nationwide best practices and lessons learned during the ZEV procurement process can help support Colorado transit agency service and maintenance sector readiness for the transit ZEV transition.

The transit ZEV transition has the potential to create new job opportunities in Colorado. Maintaining and operating ZEV fleets require different parts, maintenance practices, and staff skill sets than have been historically required for transit fleets. Early adopters note that transit agencies preparing for a ZEV transition should ensure that ZEV-specific documentation and manuals are supplied for[33]:

- Preventative maintenance
- Diagnostic procedures
- Spare parts/final parts
- Component repair
- Operator instructions
- Bus schematics
- Training materials
- Charger/charging use
- Smart charging & battery health management systems

Traditionally, OEMs provide operator training to agency trainers. Successful agencies highlight the benefit of strategically identifying and scheduling operator training to coincide with initial vehicle deployments.[34]

Training Topics and Recommended Training Hours from ZEV Bus OEMs

- BEB Orientation = 4-8 hours
- Operator Training = 8-16 hours
- Maintenance Training = 32-48 hours
- Depot Charger Maintenance Training = 16-32 hours

Operator Training Activities

- General BEB orientation
- Normal operating procedures
- Emergency operating procedures
- Moving a BEB with a problem
- Revenue service preparation

Maintenance Training Activities

- Multiplex systems
- Entrance and exit doors
- Wheelchair ramps
- Brake systems and axles
- Air systems and ABS
- Front and rear suspension and steering
- Body and structure
- Towing and recovery
- Propulsion systems
- High voltage systems
- Depot charger
- HVAC

More information on each of the service and maintenance readiness actions is summarized in Appendix B, which also includes several case studies and lessons learned.

Training should include both classroom and hands-on activities, ensuring operators and maintenance staff have opportunities to familiarize themselves with their new vehicles to maximize the benefits and performance of ZEVs.

Photo Credit: RFTA

Colorado ZEV Environment

Current Fleet Snapshot

Colorado is home to a variety of transit options operated by public, private, and non-profit agencies. Transit service across the state includes bus service (local, regional, interregional, intercity), passenger rail service (light rail, commuter rail) and human services transportation.

The current fleet inventory includes open door, general public transit services. This section summarizes the transit agencies and providers included in the Transit ZEV Roadmap. The inventory of the existing general public transit fleet in Colorado was developed referencing the 2045 Statewide Transit Plan (STP), associated rural Regional Transit Plans, federal transit data, and CDOT collected transit fleet information.

Several databases and resources provide information critical to understanding the current composition of the larger Colorado transit fleet, including:

- Colorado Transit and Rail Awards Management System (COTRAMS) Capital Inventory Records
- CDOT's Transit Asset Inventory Master Database
- 2018 Colorado DOT Transit Asset Management Group Plan
- FTA's National Transit Database (NTD) Annual Vehicle Tables

Appendix C includes additional information about the current reporting of transit fleet asset information, including information about which agencies report to each of the above noted databases.

[Table 3](#) summarizes the current inventory of the Colorado transit fleet, excluding providers that are not open to the general public, by vehicle type and fuel type. Vehicle type definitions are included in Appendix D. It is important to note that the transit vehicle inventory summarizes 2018 data due to the completeness of available information. As of November 2021, Colorado's transit fleet has 60 BEBs, a 58 percent increase from 2018.

Table 3: 2018 Colorado Transit Fleet by Vehicle & Fuel Type

		Compressed Natural Gas	Diesel Fuel	Gasoline	Hybrid Diesel	Hybrid Gasoline	Electric Propulsion Power	Electric Battery	Dual Fuel	Total
Revenue Vehicles	Aerial Tramway						71			71
	Articulated Bus	8	117							125
	Automobile			96		14		1	3	114
	Over-the-Road Bus	10	187							197
	Bus	79	1,123	12	39	4		37	2	1,296
	Cutaway	22	50	777	1	1				851
	Light Rail Vehicle						172			172
	Minivan	9		112					1	122
	Commuter Rail Self-Propelled Passenger Car						66			66
	Sports Utility Vehicle			4						4
	Van	7		116					4	127
Service Vehicles*	Automobile			44		5				49
	Truck and Other Rubber Tire Vehicle		5	64		1				70
Total		**135**	**1,482**	**1,225**	**40**	**25**	**309**	**38***	**10**	**3,264**

Note: Vehicle totals in the table sum the number of vehicles that meet the dual variables. Data entries missing information in either variable are excluded from table totals, resulting in variations in table totals. NTD data reported in the following table has been verified and updated to address reporting errors and inconsistencies.

* As previously noted, the Colorado EV Plan defines transit vehicles as vehicles operated by transit agencies that carry passengers or public riders. The Colorado transit fleet overview summarizes all vehicles included in the CDOT inventory. Accordingly, 2030 and 2050 goal attainment has been evaluated based on revenue vehicles only.

Aerial Tramway Defined:
A vehicle propelled by separate cables attached to the vehicle suspension system and powered by engines or motors not onboard the vehicle. These vehicles have been reported to NTD with the "Electric Propulsion Power" fuel type due to their reliance on electric motors.

Electric Propulsion Defined:
Electric propulsion technologies use electric power to drive a vehicle. These systems use components such as electric motors, electric energy storage devices, inverters, and electronic controllers.

Dual Fuel Defined:
A vehicle that uses more than one source of fuel per the NTD. This includes plug-in hybrids that consume both liquid fuel and electricity from an external outlet. It does not include hybrids that charge their batteries using systems onboard the vehicle. For dual fuel vehicles, agencies should report both fueling types (e.g., gasoline and electric battery for a plug-in hybrid).

The availability of ZEV options and opportunities to replace the existing revenue and service vehicle fleets also vary by vehicle capacity, current vehicle ownership structure, and the vehicle's remaining service life.

Vehicle capacity by fuel type is summarized in Table 4.

Table 4: 2018 Colorado Transit Fleet Capacity by Fuel Type

Capacity (seated + standing wheelchair)	Compressed Natural Gas	Diesel Fuel	Gasoline	Liquid Petroleum Gas	Hybrid Diesel	Hybrid Gasoline	Electric Propulsion Power	Electric Battery	Dual Fuel	Total
0-5	17	6	250	-	-	20	-	1	1	295
6-10	-	8	397	-	-	-	71	-	3	479
11-15	3	14	437	-	-	-	-	-	4	458
16-20	-	4	113	-	-	1	-	-	-	118
21-25	2	28	43	-	9	-	-	-	-	82
26-30	-	49	12	-	1	-	-	1	-	63
31-35	-	6	7	-	-	-	-	-	-	13
36-40	20	135	2	-	6	-	-	-	-	163
41-45	4	76	1	-	8	-	-	-	-	89
46-50	7	521	-	-	9	-	-	-	-	537
50+	82	635	-	-	7	4	238	36	2	1,004
Total	**135**	**1,482**	**1,262**	**-**	**40**	**25**	**309**	**38**	**10**	**3,301**

There are several transit vehicle ownership types:

- Owned outright by public agency (OOPA)
- Owned outright by private entity (OOPE)
- True lease by public agency (TLPA)
- Leased or borrowed from related parties by a public agency (LRPA)
- True lease by private entity (TLPE)
- Leased under lease purchase agreement by a public agency (LPPA)
- Leased or borrowed from related parties by a private entity (LRPE)
- Leased under lease purchase agreement by a private entity (LPPE)

In all, the Colorado transit fleet is largely owned outright by a public agency with approximately 10 to 15 percent of vehicles owned by a private entity and only thirty vehicles falling under a leasing mechanism. A table summarizing ownership by vehicle type is included in Appendix E.

Remaining Service Life

The CDOT Transit Asset Inventory Master Database automatically populates Revenue Vehicle Service Years and is analogous to the Useful Life Benchmark (ULB) for evaluating state of good repair performance and set annual performance targets in NTD. ULB is the age at which a vehicle has met its economic useful life. The FTA established a default benchmark for each vehicle type, and transit agencies set ULBs for each vehicle type in their fleet within their FTA-approved transit asset management plan. A vehicle that has met or exceeded its ULB is no longer in a state of good repair and should be prioritized for replacement. The remaining service life has been calculated using the manufacturing year. Table 5 summarizes the Colorado transit fleet by years of remaining service life and fuel type.

Table 5: 2018 Colorado Transit Fleet – Years of Remaining Service Life by Fuel Type

	Compressed Natural Gas	Diesel Fuel	Gasoline	Liquid Petroleum Gas	Hybrid Diesel	Hybrid Gasoline	Electric Propulsion Power	Electric Battery	Dual Fuel	Total
Exceeded	15	152	334	-	14	15	60	-	2	592
0-5 Years	30	525	359	-	21	10	-	2	8	955
6-10 Years	64	350	453	-	5	-	28	-	-	900
11-15 Years	26	450	4	-	-	-	32	36	-	548
15+ years	-	-	-	-	-	-	189	-	-	189
TOTAL	**135**	**1,477**	**1,150**	**-**	**40**	**25**	**309**	**38**	**10**	**3,184**

Understanding where the Colorado transit fleet is stored and where associated maintenance occurs is critical to ZEV planning efforts. Maintenance facilities will need to be upgraded to accommodate ZEVs, and parking and storage facilities will likely require modifications to accommodate fleet charging. The CDOT Transit Asset Inventory Master Database includes an inventory of support facilities. Table 6 summarizes facility types included in the CDOT inventory and the number of each facility type.

Table 6: Support Facilities Included in the 2018 CDOT Inventory

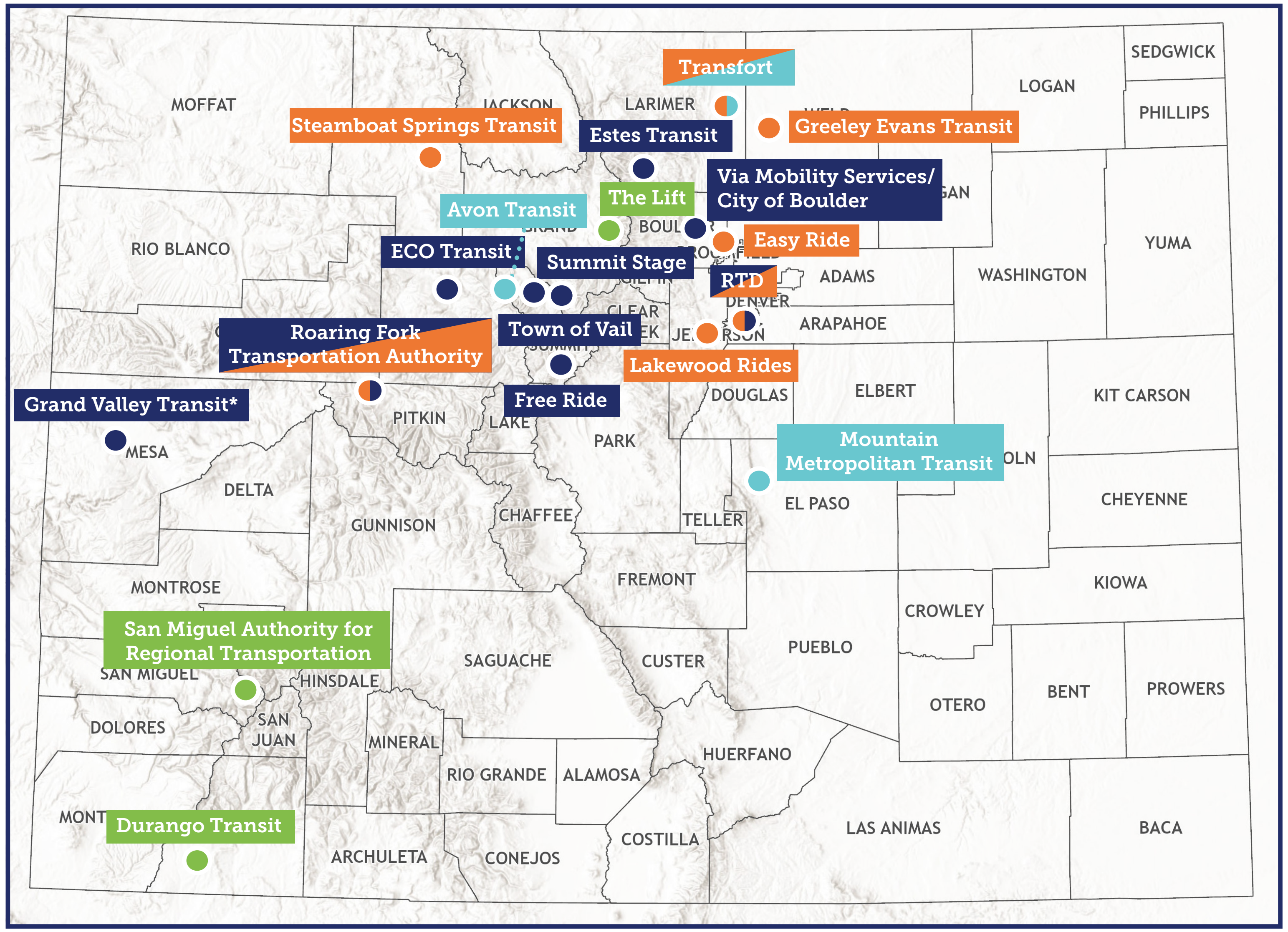
Support Facilities	Count
Administration Building	23
Bus Maintenance Facility	28
Bus Parking Facility	18
Storage Yard	7
Other Support Facility	21
Total	**97**

The current CDOT transit facility inventory does not include information specifying if vehicles are stored indoors or outdoors. There is a need to understand the percentage of the Colorado transit fleet that parks overnight outdoors versus indoors, given that a vehicle battery's state of charge can decrease by 30 to 35 percent at temperatures below 32 degrees as compared to temperatures between 32 and 77 degrees.[35] The performance differential associated with cold temperatures highlights the importance of indoor vehicle storage and charging as a means of maximizing vehicle range and overall transit service.

Photo Credit: Summit County

State of Transit ZEVs in Colorado (as of Summer 2021)

Twelve transit agencies across the State of Colorado have begun operating ZEVs or currently have them on order. Additionally, 10 agencies have completed, are in the process, or will be completing a ZEV Transition Plan in the near future.



*Grand Valley Transit uses Renewable Natural Gas (RNG) for 50% of its operations; the remaining 50% uses Xcel Energy natural gas.

- Operating ZEVS
- ZEVs Ordered (not yet in operation)
- Fleet Transition Plan Complete
- Fleet Transition Plan Underway/Imminent

Renewable Natural Gas Defined:

Natural gas captured from sources such as wastewater treatment plants, landfills, etc. RNG is often considered a carbon-neutral fuel because the carbon it emits via combustion originates from organic sources that absorbed carbon dioxide from the atmosphere during photosynthesis. RNG captured from organic waste that would otherwise decay, causing methane emissions, can sometimes even be considered a carbon-negative energy source.

Funding Sources Snapshot

Existing Funds

Several existing funding sources and programs are available to support the many facets of transitioning the Colorado transit fleet to ZEVs.

The funding from these programs and sources can be used to supplement and/or cover:

- Operating Costs
- Technical Studies
- Transit Plans
- Capital Facilities Costs
- Capital Equipment Costs
- Capital Vehicle Costs

FTA Metropolitan & Statewide Planning and Non-Metropolitan Transportation Planning – 5303, 5304, 5305

Section 5303, 5304, and 5305 multimodal planning funds are available to support transit-related planning activities (e.g., preparing transit plans and programs, engineering and technical studies, etc.) in both urban and rural areas. Funding is apportioned to states through a formula, and urban planning dollars are suballocated to the five Metropolitan Planning Organizations across Colorado. Section 5304 funds are administered by CDOT's Division of Transit and Rail (DTR), and awards typically range from $15,000 to $40,000. It is important to note that these funds are not eligible for administrative, capital, or operating expenses but can be used to support ZEV planning and the development of fleet electrification feasibility studies.

FTA Grants for Buses and Bus Facilities Formula Program – 5339(a)

The Bus and Bus Facilities Formula Program provides funding to states and transit agencies via a statutory formula for funds to operate fixed-route bus service. Eligible activities include "Capital projects to replace, rehabilitate and purchase buses, vans, and related equipment, and to construct bus-related facilities, including technological changes or innovations to modify low or no emission vehicles or facilities."[36]

FTA Bus and Bus Facilities Program – 5339(b)

The Bus and Bus Facilities competitive grant program provides funding for the following types of projects:[37]

- The replacement, rehabilitation, and purchase of buses, vans, and related equipment
- The construction of bus-related facilities, including technological changes or innovations to modify low- or no-emission vehicles or facilities

FTA Low or No Emissions Vehicle Program – 5339(c)

The FTA's Low or No Emissions Vehicle competitive grant program provides funding to state and local governments for the following costs related to zero and low-emission buses:[38]

- The purchase or lease of low-emission and zero-emission buses
- The acquisition of low-emission or zero-emission buses with a leased power source
- Construction or lease of related facilities and equipment (including technology and software) for low-emission and zero-emission vehicles
- Construction of new transportation facilities to accommodate low-emission and zero-emission vehicles
- Rehabilitation or improvement of existing public transportation facilities to accommodate low-emission or zero-emission vehicles

In 2021, Transfort (Fort Collins) received $3.5 million under the FY 2021 FTA Low or No Emissions Vehicle Program - 5339(c). In 2020, CDOT received $1.6 million in 5339(c) funds on behalf of Avon Transit for the purchase of new electric buses to replace diesel vehicles that were at the end of their useful life. In 2019, RTD received $2.6 million in 5339(c) funds for electric vehicles, charging stations, and infrastructure upgrades.

FTA Formula Grants for Rural Areas - 5311

The Formula Grants for Rural Areas Program provides capital, planning, and operating assistance to states to support public transportation in rural areas with populations of less than 50,000, where many residents often rely on public transit to reach their destinations. Eligible recipients include states and federally recognized Indian Tribes. Subrecipients may include state or local government authorities, nonprofit organizations, and operators of public transportation or intercity bus service. Low and/or no emission planning and capital purchases are eligible under this program.

FTA Urbanized Area Formula Grants - 5307

The Section 5307 Urbanized Area Formula Program provides funding nationwide to census-designated urbanized areas for transit capital and operating assistance for transportation-related planning. Eligible expenses and allocation formula depend on population, population density, and revenue and route mile thresholds.

Section 5307 specifies that funds are eligible for projects to comply with the Clean Air Act (CAA) for nonattainment or maintenance areas, and therefore, can also be used to purchase low or no emission vehicles and to invest in supporting infrastructure.

FTA Areas of Persistent Poverty Program

FTA's Areas of Persistent Poverty Program (formerly known as the Helping Obtain Prosperity for Everyone - HOPE) is a competitive funding program that helps lift communities out of poverty by supporting transit service improvements in underserved communities. The program supports planning, engineering and technical studies, or financial planning to improve transit services in any areas experiencing long-term economic distress, in rural and urban communities alike. It can also fund low and no emissions transit vehicles and associated infrastructure.

FTA & FHWA Flex Funding

FTA and the Federal Highway Administration (FHWA) offer several flexible funding programs to fund transit-related projects. Flexible funds are legislatively specified funds that may be used either for transit or highway purposes and provide flexibility to fund locally prioritized projects.

The Congestion Mitigation and Air Quality (CMAQ) Improvement Program and the Surface Transportation Block Grant (STBG) Program are two flexible funding sources that can be used for fleet electrification.

The Fixing America's Surface Transportation (FAST) Act authorized the CMAQ Program as a flexible funding source for transportation projects and programs that help to meet the requirements of the CAA, including electric vehicles and related infrastructure projects. These funds support projects to reduce congestion and improve air quality for areas that do not meet the National Ambient Air Quality Standards for ozone, carbon monoxide, or particulate matter (nonattainment areas), and for former nonattainment areas that are now in compliance. Eligible uses for CMAQ funding include capital costs of transit projects and up to three years of operations and maintenance costs of new transit services.

The FAST Act authorized the STBG program as a flexible funding source to address state and local transportation needs. Eligible projects include planning, design, construction, and capital projects; operational and safety improvements; and surface transportation environmental improvement measures. Due to the broad eligibility of the program, this funding source has the most flexibility among all federal-aid highway programs. The program implementation guidance[39] explicitly states that electric vehicles and infrastructure are eligible for funding.

In 2018, Transfort (Fort Collins) was awarded $775,000 CMAQ funding from the North Front Range Metropolitan Planning Organization (NFRMPO) for the purchase of one ZEV and one charging unit.[40]

Funding Advancements for Surface Transportation and Economic Recovery Act

The Funding Advancements for Surface Transportation and Economic Recovery Act of 2009 (FASTER), also known as Senate Bill (SB) 09-108, approved and/or modified a number of fees and fines to provide approximately $200 million annually for state transportation projects. FASTER funds include $5 million annually for the purchase of new or replacement transit vehicles, construction of multimodal stations, and acquisition of equipment for consolidated call centers. FASTER funds also include $10 million in funds awarded by CDOT's DTR for statewide, interregional, and regional projects.

Public Private Partnerships

Public-Private Partnerships (P3s) have the potential to support a significant share of project costs and could facilitate lower project costs as part of a comprehensive program delivery strategy. However, P3s include a transfer of associated risk to the private sector, meaning program sponsors will have less direct control of the program.

- **P3 Equity** is an ownership stake in an enterprise with the aim of making a profitable return. This may include investment from commercial developers, financial investors, pension funds, sovereign wealth funds, insurance companies, and private equity funds. A P3 equity stake is just one component of an overall project delivery strategy.

- **P3 Debt** can be coupled with equity to finance the initial investment and may include Private Activity Bonds (PABs), taxable bonds, bank loans, and other debt instruments. P3s have the potential to finance a significant share of project costs and could facilitate lower project costs as part of a comprehensive program delivery strategy to manage project risks. Elements of P3 financing may include equity—direct investment by the P3 concession—and PABs, which are relatively low-cost bonds issued by private entities to support eligible public works infrastructure projects. Equity and PABs are frequently combined with Railroad Rehabilitation & Improvement Financing (RRIF) or other direct federal loans to finance P3 projects in the U.S.

Volkswagen Settlement Funds

In 2016, the Department of Justice filed a complaint on behalf of the Environmental Protection Agency against Volkswagen (VW) for violations of the CAA. The State of Colorado received $68.7 million from the resulting legal settlement and funds are used for projects that reduce nitrogen oxide emissions from the transportation sector.[41] CDOT's DTR manages the Consolidated Call for Capital Projects and handles dispersing the $30 million allocated in the Beneficiary Mitigation Plan (BMP) for zero emission transit bus replacements as a part of the Transit Bus Replacement Program. As of March 2021, approximately $9 million was left to be awarded for the replacement of Class 4-8 diesel transit buses with zero-emission transit buses and to install related charging infrastructure.[42] DTR may combine state or federal grant funds with settlement grant funds to significantly reduce the cost of a new transit ZEV and provides up to $100,000 for charging infrastructure and equipment per awarded vehicle.

Photo Credit: Mass Transit Magazine

Senate Bill 17-267

In 2017, the Colorado Legislature passed SB 17-267, which authorized an additional $500 million annually in proceeds from lease-purchase agreements on state assets for transportation projects. SB 17-267 mandates that at least 10 percent, or $50 million, be allocated to transit capital projects annually. Twenty-five percent of the SB 17-267 transit funds are allocated to CDOT projects, including Bustang; approximately 50 percent of funds are to be allocated to CDOT and partner agency projects; and 25 percent of funds are allocated to local agency transit improvement projects. SB 17-267 is only a four-year program and to date only years one through three have been funded.

Senate Bill 21-260

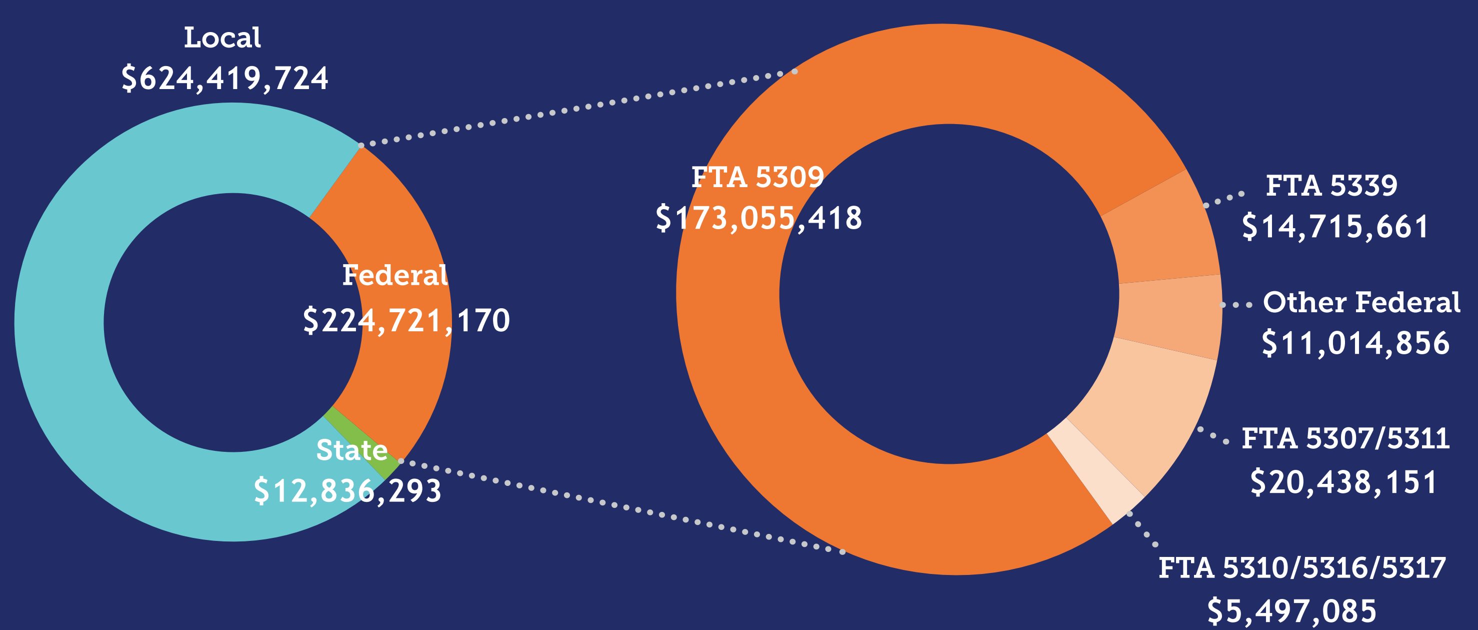
Colorado SB 21-260, Sustainability of the Transportation System, passed during the 2021 legislative session and will provide over $5 billion in new funding for transportation in Colorado. Approximately $3.8 billion will be generated by new enterprises and fees, with an additional $1.5 billion expected to come from the state general fund and stimulus funding.

SB 21-260 includes the formation of a Clean Transit Enterprise within CDOT to support public transit electrification. The enterprise is authorized to impose a clean fleet fee on retail deliveries and rides provided by transportation network comapanies (TNCs). The enterprise is also authorized to issue grants, loans, and rebates to support electrification of public transit.

Transit ZEV transition projects may also be eligible to pursue funding through the renamed Multimodal Transportation and Mitigation Options Fund, which adds eligibility for GHG mitigation projects.

Figure 3: 2018 Funding of the Colorado Transit Fleet

The Colorado transit fleet is currently funded through a combination of local, state, and federal funds. CDOT maintains the Transit Asset Inventory, including documentation of the associated funding with the various vehicles tracked in the database. The graph below summarizes CDOT's record of sources of dollars used to fund Colorado transit vehicles operating in 2018.



The Role of Utilities in Transit Fleet Electrification

Colorado is home to 60+ public transportation providers and 53 electric utilities, highlighting the importance of coordinated planning for BEB deployment. Local electric utilities play an essential role in any successful ZEV planning and implementation process because they have a responsibility to provide customers with reliable electrical service and understand both the challenges and benefits of increasing the overall demand on the electrical grid at given times and locations. Proactive coordination between the local utility and transit agency allows both entities to identify fleet electrification needs and constraints early in the process and to streamline implementation over the long term.

Utility coordination and collaboration can help reduce the barriers to BEB deployments, including:

- Fleet charging time/scheduling requirements
- Estimating operating costs associated with charging
- High upfront infrastructure capital costs

Electric utilities have the necessary experience to support the expansion of transit ZEV infrastructure at a scale large enough to meaningfully impact the feasibility of transit electrification. Program development and strategic rate design to incentize charging behaviors that benefit customers and society can expand the cost savings and emission reduction potential of transit electrification.

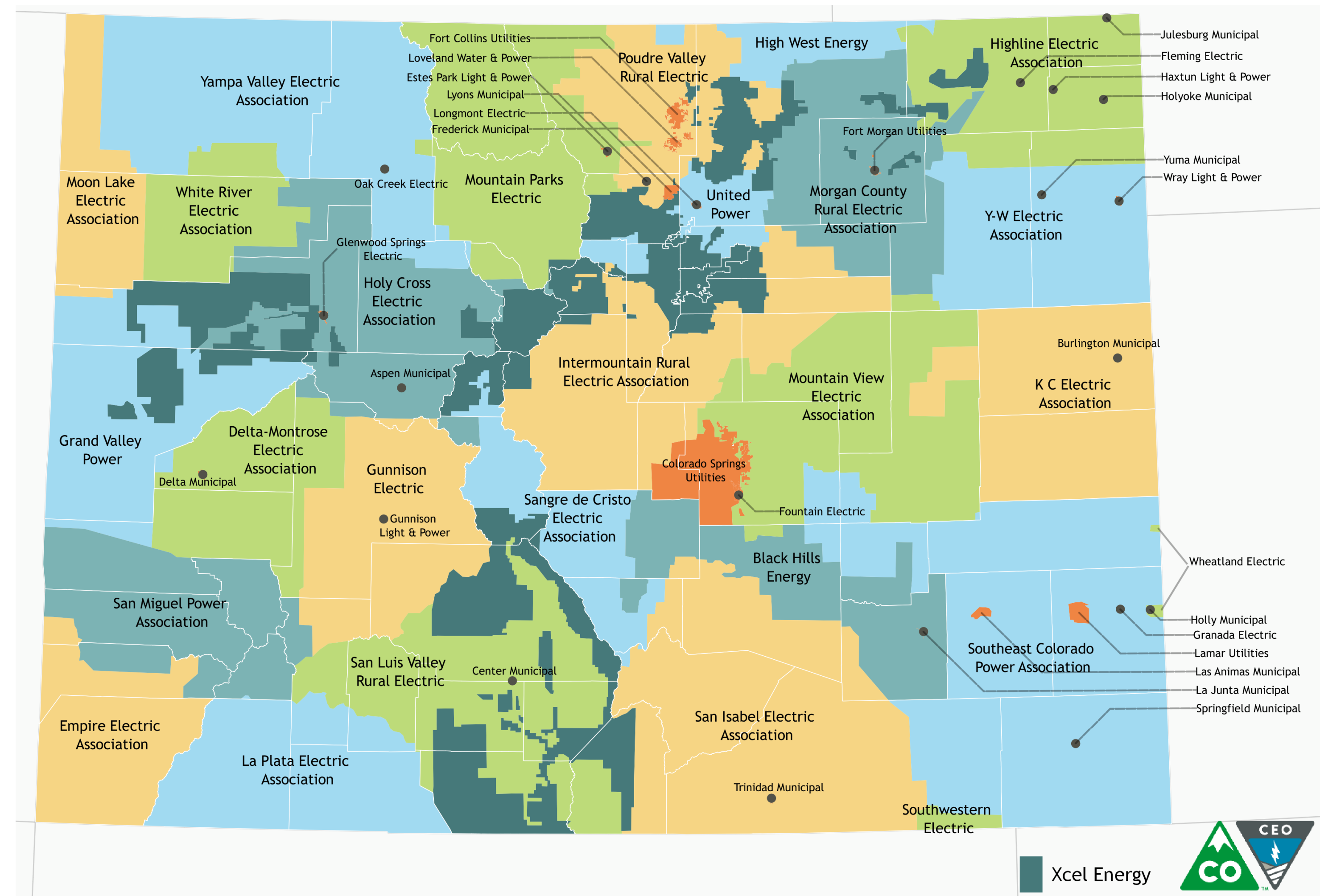
Colorado electricity customers are served by a combination of retail investor-owned utilities (IOUs), municipal owned utilities, and cooperative utilities. IOUs are for-profit monopolies regulated by the Colorado Public Utilities Commission (CPUC).

Figure 4 provides a comparison of electric utility models. Colorado electric utilities' service territories are shown on Figure 5.

Figure 4: Types of Electric Utility Providers in Colorado

	IOU *Investor Owned Utility*	MUNICIPAL UTILITY	CO-OP *Cooperative Utility*
Structure:	Private, for-profit	Public, non-profit	Private, non-profit
Owned by:	Shareholders	Local Government	Member-Owned
Regulated by:	Public Utilities Commission	Elected Officials	Co-op Board of Directors
Business Model:	Return on Investment	At-Cost Electricity Rates	At-Cost Electricity Rates

Figure 5: Map of Colorado Utility Service Territories[43]



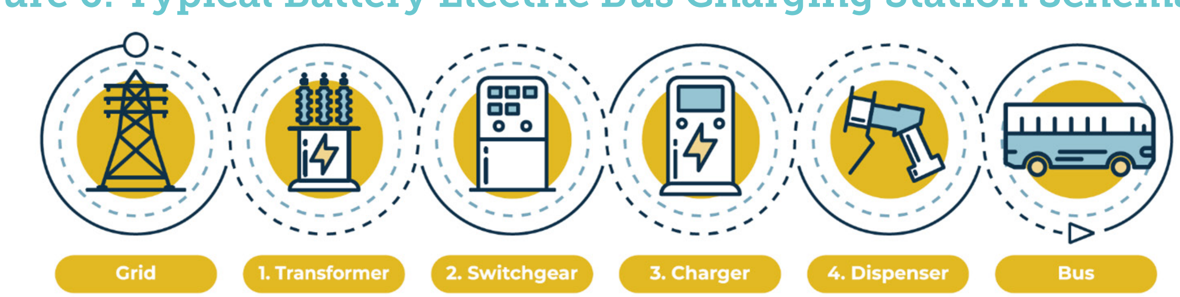
Battery Electric Bus Charging Infrastructure

Electric bus charging infrastructure falls into four categories:

- Plug-in depot charging
- On-route fast charging
- Overhead conductive charging (depot or on-route)
- Inductive charging (depot or on-route)

The appropriate charging infrastructure will require a case-by-case evaluation to ensure that vehicles have the necessary infrastructure to meet agency operational needs. Coordination with the local utility can inform lifecycle cost analyses for these scenarios. Typical charging configurations require a connection to the electric grid, transformer, switchgear, charger, and plug (dispenser) as shown on Figure 6.

Figure 6: Typical Battery Electric Bus Charging Station Schematic[44]



Having existing electricity service does not guarantee that a candidate charging location has the necessary site-specific infrastructure to support increased energy demands. The amount and rate at which electricity can be delivered to a customer in real time is a function of the size and type of infrastructure that connects the customer to the electric grid.

Many infrastructure and utility coordination challenges relate to getting electricity to the vehicles. While conventional fuels such as diesel and gasoline can be stored in large quantities in onsite tanks and pipes, electricity is typically delivered in real time. Accordingly, the energy grid and a customer's onsite connection must be designed to accommodate peak demand rather than just the anticipated average demand.

Accommodating EV transit charging infrastructure requires investment from both the utility and the transit agency. "Make ready" infrastructure refers to the necessary utility investments and electric grid infrastructure additions and upgrades to enable customer side electric vehicle supply equipment (EVSE) installations. The transit agency is responsible for the procurement, installation, and ownership of the EVSE. This model, as shown on Figure 7, provides the transit agency greater flexibility to choose an EVSE provider and system that best meet their needs. This model allows the utility to leverage its access to capital and low-interest financing to lower the cost of these investments and expedite the rate of expansion of utility infrastructure upgrades.

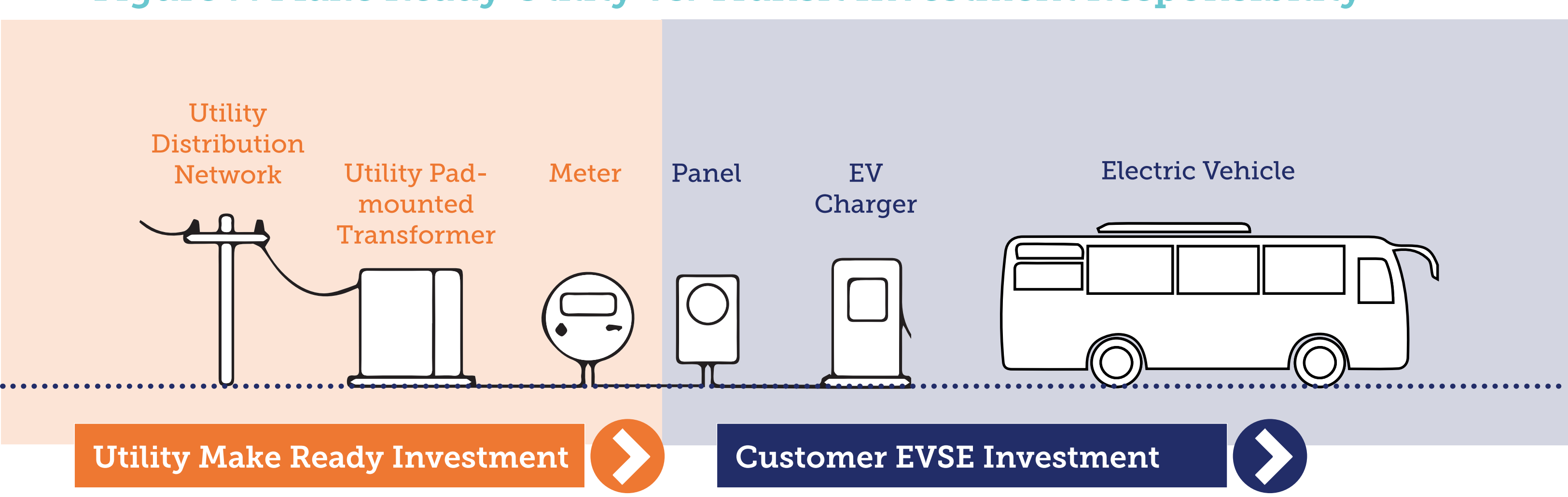
Under the Make Ready model, customers do not have to come up with the upfront capital for the utility investments to upgrade their electrical service and rate base cost recovery allows the utility to recover the cost of these investments over the life of the infrastructure through energy and demand rates.

The infrastructure investment component of existing rates and the additional revenue generated from increased electricity sales may account for a portion of these upgrade costs. However, rate increases will likely be needed to finance system-wide infrastructure upgrades.

Transit agencies should factor future rate increases into planning processes. While the "make ready model" eliminates the need for the transit agency to come up with the upfront capital for infrastructure improvements, regulated rate design must ensure equitable allocation of costs to the customers whose usage necessitates infrastructure upgrades, so transit agencies will be responsible for bearing the cost of the utility side investments they necessitate.

Working with utility staff early in the planning process to integrate electrification plans into their 10-year plan, rather than a nearer-term 5-year plan, can significantly reduce the costs of infrastructure investment in substation upgrades, garage refurbishment, additional service lines, etc.[45]

Figure 7: Make Ready Utility vs. Transit Investment Responsibility[46]



Impacts of Utility Rate Structures on the Economic Viability of Transit Fleet Electrification

Utility rate structures for commercial customers (transit agencies are typically on commercial rate schedules) include a fixed charge, a demand charge, and an energy charge:

- Fixed Charge - also known as the service and facilities charge - represents the "cost of being connected to the grid," which is independent of energy consumption.
- Demand Charge - reflects the costs that vary with capacity (i.e., larger wires to transfer larger volumes of energy). Demand charges are generally applied at tiered rates related to the customer's peak demand (measured in kW).
- Energy Charge - recovers costs that vary with energy usage (measured in kWh) and is based on total consumption over a given billing period; the energy charge is similar to a volumetric cost for conventional fuels.

Many utility bills also include riders or bill "surcharges" that contribute to the total bill amount. However, many of these riders and surcharges are applied across rate schedules and are considered fixed charges that do not change based on rate selection.

Analyzing historic utility bills allows the transit agency to understand pre-fleet electrification consumption and conditions of the existing utility rate schedule. Transit agencies should work with the local utility to identify the best schedule to align with the service requirements of the transit agency, minimize demand charges, and promote charging behavior that benefits the entire utility system.

In states like Colorado with high wind energy generation occurring in the overnight hours, utilities can leverage time-of-use (TOU) rates to incentivize charging activities to coincide with peak renewable wind energy generation. Aligning the EV energy demand curve with the renewable energy generation curve will maximize the economic and environmental benefits of EVs and can even eliminate or defer the need for additional generation capacity. In the longer term, coordinated vehicle and utility planning offers the potential for ZEVs to move beyond zero tailpipe emissions to true zero emission mobility.

The utility is responsible for matching demand to supply electricity reliably at the least cost. The electric load associated with transportation can provide increased system flexibility. Programmatic rate design is a powerful tool to educate customers of the full costs of energy consumption and usage patterns, including EV charging. Innovations to facilitate dynamic load control and enable smart EV charging can allow transit agencies and utilities to make decisions about energy use and consumption that can reduce costs and improve system efficiency.[47]

Starting January 2020, Xcel Energy (one of Colorado's IOUs) began offering a Secondary Voltage Time of Use - Electric Vehicle Service (S-EV) rate to provide electric power and energy solely for commercial and industrial customer EV charging. The S-EV rate promotes off-peak charging and is designed to reflect the fact that the cost of energy associated with charging EVs overnight is more a function of energy consumption (kWh) as compared to typical commercial and industrial energy demand (kW) that coincides with the peak system demand.

Appendix F provides additional information about Xcel Energy's EV rate schedule and an illustrative example of how a transit agency's operating profile, charging strategy, and rate schedule selection can result in significantly different utility bills.

Senate Bill 19-077 – Electric Motor Vehicles Public Utility Services

SB 19-077 authorized ownership of EV charging infrastructure by electric utilities and created a regulatory process for filing transportation electrification plans for a portfolio including EV charging facilities, EV make-ready infrastructure investment, multifamily and community-based charging programs, electrification of transit, and low-income programs.

While the State of Colorado does not currently require municipal and cooperative utilities to develop transportation electrification plans (TEPs), TEPs can be valuable tools for all Colorado utilities to plan for load growth associated with not only transit electrification, but larger transportation electrification trends more generally. TEPs maximize the utility's ability to provide a range of service offerings to customers that deliver on low fuel costs and align with larger state sustainable energy requirements.

TEPs should:

- Include strategies for estimating, planning, and measuring the impact of increased EV adoption on grid reliability
- Evaluate the geographic impacts of high EV market penetration in different portions of the utility service area
- Identify low-cost transmission and distribution upgrades
- Include strategies and programs to shape customer/consumer behavior that maximize transportation electrification benefits
- Create a blueprint that identifies and plans for complementary investment in actions driving transportation electrification

Consistent with SB 19-077, Public Service Company of Colorado (Xcel Energy) and Black Hills Energy filed TEPs with the CPUC. For additional information about these TEPs, see Appendix G.

Key Findings for the Transit ZEV Roadmap

- Local electric utilities will play an essential role in any successful ZEV planning and implementation process.
- Increased load associated with charging transit fleets could put significant strain on the existing electric infrastructure. Utilities and transit agencies will both have to invest in distribution upgrades and new infrastructure to meet the increased electrical demand to support electric fleets.
- The utility and transit agency relationship will look very different depending on the size of fleet, type of vehicles, type of chargers, and geographic location. Mutual understanding of both utility and transit agency operating needs will go a long way to ensuring reliable energy to meet evolving transit service schedules and operational needs. There are also opportunities to develop resiliency plans for planned and unplanned outages.
- State and local governments can encourage utility investment in ZEVs by supporting infrastructure development. For example, the state and CDOT could oversee and manage coordinated infrastructure planning processes for both utilities and transit agencies.

Photo Credit: Breck Free Ride

ZEV Financial Modeling

Goal of the Financial Model

The ZEV transit financial model uses information from the 2018 Colorado Fleet Inventory, available national ZEV model research, and existing ZEV procurement and operating experience in Colorado. The goal of the financial model is to create a tool to assess the range of ZEV transition scenarios for the 2022-2050 timeframe to answer the following questions:

- What does it take to get to 1,000 transit ZEVs by 2030?
- What does it take to get to 100 percent transit ZEVs by 2050?

The Transit ZEV Roadmap financial model evaluates the transition of rubber-tired revenue transit vehicles in Colorado and has excluded commuter rail, light rail, and aerial tramway vehicles, all of which are existing ZEVs that will count toward the goal of a 100 percent transit ZEV fleet by 2050.

The financial model does not include ongoing operating and maintenance costs, nor does it include costs for utility upgrades beyond charger and charger installation due to the high variability of these costs.

Overview of Methods & Assumptions

Appendix H includes a technical memorandum that includes additional information summarizing the development, assumptions, and results of the financial modeling exercise. The steps and assumptions used in the development of the financial model include:

1 Updating the 2018 Transit Fleet Inventory: To determine the current state of the fleet, all known ZEV acquisitions were included in the inventory. For the purposes of the financial model, two replacement schedules were evaluated:

- Replacement of a vehicle upon reaching the end of the useful life benchmark (ULB)
- Replacement of a vehicle upon reaching the end of the minimum useful life (MUL)

Vehicles projected to exceed their ULB or MUL by 2021 have been assumed to be replaced with a non-ZEV. All known ZEV deployments and vehicles on order or soon to be on order (see Figure 1) were assumed to replace the oldest similar vehicle in the agency's fleet and have been included as part of the 2022 fleet.

At the start of 2022, the Colorado fleet is projected to have 100 ZEVs (in service, on order, or soon to be ordered) – 10 percent of the 2030 goal!

Useful Life Benchmark (ULB) Defined:

TA has set a default ULB as the expected service years for each vehicle class. The ULB is determined by using the average number of years at which a vehicle would reach a 2.5 rating on the FTA Transit Economic Requirements Model (TERM) scale assuming a standard maintenance schedule.[48]

Minimum Useful Life (MUL) Defined:

CDOT defines MUL as the minimum number of years or miles transit vehicles must be in service before they can be retired. This assumes that most vehicles still have additional years of useful and cost-effective service life available but that most of the asset's value has been consumed.[49]

2 Determining Vehicle Replacement Schedule: The vehicle manufacture year was used to determine when a vehicle is projected to reach its ULB and MUL to determine the timing of all vehicle replacements occurring between 2022 and 2050.

Between 2022 and 2030, 2,000 to 3,000 vehicles will be due for replacement.

Approximately 850 to 900 vehicles are due for replacement between 2028 and 2030.

3 Identifying ZEV Replacement Vehicles: National ZEV trend research, information shared by Colorado transit agencies operating ZEVs, and stakeholder feedback were used to identify ZEV replacement cost and vehicle types to correspond with existing non-ZEVs based on vehicle type, length, seating capacity, and ADA needs. The model results presented in the Roadmap assume 1:1 vehicle replacement.

Limitations of Model Assumptions

In the near term, several Colorado transit agencies expressed concerns with ZEV range and charging requirements and the ability to replace vehicles one-for-one. Range extending strategies shared included providing on-route charging or replacing existing vehicles with more than one ZEV. Each transit agency should evaluate the charging infrastructure and fleet mix that will best meet their operational requirements. For the purposes of this Roadmap, the model had to make general assumptions for the entire Colorado fleet. The financial model has been provided to CDOT and agencies can use it as a tool to conduct high-level sensitivity analyses with different pricing and vehicle scenarios to inform fleet transition needs.

4 Calculating Average Vehicle and Charger Costs: ZEV costs were revised based on cost information shared by Colorado transit agencies, costs compiled from ZEV studies, and industry research. Each ZEV replacement vehicle type was assigned an approximate average of the commonly cited purchase prices, Colorado ZEV purchases, professional judgment, and stakeholder input.

Table 7 summarizes the final cost assumptions used in the high-level statewide financial model.

Table 7: 2022 Final Cost Assumptions

Revenue Vehicle Type	ZEV Cost	Non-ZEV Cost	Depot Charger Type	Charger Unit Cost	Charger Install Cost
Articulated Bus	$1,200,000	$672,000	Level 3	$50,000	$60,000
Standard Bus (35-45 ft)	$950,000	$500,000	Level 3	$50,000	$60,000
Small Bus (35 ft or less)	$580,000	$350,000	Level 3	$50,000	$60,000
Large Cutaway	$360,000	$200,000	Level 2	$30,000	$20,000
Standard Cutaway	$170,000	$88,000	Level 2	$30,000	$20,000
Passenger Van	$100,000	$55,000	Level 2	$30,000	$20,000
Automobile	$60,000	$30,000	Level 2	$30,000	$20,000
Minivan	$60,000	$33,500	Level 2	$30,000	$20,000
Sports Utility Vehicle	$60,000	$35,500	Level 2	$30,000	$20,000
Over-the-Road Bus/ Motorcoach	$1,100,000	$630,000	Level 3	$50,000	$60,000

Initial ZEV replacement costs include vehicle cost and initial depot charger unit and installation costs. Depot chargers were selected for modeling with the assumption of providing a 1:1 bus to charger installation rate. Charger installation and unit costs were not included in subsequent ZEV replacements.

5 **Estimating ZEV Price Parity Point:** Expert estimates range from EV batteries reducing to the point of reaching parity with diesel or other traditional vehicles by 2024 to 2030 at the latest.[50] A financial analysis conducted by the National Renewable Energy Laboratory (NREL) assumed an 8 percent annual reduction in battery cost. The financial analysis built on research that correlated commercial price parity of battery electric vehicles to battery prices.[51] The research found that battery costs decreased 14 percent annually from 2007 to 2014 and estimated costs would continue to decline at a rate of 6 to 9 percent annually.[52] Consistent with the NREL research, the financial modeling results included in the Roadmap assumed an 8 percent annual reduction in cost. The financial model, as a tool, provides CDOT with the ability to modify this assumption. This assumption conservatively places most transit ZEVs reaching cost parity in the 2029 to 2031 timeframe.

6 **Identifying Replacement Scenarios & Calculating Costs:** The total cost for each vehicle replacement was calculated based on the relevant costs and the number of vehicles being replaced. The model aggregates inventory-level results at both the annual level and the total cost from 2022-2050 for each of the five scenarios.

Financial Model – Comparing the ULB & MUL Scenarios

The financial modeling exercise started with looking at two extreme scenarios using the ULB as the threshold for determining the vehicle replacement schedule:

- What does replacing all vehicles like-for-like cost? No more ZEVs would be added to the Colorado fleet beyond 2021 - this is the baseline scenario.
- How does this compare to an aggressive transition schedule under which all vehicles due for replacement would be replaced with their ZEV counterpart beginning in 2022?

These bounding scenarios led to the development of three intermediate scenarios:

- How does this compare to replacing all vehicles with ZEVs starting in 2025?
- How does this compare to replacing all vehicles with ZEVs starting in 2027?
- How does this compare to replacing all vehicles with ZEVs starting in 2030 (after reaching the projected ZEV price parity point)?

The financial analysis was subsequently repeated using the MUL as the threshold for determining the vehicle replacement schedule. Table 8 provides an overview of the scenarios results.

Table 8: Scenario Overview

Scenario	Do we meet the 2030 goal? (# of ZEVs in 2030 Fleet, ULB/MUL)	Do we hit the 2050 goal? (Year Fleet is 100% ZEV, ULB/MUL)	Cost of Vehicle Replacements (ULB/MUL)	Incremental Cost (ULB/MUL)
No ZEVs (Baseline)	✗ - (100)	✗ - (N/A%)	$595M / $785M	-
2022	✓ - (2,050 / 2,325)	✓ - (2035 / 2033)	$870M / $1,070M	$275M / $285M
2025	✓ - (1,580 / 2,250)	✓ - (2038 / 2036)	$840M / $1,045M	$245M / $260M
2027	✓ - (1,150 / 1,225)	✓ - (2040 / 2038)	$830M / $1,020M	$235M / $235M
2030	✗ - (245 / 205)	✓ - (2043 / 2041)	$825M / $1,015M	$230M / $230M

COLORADO
Department of Transportation

Key Considerations & Takeways

Based on the results of the financial modeling exercise, it is technically possible to achieve the transition of 1,000 transit ZEVs by 2030 and 100 percent fleet transition by 2050, provided sufficient funding resources, complementary policies, and vehicle availability.

- **Transitioning the Colorado fleet to ZEVs is projected to cost $230 to $285 million more than the baseline scenario. This equates to a 30 to 45 percent premium over maintaining the existing fleet.**
- **The initial capital investment in EV chargers represents a majority of the incremental ZEV costs ($225 million to $230 million).**
- **The incremental cost difference of the vehicles alone (excluding associated charger costs) is $45 to $60 million, reflecting a 5 to 10 percent premium over the vehicle costs of replacing the existing non-ZEV fleet.**
- **The near-term push to 1,000 will cost an additional $5 to $10 million in transit ZEV replacement costs to meet the 2030 goal.**
- **Assuming parity is reached in the 2029 to 2031 timeframe, waiting until 2030 to begin the transitions delays reaching the 1,000 ZEV target to 2031 to 2034, depending on the vehicle replacement threshold assumptions.**

Photo Credit: Mountain Metropolitan Transit

Figure 8: Total ZEVs in Colorado Fleet - ULB

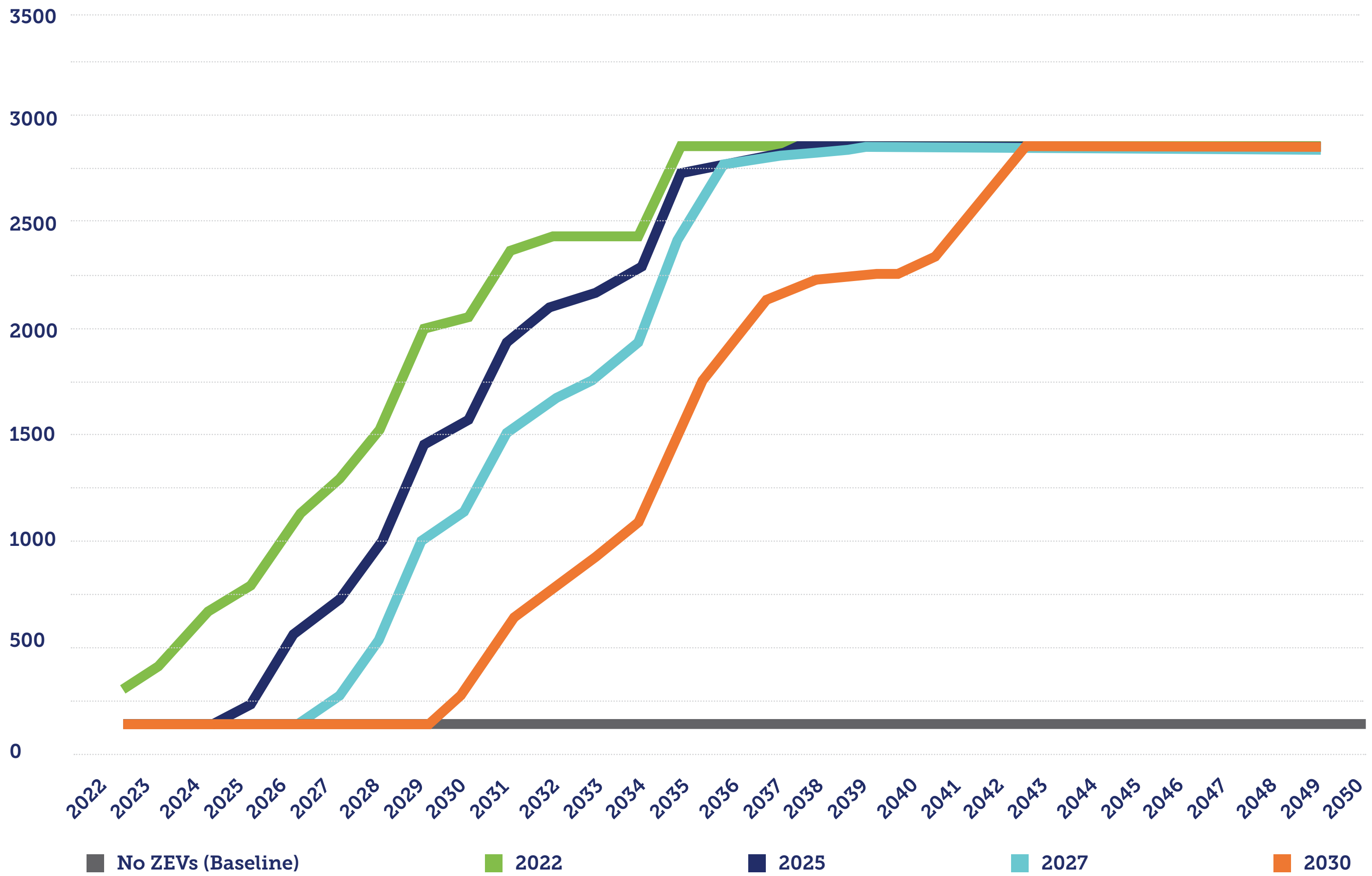


Figure 10: Total ZEVs in Colorado Fleet - MUL

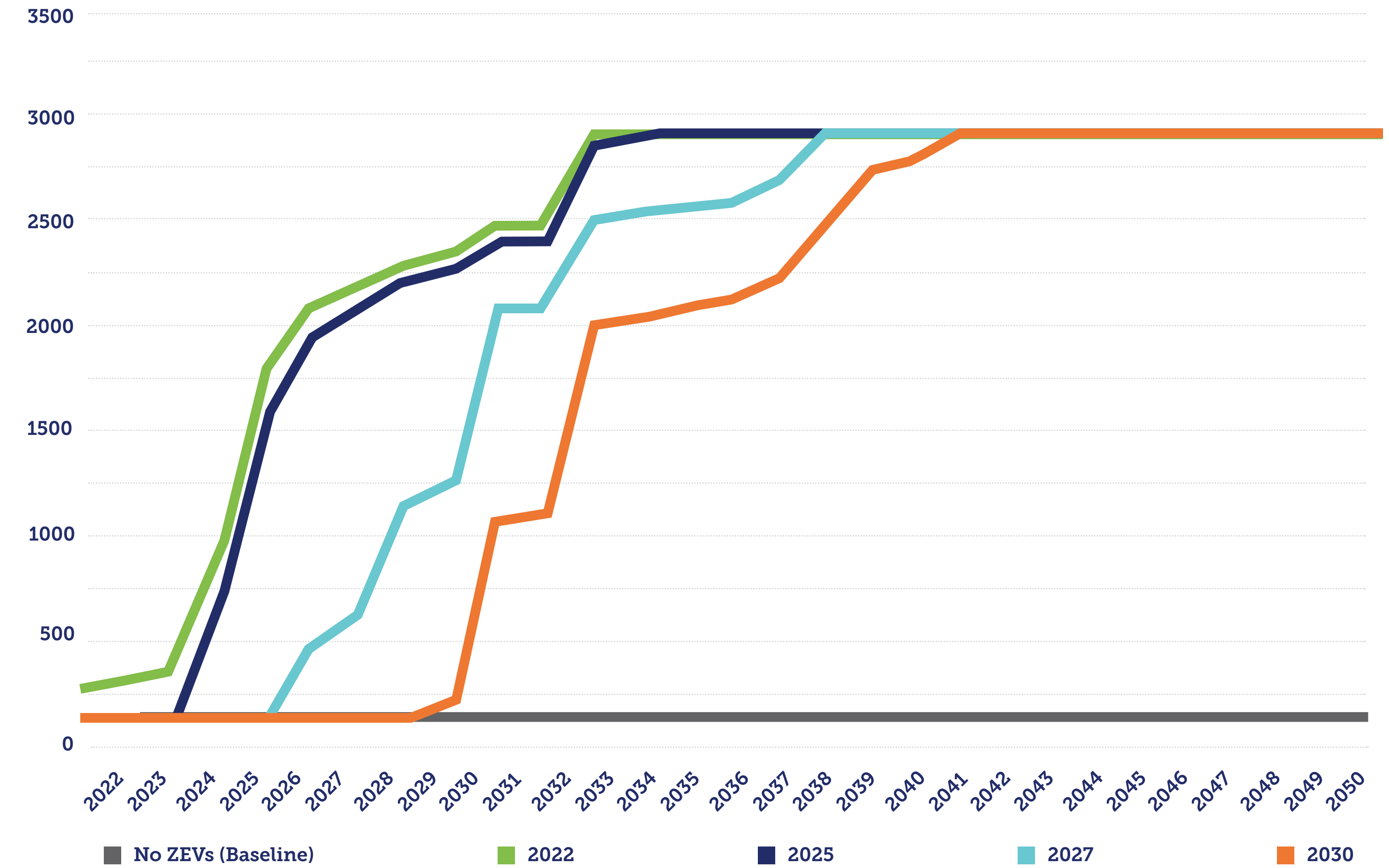


Figure 9: Number of Non-ZEVs Being Replaced - ULB

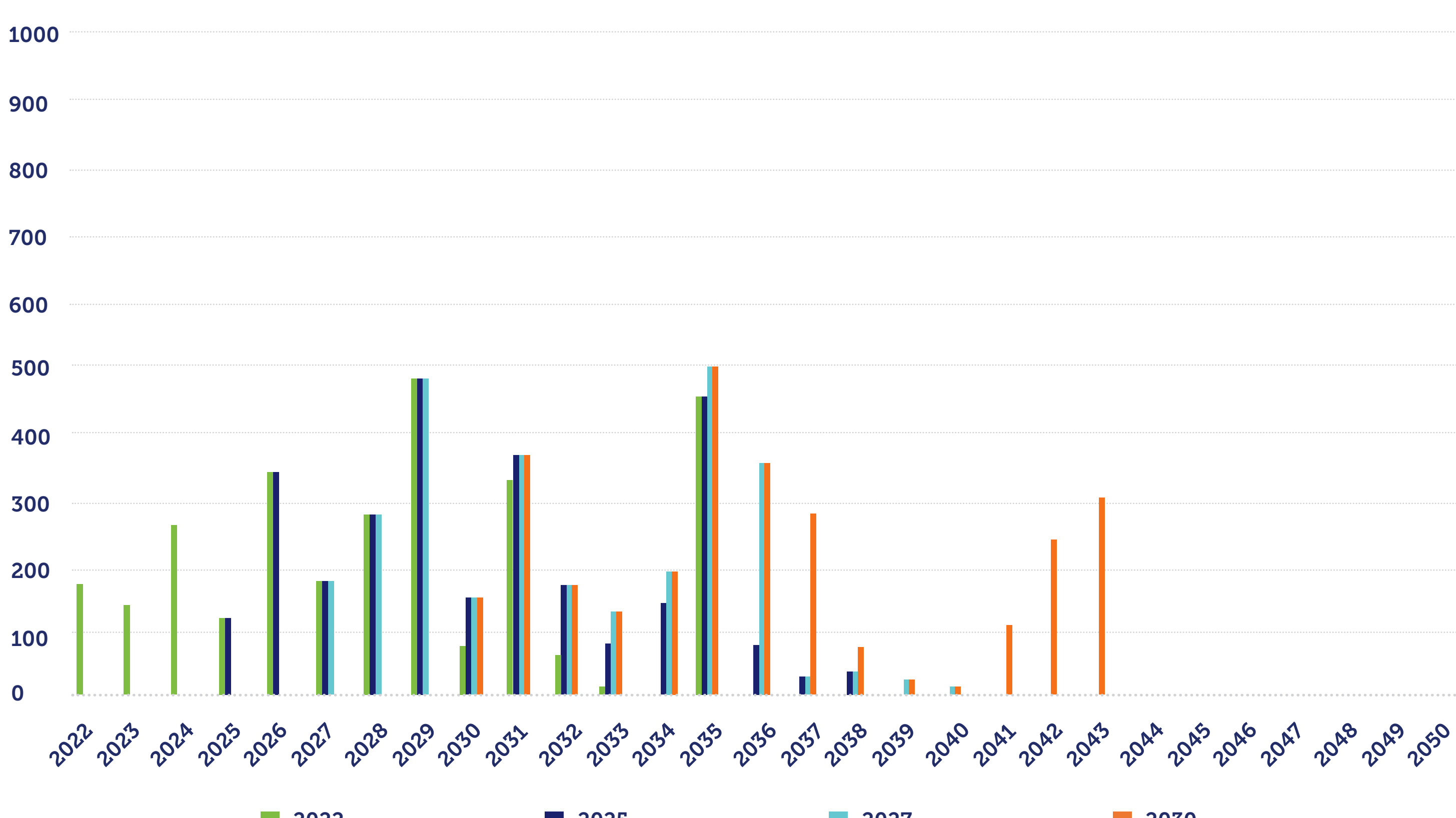


Figure 11: Number of Non-ZEVs Being Replaced - MUL

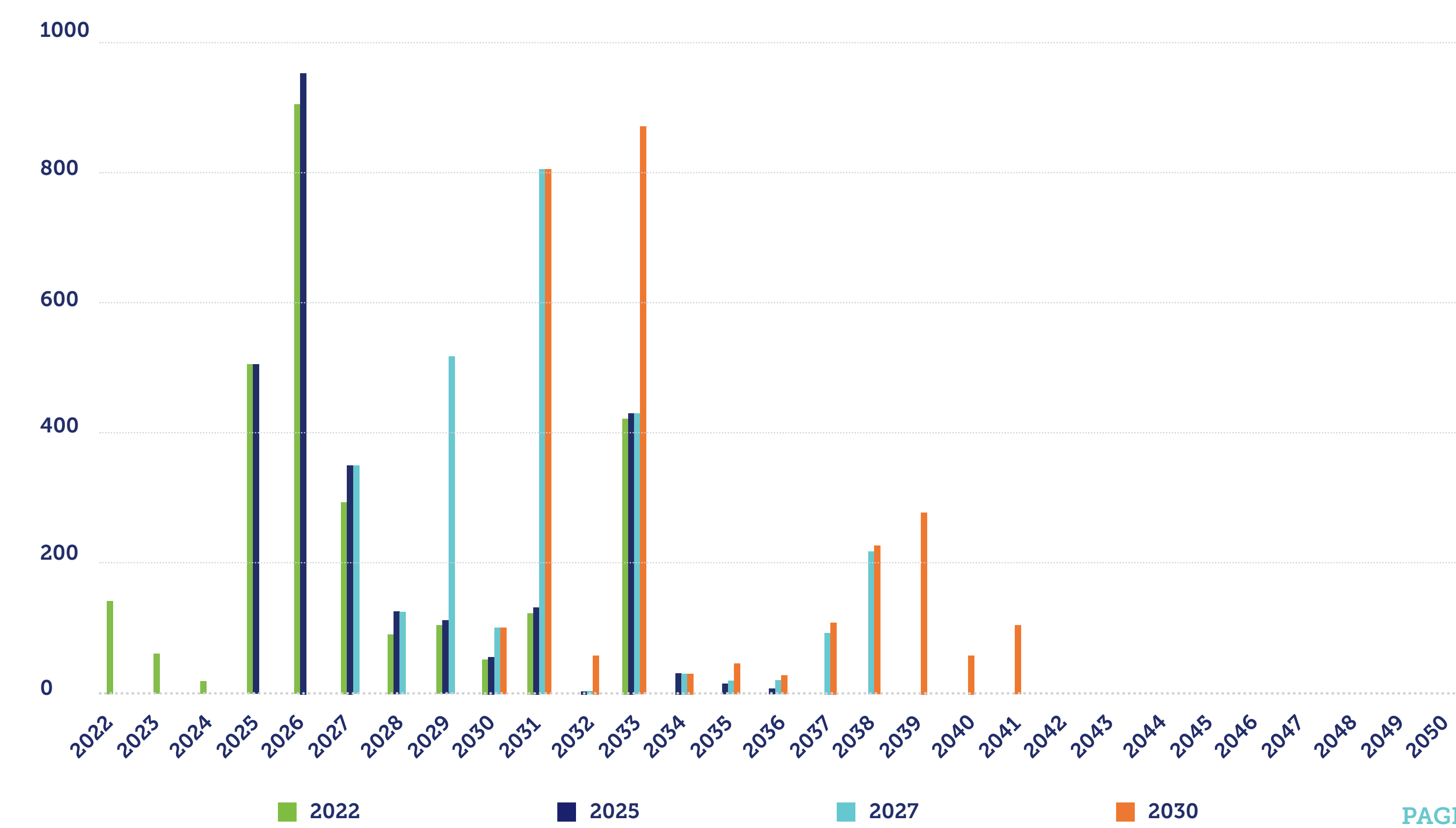


Figure 12: Vehicle Replacement Costs by Year - ULB

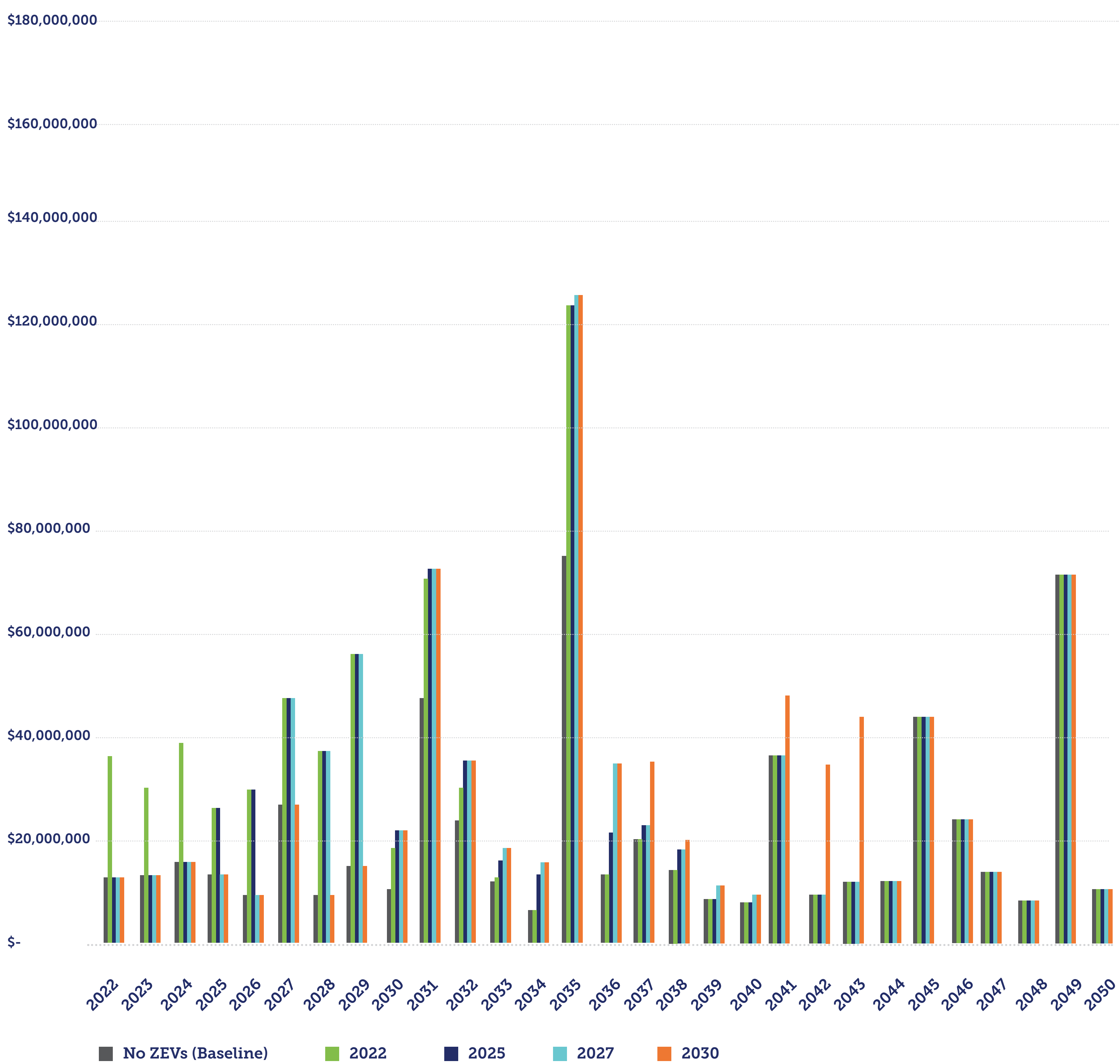
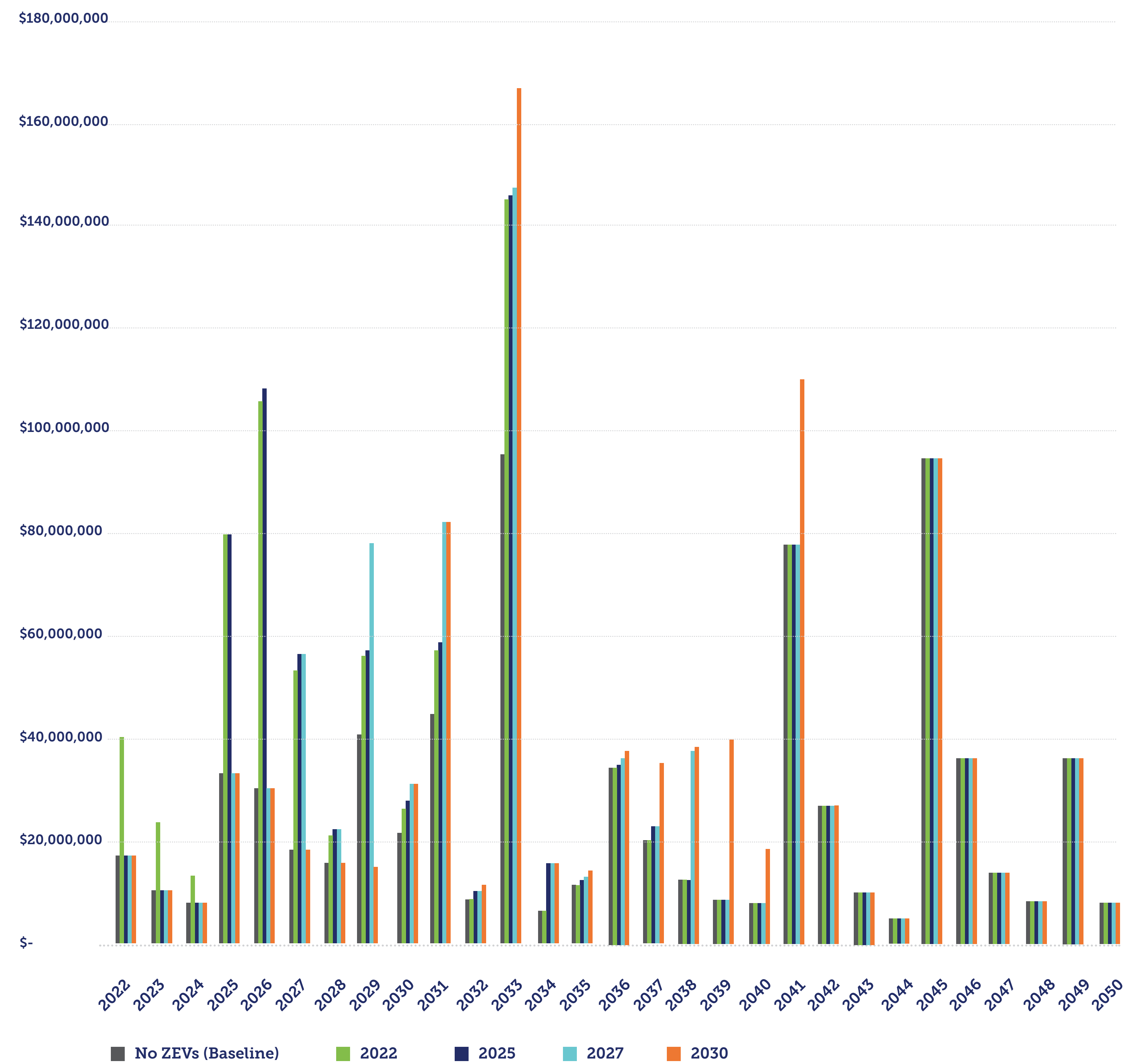


Figure 13: Vehicle Replacement Costs by Year - MUL



Achieving Colorado's Transit ZEV Goals

Transit ZEV Roadmap Goal: Full transition of Colorado's transit fleet to Zero Emission Vehicles.

The Transit ZEV Roadmap is an outcome of the 2020 Colorado EV Plan and supports the following transit goals:

- Transitioning 1,000 transit vehicles to ZEVs by 2030.
- Operating a 100 percent ZEV transit fleet by 2050.

The 2020 EV Plan includes the following transit-specific goals, objectives, and actions:

- CEO, CDOT and Colorado Department of Public Health and Environment (CDPHE) will work with stakeholders to investigate adoption of a Clean Transit Rule that requires a long-term transition to zero emission buses.
- CEO, CDOT, CDPHE and the CEVC will explore equity and rural-focused transit options and provide a recommendation for action in the next iteration of the EV Plan.
- CDOT will develop a state-approved master purchasing contract for zero emission vans, cutaways, and large buses to streamline transit agency procurement of ZEVs.
- CDOT will continue to expand transit electrification planning to attain 2020 ZEV Plan Transit Goals.
- CEO will work through the CEVC Beneficial Electrification Subgroup on a survey to gather data on utility rates with municipal utilities and rural co-ops to develop new rates that encourage EV charging and adoption by individuals, fleets, and transit agencies in spring 2020.
- CDOT's Division of Transit and Rail will continue to use remaining VW settlement funds to support the purchase of transit ZEVS.
- CDOT will incorporate EV Plan transit goals into program planning by January 2021.
- CDOT will work to integrate recommendations from CEO's EV Equity Study into its transit electrification grant programs by January 2023.

The Transit ZEV Roadmap addresses some of these elements from the 2020 EV Plan while others are being addressed in other on going efforts by CDOT, CEO, and CDPHE.

The Transit ZEV Roadmap implementation plan has five goal areas:

POLICY
Identify policies to reduce barriers to ZEV transition and implementation.

EDUCATION & TRAINING
Provide training to promote workforce readiness and educational programs for riders and policy-makers.

PLANNING & TECHNICAL SUPPORT
Increase access to technical resources and expertise to support the planning, design, and implementation activities.

INFORMATION SHARING & RESEARCH
Define data collection, research, and analysis methods to facilitate statewide information sharing and support a successful transition to transit ZEVs in Colorado.

FUNDING
Prioritize funding and identify state funding types and methods to effectively support ZEV planning and implementation.

Strategies for each goal area were developed through a collaborative process including CDOT, the Colorado EV Coalition Transit Subgroup, Colorado's transit agencies, and other key stakeholders. In support of the development of the Transit ZEV Roadmap and the Implementation Plan, virtual stakeholder interviews were held with transit agencies and an online survey was distributed to all transit agencies to inform the State of the current transit ZEV transition, to understand issues and opportunities, and to inform priorities. The transit agency ZEV Transition Survey summary can be found in Appendix I. Stakeholder input, combined with the data, analysis, and research, informed the Implementation Plan and priorities to support Colorado's transit agencies in transitioning to ZEV fleets.

Implementation Plan

This Implementation Plan provides a framework to help CDOT and partner transit agencies advance the ZEV transition across Colorado. All strategies have been identified for near -, mid-, or long-term implementation and include which goal area(s) each strategy supports. The strategies provide CDOT with guidance and direction on the key actions it should implement by 2030 to support the transit ZEV transition.

Strategies that span multiple goal areas are indicated with multicolored bullets.

- Policy
- Information Sharing & Research
- Education & Training
- Planning & Technical Support
- Funding

COLORADO Department of Transportation

Near-Term (2021 - 2024)

Policy

- Integrate Transit ZEV Roadmap strategies into the next revision of the Colorado EV Plan.
- Develop a ZEV Transition Plan for CDOT operated transit services (e.g., Bustang, Outrider, Snowstang) to demonstrate CDOT's commitment to ZEV goals and to lead by example.
- Integrate recommendations from CEO's EV Equity Study into transit electrification grants, programs, and initiatives.
- Explore opportunities to better define the process for tracking RNG and to substantiate the use of RNG as a transit ZEV option.
- Evaluate opportunities and methodologies for integrating environmental impact analyses to capture the environmental and societal costs of tailpipe emissions in procurement processes.
- Serve as a facilitator or convenor to bring together transit agencies and utilities to actively address known ZEV transition challenges and overcome barriers to transit ZEV fleet transition. Workshop and/or working group topics should include:
  - Transit agency and utility programmatic coordination
  - Generation, transmission, and distribution planning
  - Best practices for transit agency/utility coordination
  - Facility planning (including strategies for overcoming building and lease limitations)
  - Transit ZEV electric rate design
  - ZEV model availability and applications

Planning & Technical Support

- Define a standard approach for measuring GHG emissions and reductions for transit agencies that is consistent with the Transit Emission Dashboard methodology.
- Hire staff and/or contract with consultants to provide on-call technical assistance to transit agencies to support ZEV fleet transition planning. Support activities could include utility coordination, grant application support, route modeling, maintenance/operations planning, facility planning, GHG emissions tracking, etc.
- Identify opportunities to streamline data collection for the entire Colorado transit fleet to efficiently track progress toward the statewide ZEV transit and related GHG emission reductions goals. Build on the CEVC Transit Subgroup Zero-Emission Bus Tracking Sheet and the COTRAMS database.
- Integrate the findings and data from the Transit ZEV Roadmap into the Group Transit Asset Management Plan update.
- Coordinate with transit agencies to better understand options and strategies for transitioning contractor owned facilities to support ZEVs.
- Track storage location of transit vehicles in COTRAMS to aid in ZEV replacement feasibility analysis and transition planning.

Near-Term (2021 - 2024)

Information Sharing & Research

- Create an informal transit-focused virtual peer exchange network (e.g., Slack channel, Listserv, etc.) to ask questions, share information and/or lessons learned, and facilitate ongoing conversations among transit agencies.
- Engage existing Colorado research groups and programs (e.g., NREL, ASPIRE[53] , CU, CSU, etc.) to support and develop opportunities for transit agencies to test/evaluate ZEVs and research transit ZEV-related technologies such as battery recycling second use cases, transit and utility business models, smart vehicle charging solutions, etc.
- Convene a rural transit working group, including electric co-ops, to define barriers and potential solutions for rural transit agencies.
- Convene interested transit agency and hydrogen fuel providers to identify pilot project opportunities and discuss potential barriers to widespread fleet adoption in Colorado.
- Collaborate with the CEO and CDPHE to assess potential benefits, costs, and timing for adoption of the California Innovative Clean Transit Rule (ICTR) in Colorado.
- Integrate Transit ZEV Roadmap data and recommendations into the Clean Transit Enterprise's 10-Year Plan.
- Track real-world transit vehicle purchase and infrastructure upgrade costs to refine assumptions and inputs to the Transit ZEV Roadmap transition financial model and conduct future scenario analyses.
- Monitor and document real-world ZEV operational costs in Colorado to inform future planning efforts.

Funding

- Evaluate strategies for vehicle leasing options, third-party financing, battery leases, utility on-bill financing, and other funding mechanisms and opportunities to use SB 21-260 Clean Transit Enterprise funds.
- Establish a permanent Statewide Local Match Fund to buy down the transit agency local match for the purchase of transit ZEVs to be equal to that of the comparable internal combustion engine vehicle option. Evaluate the potential to use the Clean Transit Enterprise to fund the Local Match Fund, as well as potential match funding strategies (e.g., incentivizing transit agencies to pursue federal funding sources by providing a higher percentage of matching funds for federal grants than state/local grants).
- Establish and maintain a state-approved master purchasing agreement for zero emission vans, cutaways, and buses to streamline transit agency procurement of transit ZEVs.
- Develop flexible funding programs to support ongoing maintenance and operations costs and long-term operations of transit ZEVs.
- Incentivize and promote private sector support for ZEV transit transition, including demonstration projects, vehicle testing and/or short-term proof of concept lease options, etc. to ensure vehicle types and technologies meet Colorado transit agency needs and to support the advancement of the larger transit ZEV market.
- Assess opportunities to support the replacement of vehicles with ZEVs prior to the end of their useful life to expedite ZEV transition.
- Consider establishing a more flexible vehicle replacement policy for zero-emission buses for so long as available vehicle technologies (i.e., battery range and low-temperature performance) do not align with the typical 1-to-1 replacement ratio.

Education & Training

- Develop Colorado-specific informational materials about transit ZEV challenges, opportunities, and benefits in coordination with existing transit and ZEV organizations (e.g., Colorado Association of Transit Agencies [CASTA]) to educate transit agency staff and key decision-makers.
- Partner with CASTA to provide OEM neutral training and/or educational sessions for transit operators and maintenance staff early in the ZEV transition process.
- Collaborate with CASTA to offer training on use of the Transit ZEV Roadmap financial modeling tool to transit agencies so that they can run their own fleet-specific analyses and effectively communicate the results to decision-makers and the public.

Implementation Plan

This Implementation Plan provides a framework to help CDOT and partner transit agencies advance the ZEV transition across Colorado. All strategies have been identified for near -, mid-, or long-term implementation and include which goal area(s) each strategy supports. The strategies provide CDOT with guidance and direction on the key actions it should implement by 2030 to support the transit ZEV transition.

Mid-Term (2025 - 2027)

Policy

- Continue coordinating with partner state agencies to develop a forum for transit agencies and utilities to discuss ZEV transit programs and initiatives to avoid programmatic conflicts and/or competing goals and objectives. Coordination could include formal workshops and/or meetings to discuss topics such as electric rates, resource planning, fleet/facilities planning, etc.

Information Sharing & Research

- Monitor the development of the US Department of Energy Livewire Data Platform and encourage transit agencies to upload data to the platform to further national ZEV information sharing.[54]

Funding

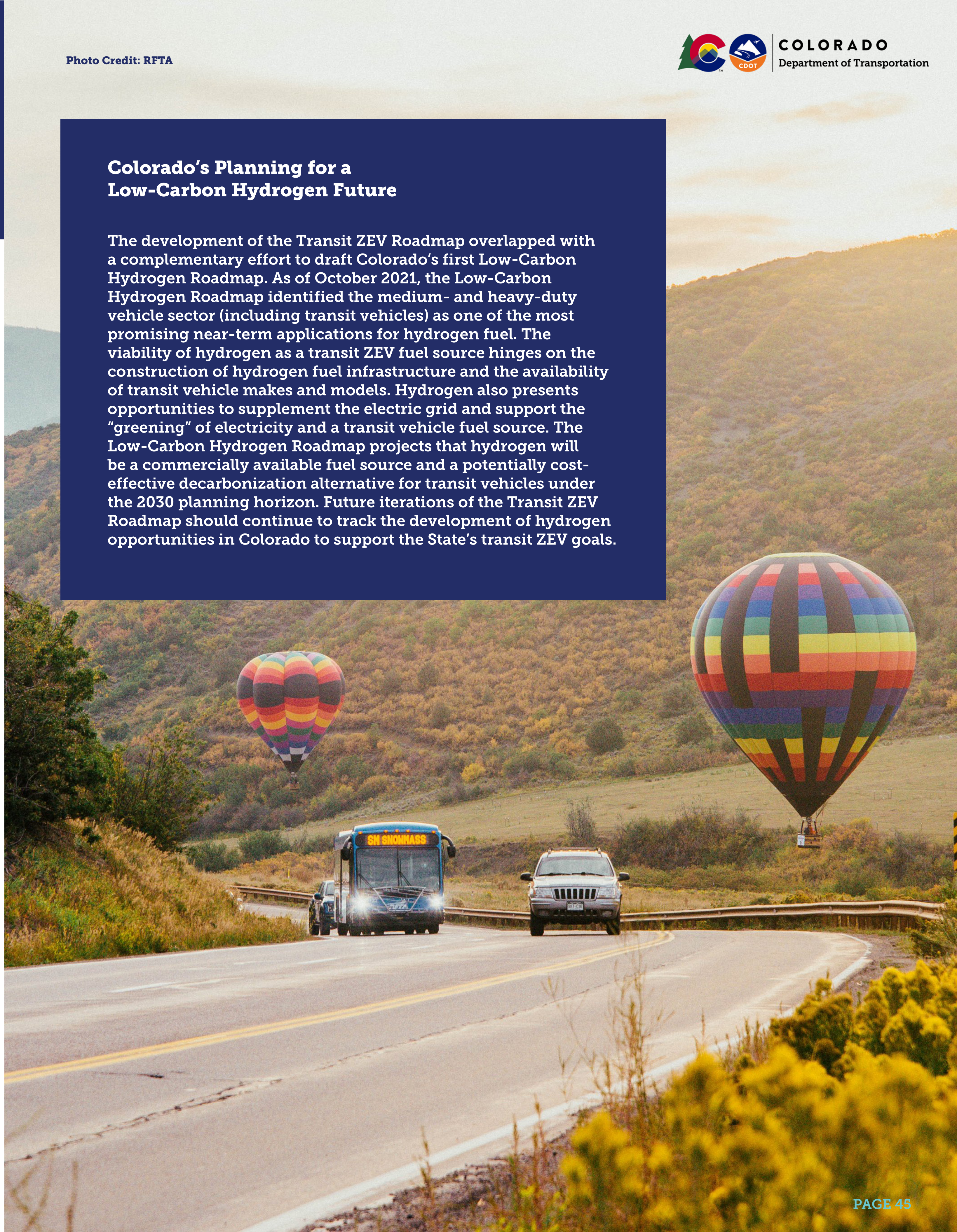
- Develop a strategy for updating DTR's master purchasing agreement in a timely manner as additional transit ZEV options emerge.
- Reassess available state funding sources to ensure that funding resources efficiently support and effectively incentivize the transit ZEV transition.
- Ensure long-term and consistent funding options for ZEV capital investments in support of facilities and maintenance equipment (e.g., larger lifts to accommodate heavier ZEVs).
- Develop a strategy and funding plan to support ZEV fleet replacement.

Long-Term (2028 - 2030)

Policy

- Monitor progress of the Transit ZEV Roadmap goals and update as needed to achieve 2050 goals.
- Update the Transit ZEV Roadmap transition financial model using Colorado-specific experience and recalculate funding requirements to reach the 2050 goal.

Photo Credit: RFTA



Colorado's Planning for a Low-Carbon Hydrogen Future

The development of the Transit ZEV Roadmap overlapped with a complementary effort to draft Colorado's first Low-Carbon Hydrogen Roadmap. As of October 2021, the Low-Carbon Hydrogen Roadmap identified the medium- and heavy-duty vehicle sector (including transit vehicles) as one of the most promising near-term applications for hydrogen fuel. The viability of hydrogen as a transit ZEV fuel source hinges on the construction of hydrogen fuel infrastructure and the availability of transit vehicle makes and models. Hydrogen also presents opportunities to supplement the electric grid and support the "greening" of electricity and a transit vehicle fuel source. The Low-Carbon Hydrogen Roadmap projects that hydrogen will be a commercially available fuel source and a potentially cost-effective decarbonization alternative for transit vehicles under the 2030 planning horizon. Future iterations of the Transit ZEV Roadmap should continue to track the development of hydrogen opportunities in Colorado to support the State's transit ZEV goals.

References

1. Zeroing in on ZEBS, 2020 Edition, CALSTART, https://www.sustainable-bus.com/wp-content/uploads/2021/02/Zeroing_In_on_ZEBs_FINALREPORT_1262021-1.pdf
2. MJB&A. Electric Vehicle Market Status – Update. April 2021.
3. ICCT. Zero-emission bus and truck market in the United States and Canada: A 2020 Update. May 2021.
4. Made in North America: Manufacturers invest in zero-emission buses and trucks, May 21, 2021, ICCT. https://theicct.org/blog/staff/north-america-invests-zero-emission-HDV-may2021
5. CyRide, Zero Emission Bus Roadmap, https://www.cyride.com/Home/ShowDocument?id=9880
6. Ibid
7. Accelerating Bus Electrification: Enabling a Sustainable Transition to Low Carbon Transportation Systems, February 2018.
8. California Air Resources Board, Literature Review on Transit Bus Maintenance Cost (Discussion Draft), August 2016.
9. "Fuel Cell Electric Bus History," https://www.fuelcellbuses.eu/category/history
10. Race to Zero: How manufacturers are positioned for zero emission commercial trucks and buses in North America. https://theicct.org/sites/default/files/publications/Canada-race-to-zero-EN-oct2020.pdf
11. https://www.latimes.com/archives/la-xpm-1995-10-03-fi-52873-story.html
12. http://apcci.org/downloads/Avass%20EV%20Bus%20Intro%20-%20General.pdf
13. https://www.bloomberg.com/news/features/2019-04-16/the-world-s-biggest-electric-vehicle-company-looks-nothing-like-tesla
14. https://www.greenpowerbus.com/
15. https://www.gillig.com/post/a-closer-look-at-gillig-cummins-battery-electric-bus-partnership
16. https://www.vaildaily.com/news/vail-cuts-back-2020-order-for-full-electric-town-buses/
17. https://lightningemotors.com/wp-content/uploads/2020/10/LeM_Via-Hop-Boulder-Bus-Repower-case-study.pdf
18. https://www.motivps.com/
19. https://www.motivps.com/motiv-estes-park-trolley/
20. Ibid
21. https://www.newflyer.com/site-content/uploads/2017/10/Xcelsior-Hydrogen-Fuel-Cell-Electric-Bus.pdf
22. https://www.metro-magazine.com/10112347/colo-s-roaring-fork-adding-8-new-flyer-charge-electric-buses?utm_source=website&utm_medium=contentoffers&utm_campaign=061520
23. https://novabus.com/
24. https://www.phoenixmotorcars.com/
25. https://www.proterra.com/
26. https://www.vaildaily.com/news/avon-lands-1-6-million-grant-to-buy-two-electric-buses/
27. https://www.summitdaily.com/news/summit-stage-set-to-unveil-new-electric-buses-monday/
28. https://vimeo.com/376863610/9d37d478a6
29. https://www.vanhool.be/en/news/van-hool-builds-bus-factory-in-morristown-tennessee-us
30. https://www.revgroup.com/blog-single/rev-group-bus-brand-enc-new-website-launch
31. Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2. Bloomberg New Energy Finance
32. https://www.cyride.com/Home/ShowDocument?id=9880
33. Guidebook for Deploying Zero-Emission Transit Buses, 2020.
34. Ibid
35. Empirical analysis of electric vehicle fast charging under cold temperatures. Idaho National Laboratory. July 2018
36. https://www.transit.dot.gov/bus-program
37. Ibid
38. https://cms7.fta.dot.gov/funding/grants/lowno
39. https://www.fhwa.dot.gov/specialfunding/stp/160307.cfm#d
40. https://citydocs.fcgov.com/?cmd=convert&vid=72&docid=3410664&dt=AGENDA+ITEM&doc_download_date=DEC-03-2019&ITEM_NUMBER=04
41. https://www.colorado.gov/pacific/cdphe/VW#:~:text=The%20State%20of%20Colorado%20will,reduce%20air%20pollution%20in%20Coloradohttps://www.codot.gov/programs/planning/grants/vw-settlement-bus
42. https://www.codot.gov/programs/planning/grants/vw-settlement-bus
43. https://energyoffice.colorado.gov/electric-utilities
44. Guidebook for Deploying Zero-Emission Transit Buses, 2020
45. https://energyoffice.colorado.gov/electric-utilities
46. https://www.cenhud.com/my-energy/electric-vehicles/EV-make-ready-program/
47. Beneficial Electrification of Transportation. Regulatory Assistance Project. January 2019.
48. NTD Reporting Manual
49. DTR, https://www.codot.gov/programs/transitandrail/assets/nofa-announcements/new-applicant-questionnaire_form.pdf
50. National Renewable Energy Laboratory, "Financial Analysis of Battery Electric Transit Buses." (June 2020) https://afdc.energy.gov/files/u/publication/financial_analysis_be_transit_buses.pdf
51. Nykvist, Björn, and Måns Nilsson, "Rapidly Falling Costs of Battery Packs for Electric Vehicles," Nature Climate Change 5 (2015): 329-32, https://www.nature.com/articles/nclimate2564 Beneficial Electrification of Transportation. Regulatory Assistance Project. January 2019.
52. Ibid
53. ASPIRE (Advancing Sustainability through Powered Infrastructure for Roadway Electrification) is an NSF Research Institute at Utah State University and includes several university partners (University of Colorado at Boulder, Purdue University, University of Texas at El Paso and the University of Auckland). ASPIRE's mission is to improve health and quality of life through sustainable and equitable electrification
54. The Livewire Data Platform has been created to "collect, preserve and disseminate data and metadate for Energy Efficient Mobility Systems (EEMS) projects) funded by the US Department of Energy's Office of Energy Efficiency and the Renewable Energy's Vehicle Technologies Office." The platform uses the Project Open Data metadata scheme to standardize data access, storage and retrieval

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