Survey of California Transit Agencies

ICT Comprehensive Review Phase II

2024 CALACT Spring Conference – April 17, 2024

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About NREL & UC-Berkeley

National Renewable Energy Laboratory
Center for Integrated Mobility Sciences

U.S. Department of Energy National Laboratory

Main campus in Golden, CO

>3,000 professionals dedicated to creating a clean energy future for the world

tsrc.berkeley.edu

University of California Berkeley
Transportation Sustainability Research Center

Created in 2006 to combine six of UC Berkeley's campus research centers.

TSRC was formed to study the economic, social, environmental, and technological aspects of sustainable transportation.

ICT ZEB Purchase Requirements

- The Innovative Clean Transit (ICT) regulation requires California transit agencies to gradually transition to zero-emission vehicle technologies.
- This schedule is designed to achieve 100% ZEB fleets statewide by 2040

Date	Large Transit Agency *	Small Transit Agency	
2023–2025 (standard 40-ft buses only)	25%	—	Focus of Phase 1 Review
2026–2028 (all bus types, if passed Altoona testing)	50%	25%	Focus of Phase 2 Review
January 1, 2029, and thereafter	100%	100%	

* A transit agency that either (a) operates more than 65 buses in annual maximum service in either the South Coast Air Basin or the San Joaquin Valley Air Basin, or (b) operates in an urbanized area with a population of at least 200,000 and at least 100 buses in annual maximum service.

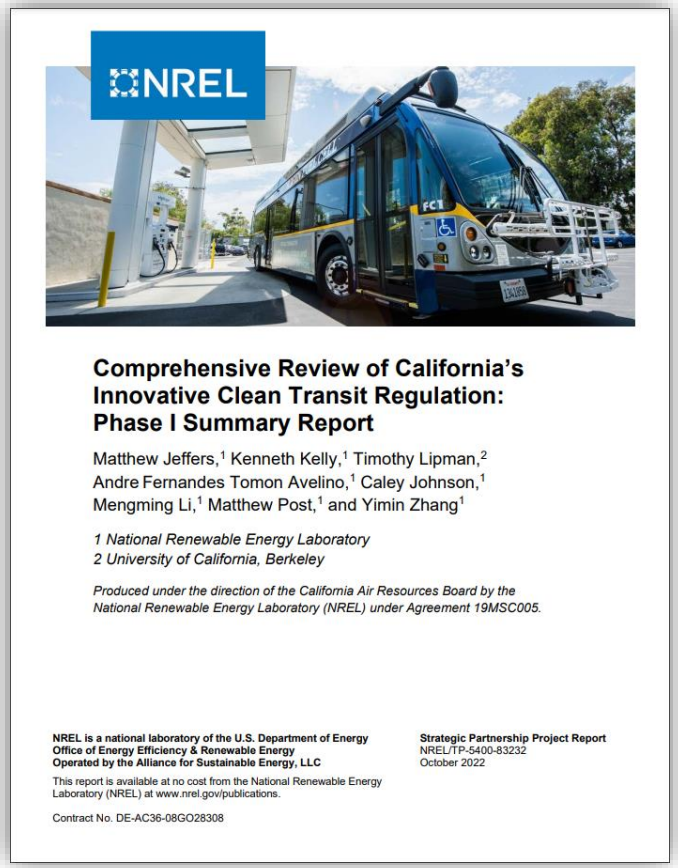
Background: Phase 1 Readiness Summary Statement

2023 Purchase Requirement for Standard 40-ft Buses, Large Transit Agencies

Summary Phase I Readiness Statement: *"The California transit industry appears to be well positioned to proceed with the 2023 requirement of 25% of new bus purchases being ZEBs for large transit agencies"*

This is supported by:

- Large transit agencies' ZEB Rollout Plans,
- Momentum developed from over a decade of ZEB demonstrations and deployments,
- Continued product development and refinement led by the transit industry,
- Progress made since 2018 adoption of ICT,
- Successful partnerships and collaboration of California transit agencies, vehicle manufacturers, charging and fuel equipment suppliers, utility providers and others.



https://www.nrel.gov/docs/fy23osti/83232.pdf

Phase 1 Summary of Key Needs Moving to 100% ZEB Fleets

To achieve a successful transition to 100% ZEB transit fleets in the coming years, some of the greatest needs include:

1. Sustained progress from the vehicle, equipment, and infrastructure manufacturing base is needed to continue ***driving down costs, improve reliability and optimize performance***.
2. ***Expansion of charging and fueling infrastructure*** is a fundamental need that will require coordinated efforts and forward-looking planning by transit agencies, utilities, and developers.
3. Comprehensive and standardized training programs to ***develop a highly skilled workforce*** that can improve the efficiency and cost of maintaining ZEB equipment while creating new jobs and ensuring safety.
4. ***Financial support*** for purchasing, installing, and operating ZEBs and the necessary fueling/charging equipment. Federal and State funding for ZEBs and related charging/fueling infrastructure are critical to achieving reasonable payback on the upfront costs, especially in the early years.

These "Key Needs" are supported by the detailed technical discussion throughout the body of the Comprehensive Review

Phase 2 – ICT Comprehensive Review

Objective

Provide an updated comprehensive assessment of Innovative Clean Transit program readiness for ***2026 ZEB purchase requirements***.

Evaluate unique considerations related to:

- Small transit agencies
- Non-standard buses – i.e., articulated, double-decker, over-the-road, and cutaway buses.
- 50% purchase requirement for large agencies/standard buses

Approach

1. Conduct literature reviews for the latest information on ZEBs and infrastructure.
2. Review submitted ZEB Rollout Plans from all CA transit agencies.
3. *Survey transit agencies* to collect qualitative and quantitative data on ZEB experience, plans, policy recommendations and remaining challenges.
4. Combine analyzed data from CARB's state-wide data collection effort, ICT Reporting Tool, and other published ZEB studies.

Phase 2 Comprehensive Review – Topic Areas

A. Cost
B. Incentive Funding Programs
C. Performance of ZEBs
D. Associated Infrastructure Necessary to Operate and Maintain ZEBs
E. Infrastructure Performance, Durability, and Reliability
F. Training Programs for Employment in Manufacturing, Operating, and Maintaining ZEBs
G. Job Creation in Manufacturing, Operating, and Maintaining ZEBs
H. Deployment Status of ZEBs and Related Technologies
I. Barriers Encountered by Transit Agencies during ZEB Operation

Data Sources Matrix

		Data Sources								
	Topic Areas	**Transit Survey**	ZEB Statewide data collection	ZEB Rollout Plans	CARB ICT RT	APTA database	Altoona reports	HVIP, LCFS, Low-No dashboards	transit assoc.	literature review
A	Cost	X	X	X				X		X
B	Incentive Funding Programs	X		X				X		X
C	Availability and Performance of ZEBs	X	X			X	X			X
D	Associated Infrastructure	X		X						X
E	Infrastructure Performance, Durability, and Reliability	X	X							X
F	Training Programs for Employment	X								X
G	Job Creation	X								X
H	Deployment Status of ZEBs	X	X	X	X	X				X
I	Barriers Encountered by Transit Agencies and Solutions	X							X	X

Phase 2 Survey of Transit Agencies

Introduction of the Survey – Outline

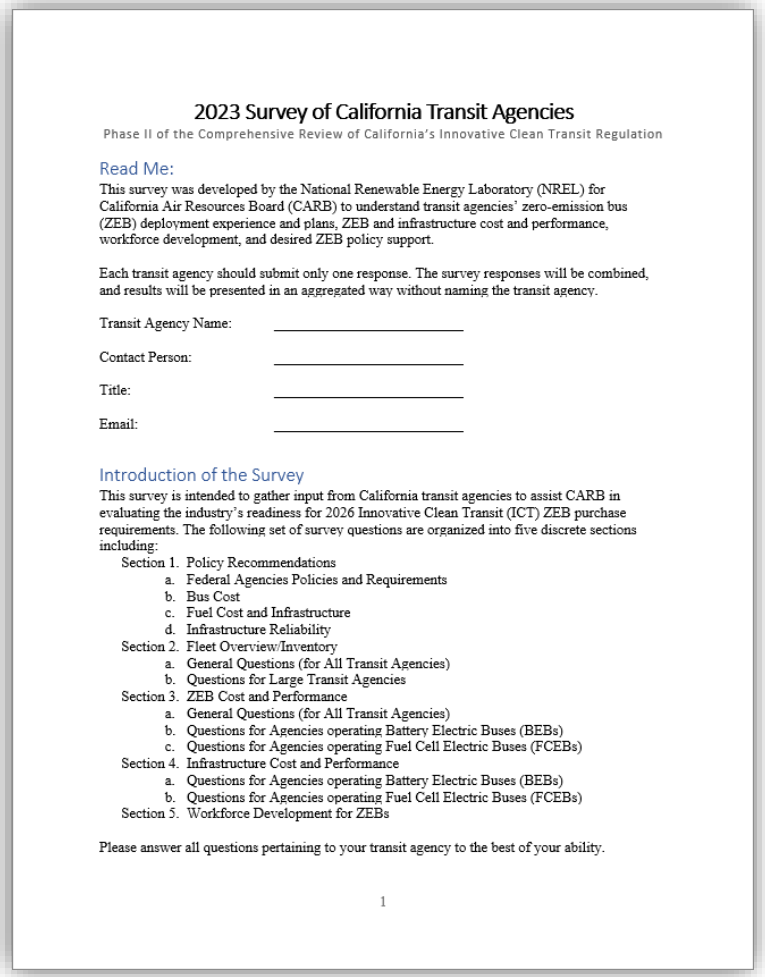
Section 1. Policy Recommendations (for All Transit Agencies)
- a. Federal Agencies Policies and Requirements
- b. Bus Cost
- c. Fuel Cost and Infrastructure
- d. Infrastructure Reliability

Section 2. Fleet Overview/Inventory
- a. General Questions (for All Transit Agencies)
- b. Questions for Large Transit Agencies

Section 3. ZEB Cost and Performance
- a. General Questions (for All Transit Agencies)
- b. Questions for Agencies operating Battery Electric Buses (BEBs)
- c. Questions for Agencies operating Fuel Cell Electric Buses (FCEBs)

Section 4. Infrastructure Cost and Performance
- a. Questions for Agencies operating Battery Electric Buses (BEBs)
- b. Questions for Agencies operating Fuel Cell Electric Buses (FCEBs)

Section 5. Workforce Development for ZEBs



2023 Survey of California Transit Agencies

Phase II of the Comprehensive Review of California's Innovative Clean Transit Regulation

Read Me:

This survey was developed by the National Renewable Energy Laboratory (NREL) for California Air Resources Board (CARB) to understand transit agencies' zero-emission bus (ZEB) deployment experience and plans, ZEB and infrastructure cost and performance, workforce development, and desired ZEB policy support.

Each transit agency should submit only one response. The survey responses will be combined, and results will be presented in an aggregated way without naming the transit agency.

Transit Agency Name: _____

Contact Person: _____

Title: _____

Email: _____

Introduction of the Survey

This survey is intended to gather input from California transit agencies to assist CARB in evaluating the industry's readiness for 2026 Innovative Clean Transit (ICT) ZEB purchase requirements. The following set of survey questions are organized into five discrete sections including:

Section 1. Policy Recommendations
- a. Federal Agencies Policies and Requirements
- b. Bus Cost
- c. Fuel Cost and Infrastructure
- d. Infrastructure Reliability

Section 2. Fleet Overview/Inventory
- a. General Questions (for All Transit Agencies)
- b. Questions for Large Transit Agencies

Section 3. ZEB Cost and Performance
- a. General Questions (for All Transit Agencies)
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Section 4. Infrastructure Cost and Performance
- a. Questions for Agencies operating Battery Electric Buses (BEBs)
- b. Questions for Agencies operating Fuel Cell Electric Buses (FCEBs)

Section 5. Workforce Development for ZEBs

Please answer all questions pertaining to your transit agency to the best of your ability.

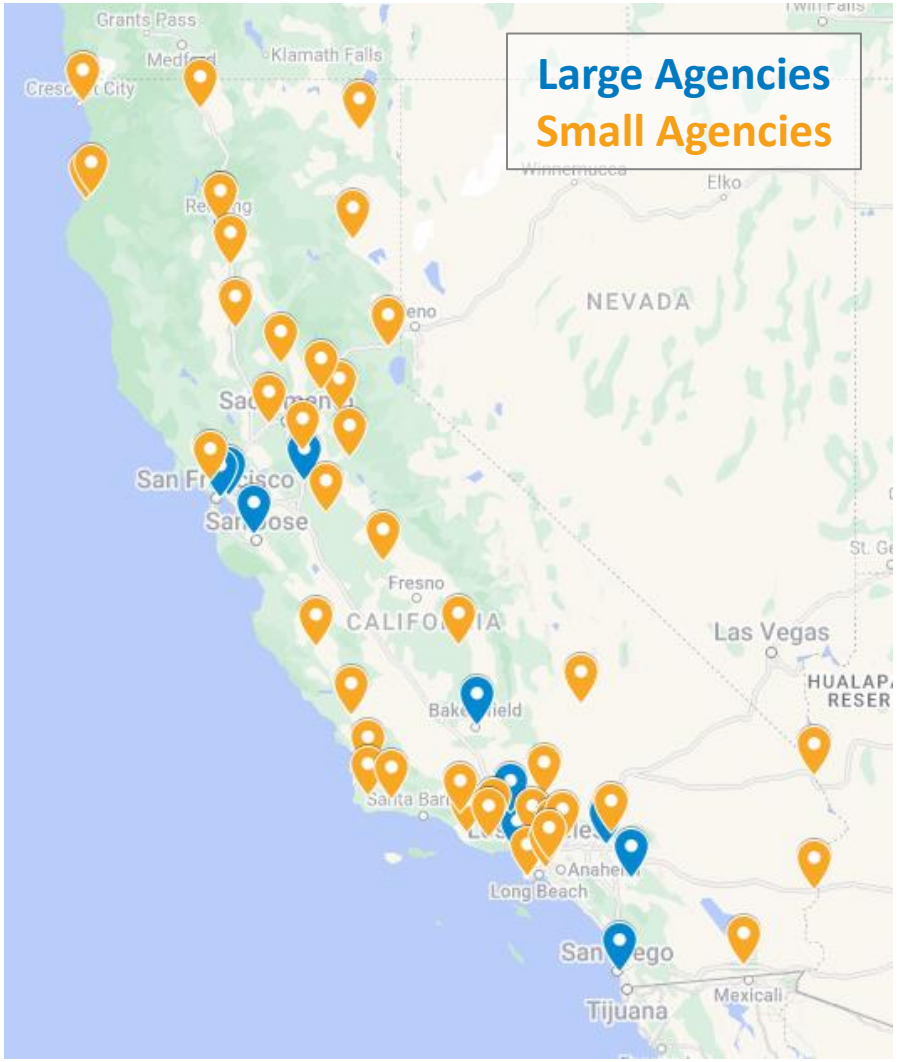
1

Survey and Comprehensive Review Timeline

☑	Fall 2023	NREL/UCB develop survey, review with CARB, CTA, CalACT
☑	Nov 3, 2023	Present survey introduction at CalACT Fall conference
☑	Nov 15, 2023	Open survey
☑	Winter 2023/24	Collect and analyze survey results
☑	April 17, 2024	Present initial findings at CalACT Spring conference
	Spring 2024	Close survey and complete analysis
	July 2024	NREL/UCB deliver comprehensive survey results to CARB
	Summer/Fall 2024	Additional Data collection and Analysis
	Spring 2025	Report on Phase 2 Comprehensive Review

Transit Survey – Overview of Responses

- CARB has received 57 valid survey responses (as of 3/25/2024)
  - 12 large agencies* (of 21) = 57%
  - 45 small agencies (of ~180) = 25%
- Transit fleet sizes range from 1-760+ buses per agency
- All bus types included
  - Standard low-floor, articulated, double-decker, over-the-road, and cutaways
- Operations include fixed route and on-demand service



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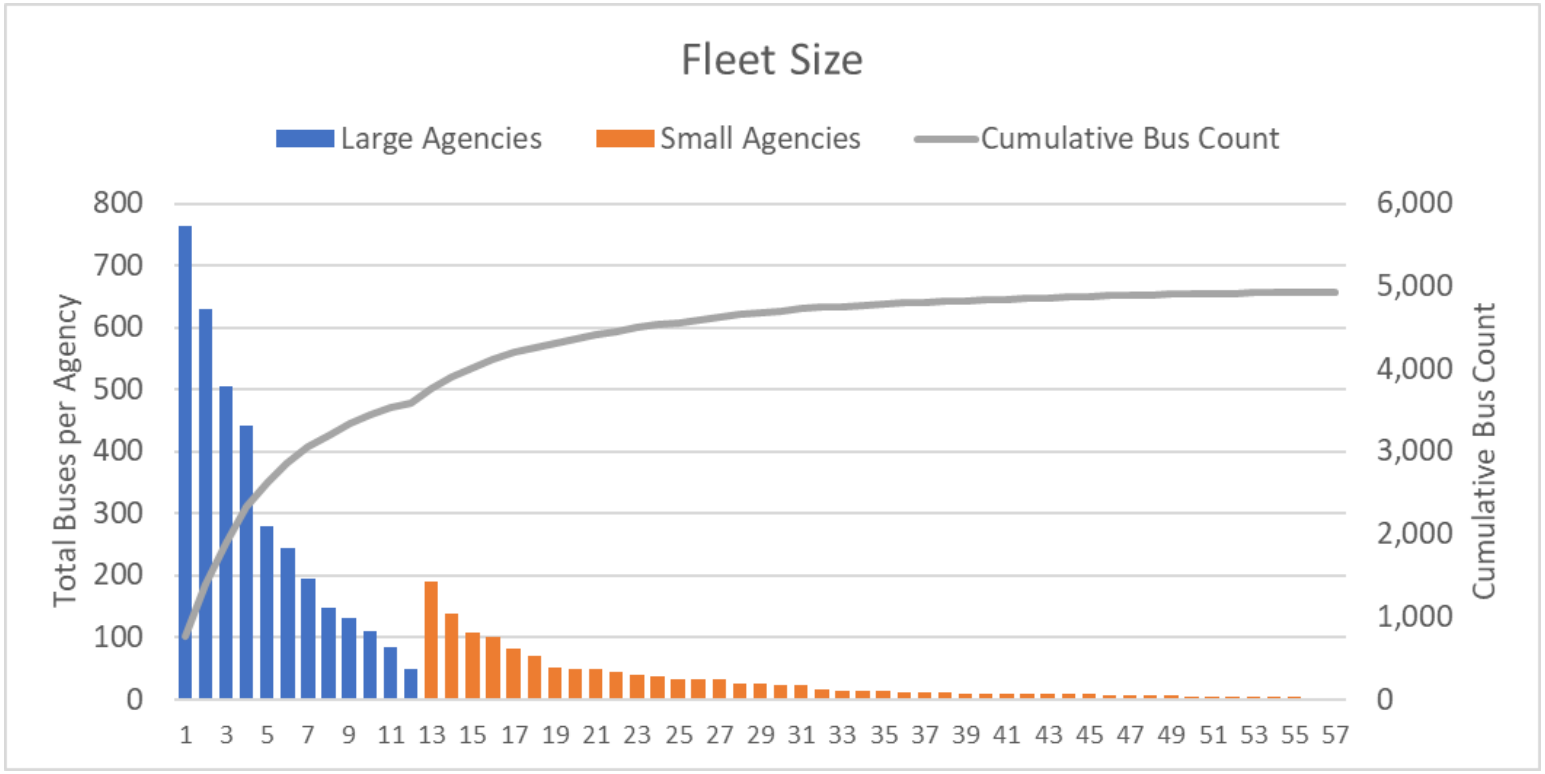
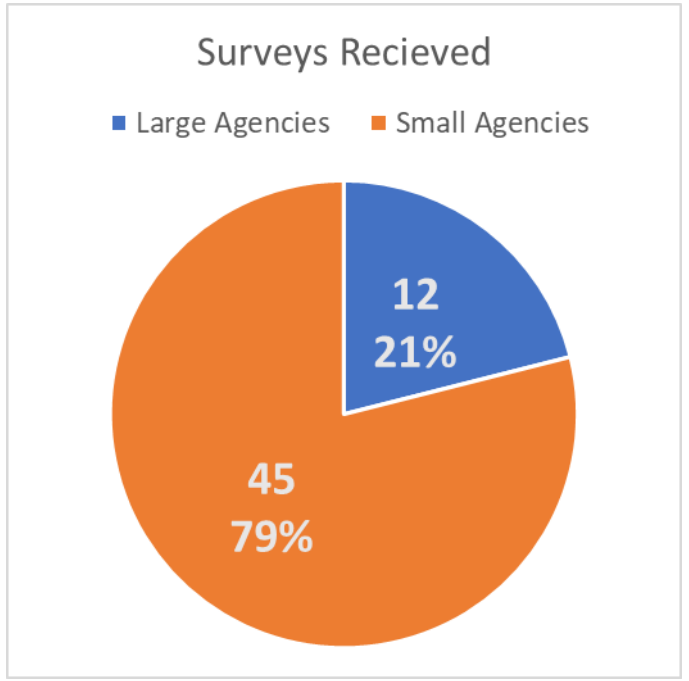
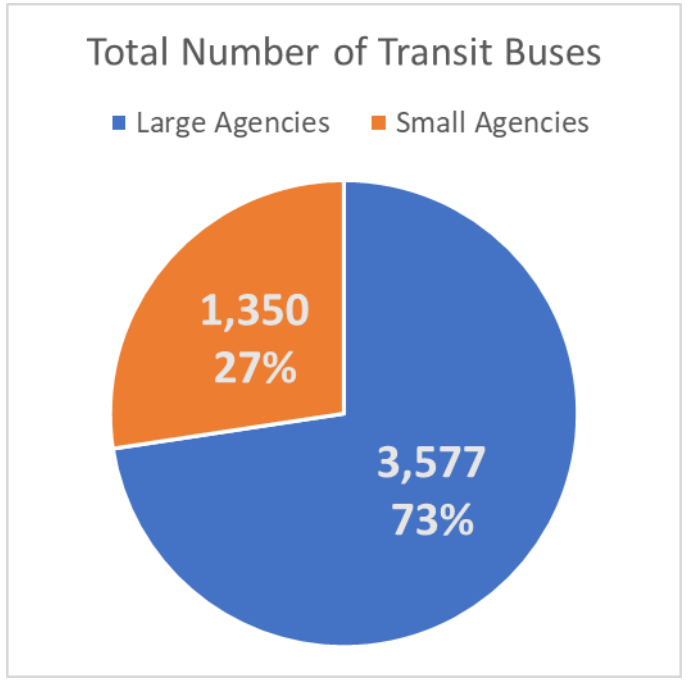
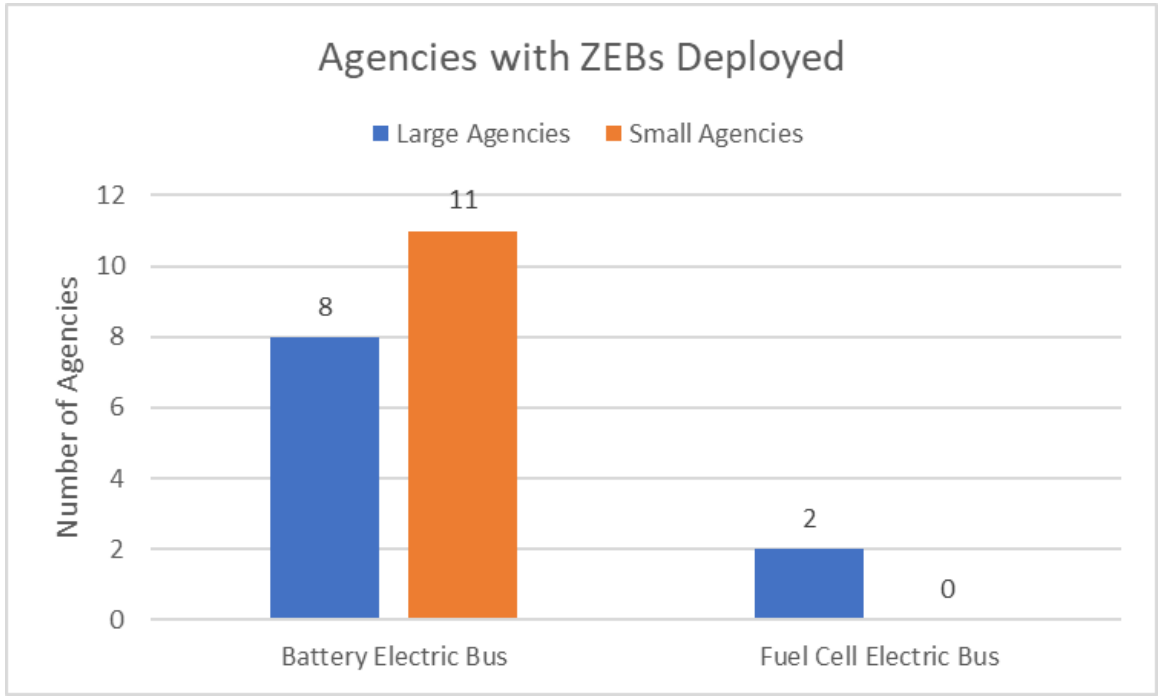
Transit Survey – Overview of Responses

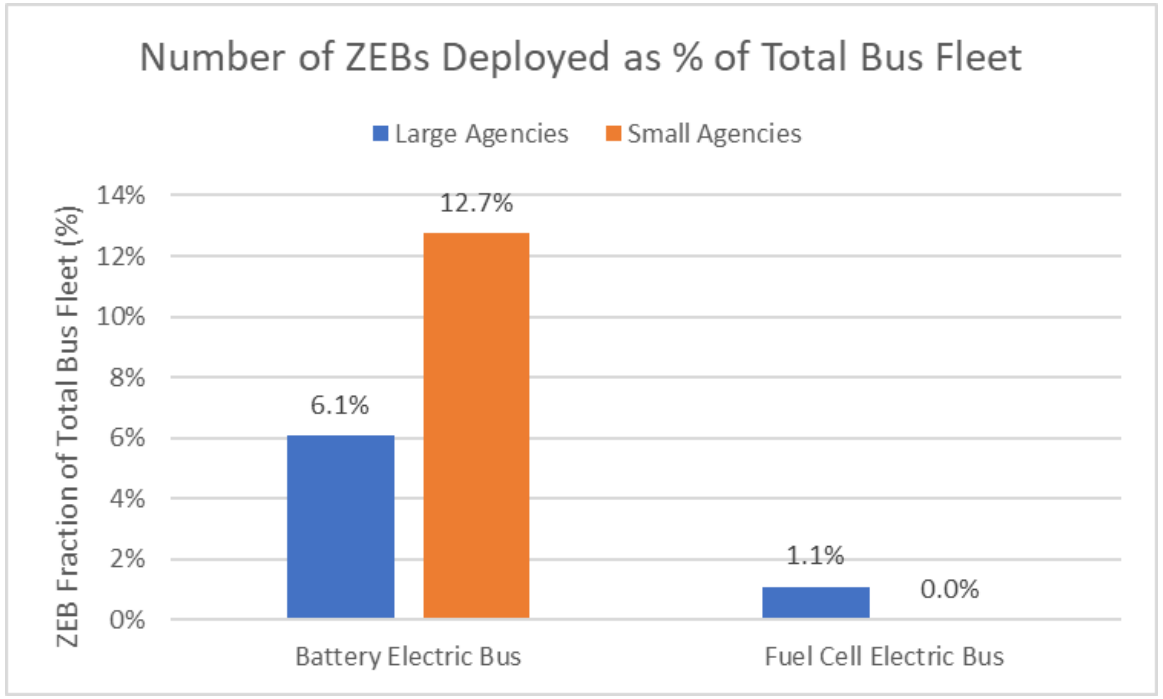






Transit Survey – Agencies with ZEBs Deployed





Large Agencies

- 8 agencies have BEBs deployed, 217 BEBs = 6.1% of buses reported in survey
- 2 agencies have FCEBs deployed, 39 FCEBs = 1.1% of buses reported in survey

→ 7.2% ZEB conversion

Small Agencies

- 11 agencies have BEBs deployed, 172 BEBs = 12.7% of buses reported in survey
- 0 agencies have FCEBs deployed, 0 FCEBs = 0% of buses reported in survey

→ 12.7% ZEB conversion

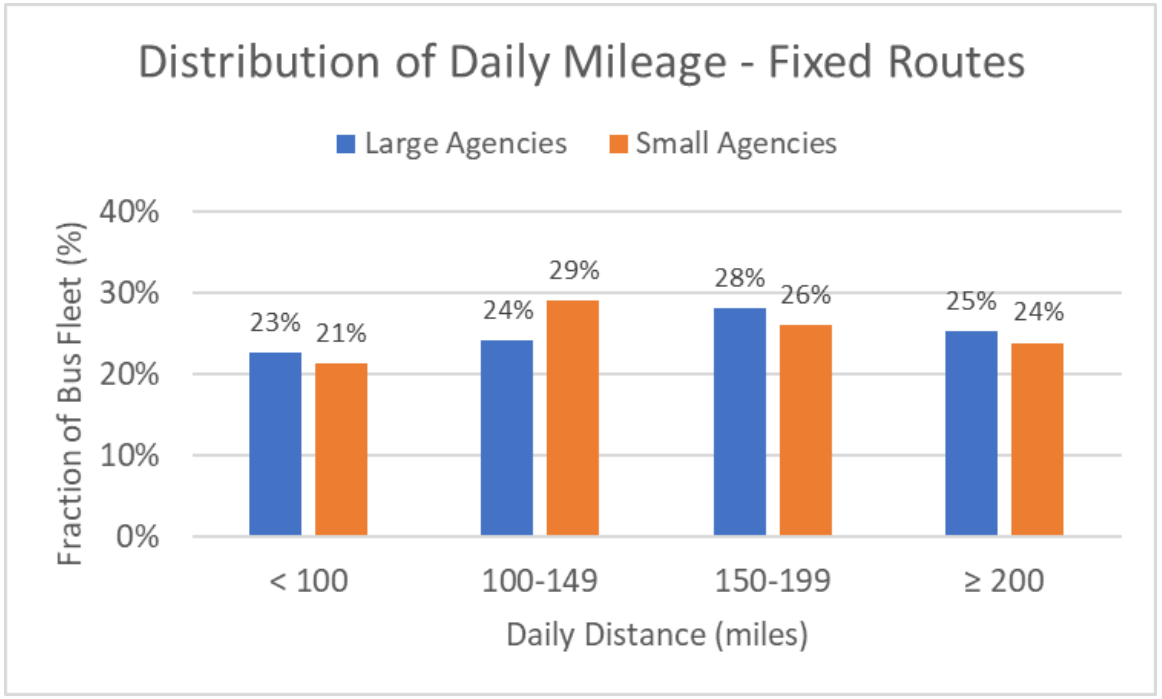
Transit Survey – Fleet Composition, Large Agencies

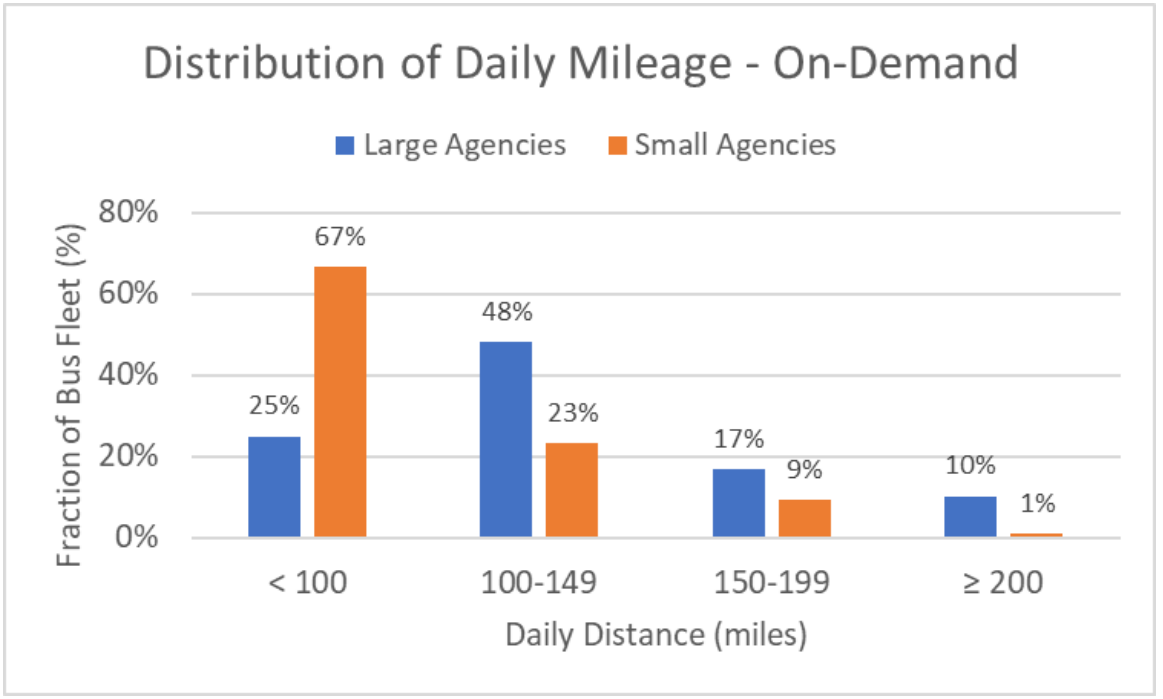
Large Agencies	Standard Low Floor Bus	Over-the-road Coach	Articulated	Cutaway	Double Decker	Total
Battery Electric (BEB)	5.9%	0.0%	0.3%	0.0%	0.0%	6.2%
CNG/LNG	34.3%	4.2%	4.5%	3.9%	0.0%	46.9%
Diesel	14.1%	3.4%	1.7%	0.0%	0.4%	19.7%
Gasoline	2.6%	0.0%	0.0%	2.8%	0.0%	5.5%
Hybrid (diesel)	11.6%	0.0%	3.1%	0.0%	0.0%	14.7%
Hybrid (gasoline)	0.5%	0.0%	0.0%	0.0%	0.0%	0.5%
Hydrogen Fuel Cell (FCEB)	1.1%	0.0%	0.0%	0.0%	0.0%	1.1%
Propane (LPG)	1.4%	0.0%	0.0%	3.9%	0.0%	5.3%
Other: _____	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	71.6%	7.6%	9.7%	10.6%	0.4%	100.0%

Transit Survey – Fleet Composition, Small Agencies

Small Agencies	Standard Low Floor Bus	Over-the-road Coach	Articulated	Cutaway	Double Decker	Total
Battery Electric (BEB)	7.7%	1.7%	2.3%	0.2%	0.0%	11.8%
CNG/LNG	16.3%	0.2%	0.0%	8.2%	0.1%	24.8%
Diesel	21.9%	4.1%	0.0%	3.9%	0.3%	30.3%
Gasoline	0.1%	1.2%	1.9%	25.0%	0.0%	28.3%
Hybrid (diesel)	3.0%	0.0%	0.0%	0.0%	0.0%	3.0%
Hybrid (gasoline)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydrogen Fuel Cell (FCEB)	0.6%	0.0%	0.0%	0.0%	0.0%	0.6%
Propane (LPG)	0.5%	0.0%	0.0%	0.7%	0.0%	1.2%
Other: _____	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	50.1%	7.2%	4.2%	38.0%	0.4%	100.0%

Transit Survey – Route Length Distributions



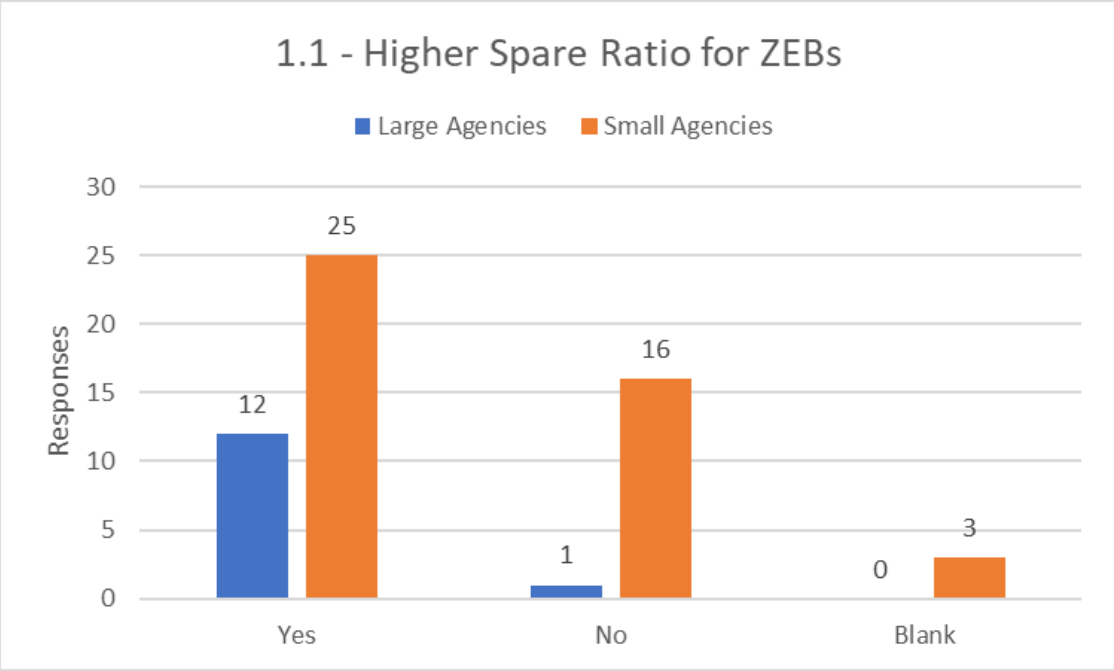


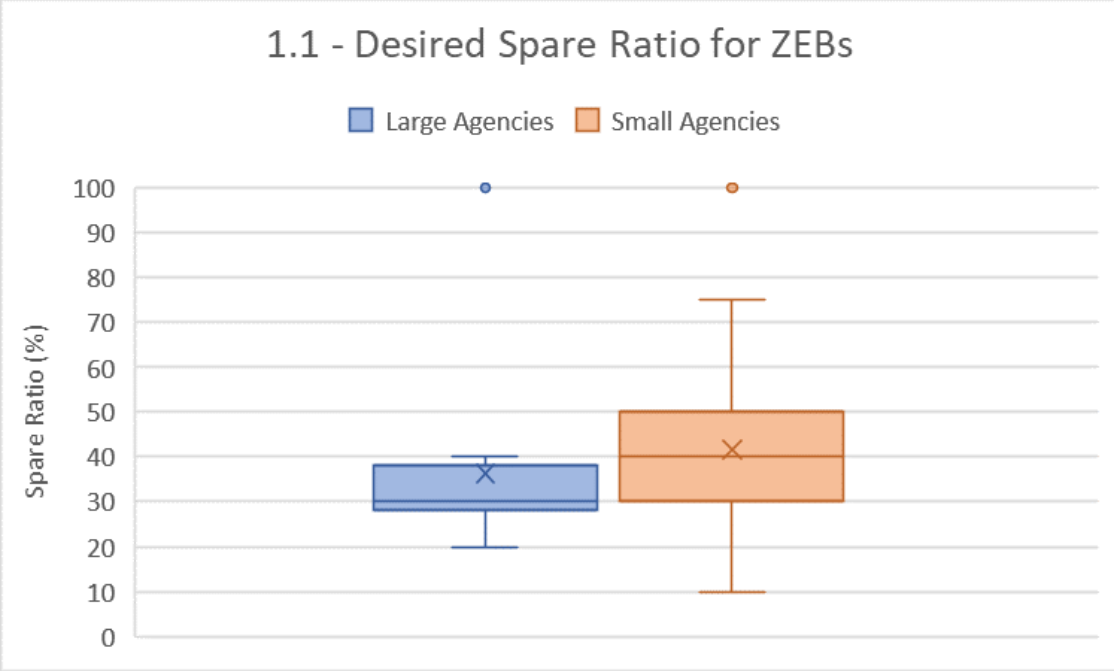
Transit Survey – Spare Ratio for ZEBs

1.1 Should the ZEB sub-fleets have a separate spare ratio that is higher than the regular spare ratio (20%)?

☐ Yes | ☐ No

If yes, what should be the ZEB spare ratio? ____ %



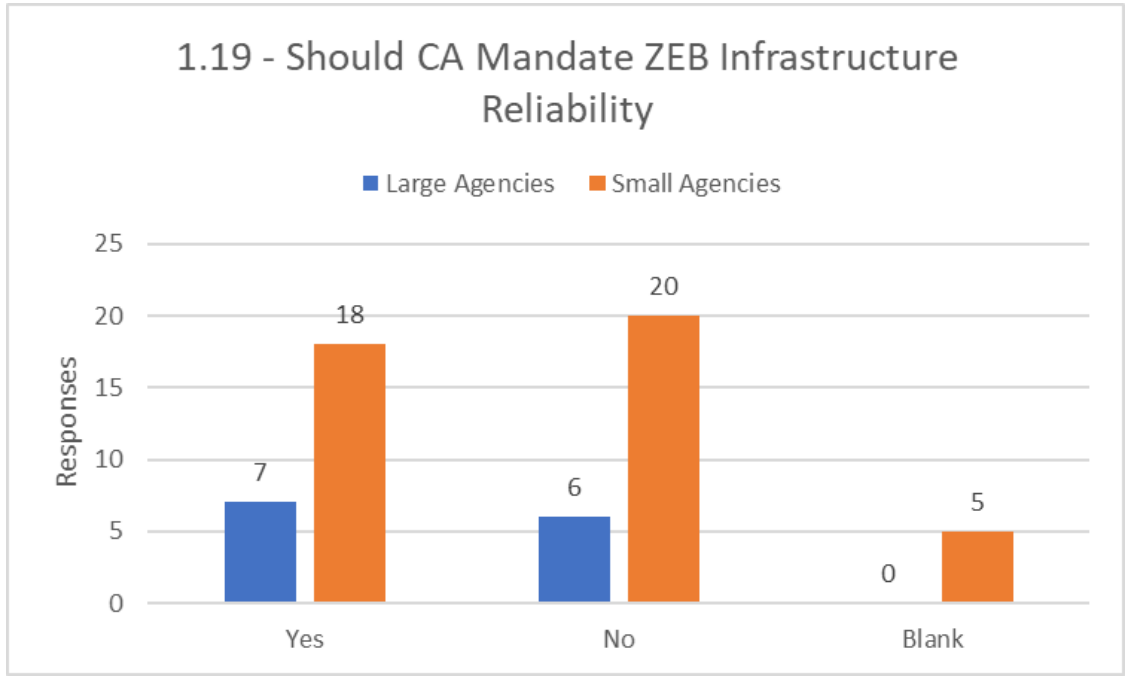


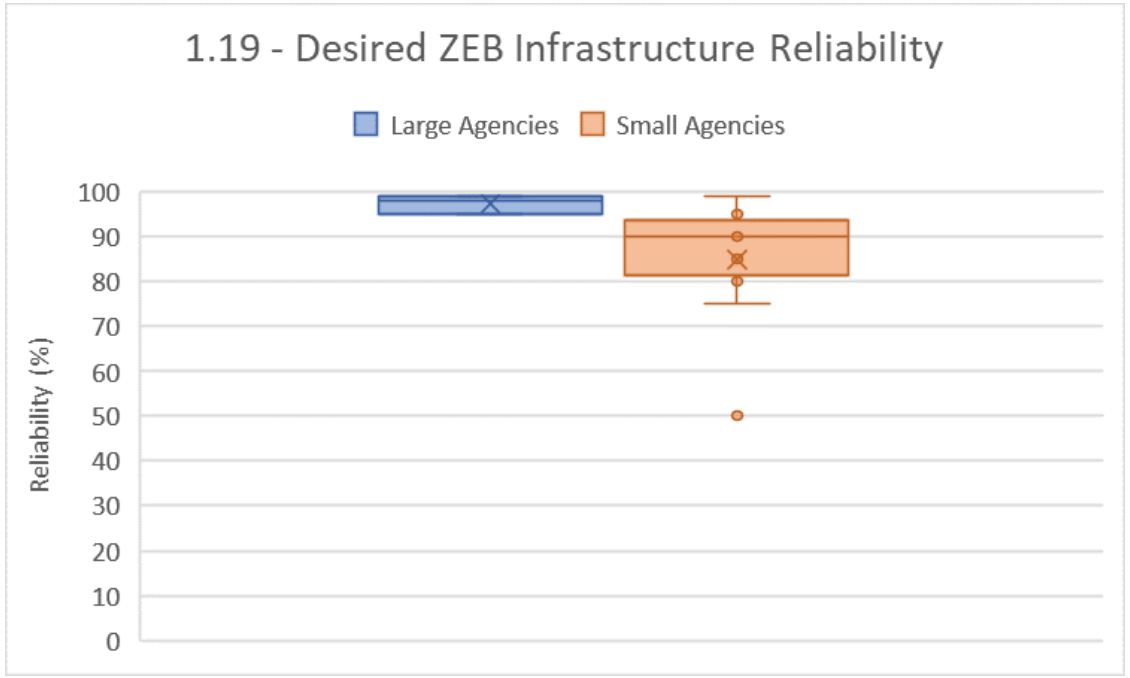
Transit Survey – Fueling/Charging Station Reliability

1.19 Should the state adopt regulations mandating hydrogen refueling station and electric charging station reliability?

☐ Yes | ☐ No

If the answer is yes, please state a satisfactory availability/uptime (in percentage): ____%



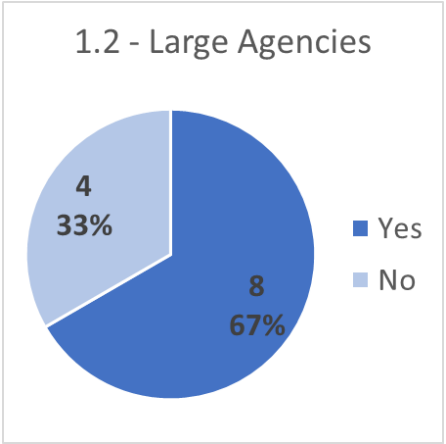


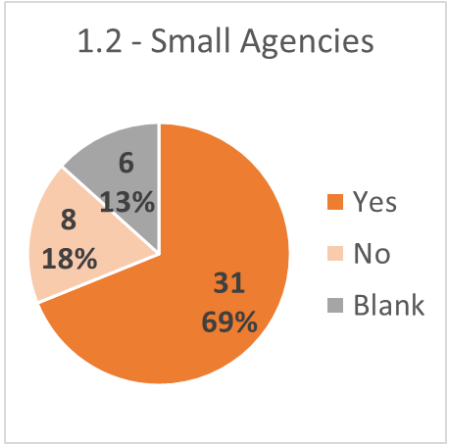
Transit Survey – FTA Safety Training for ZEBs

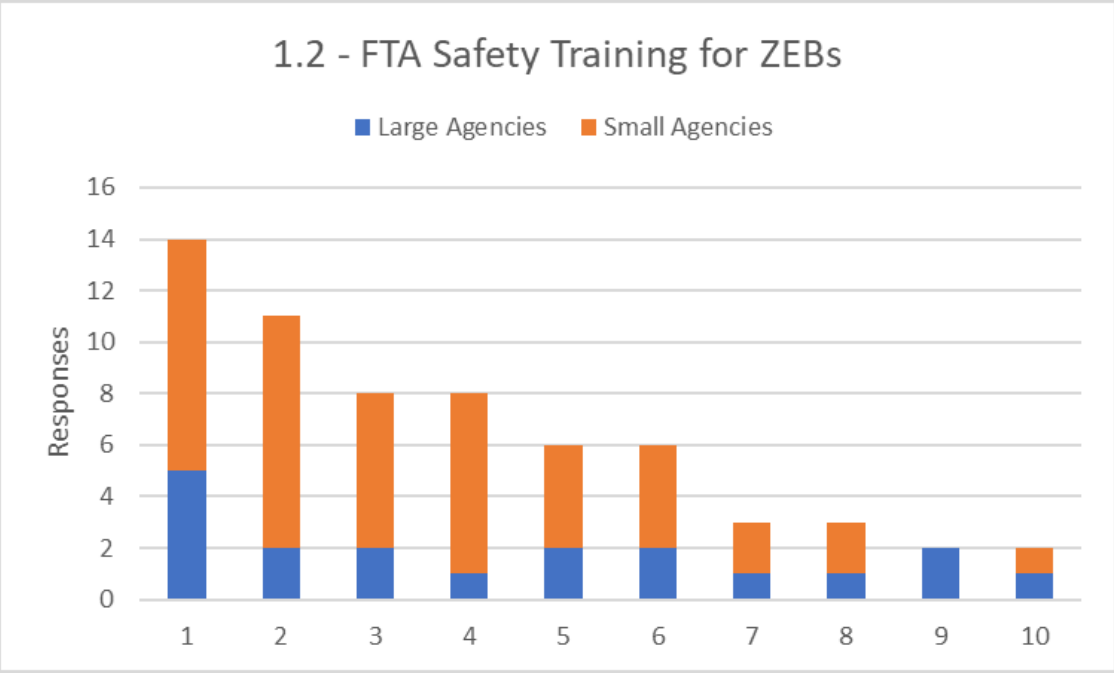
1.2 Should some of the ZEB training be part of FTA's safety training?

☐ Yes | ☐ No

If yes, please list the applicable training areas:







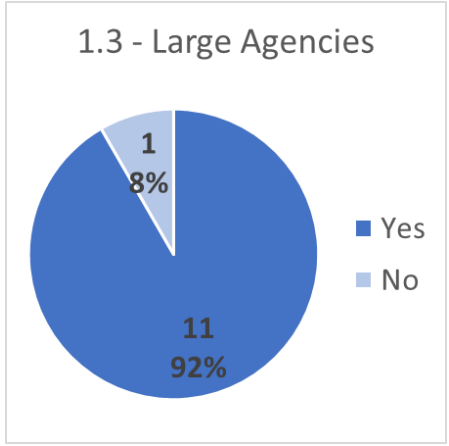
1	Battery/high voltage electrical systems
2	Accident/emergency response, fire suppression
3	ZEB operations, driver training, passenger safety/awareness training
4	Maintenance/PM procedures, mechanic training
5	Charging/fueling
6	Safe work practices, LO/TO
7	ZEB basics (battery & fuel cell)
8	Environment and health considerations, hazardous materials
9	Hydrogen/high pressure systems
10	Regulatory compliance and best practices

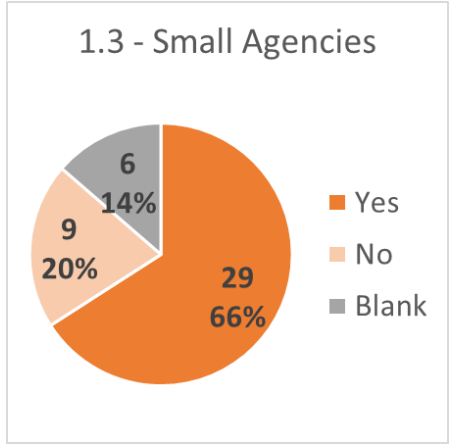
Transit Survey – ZEB Testing at Altoona

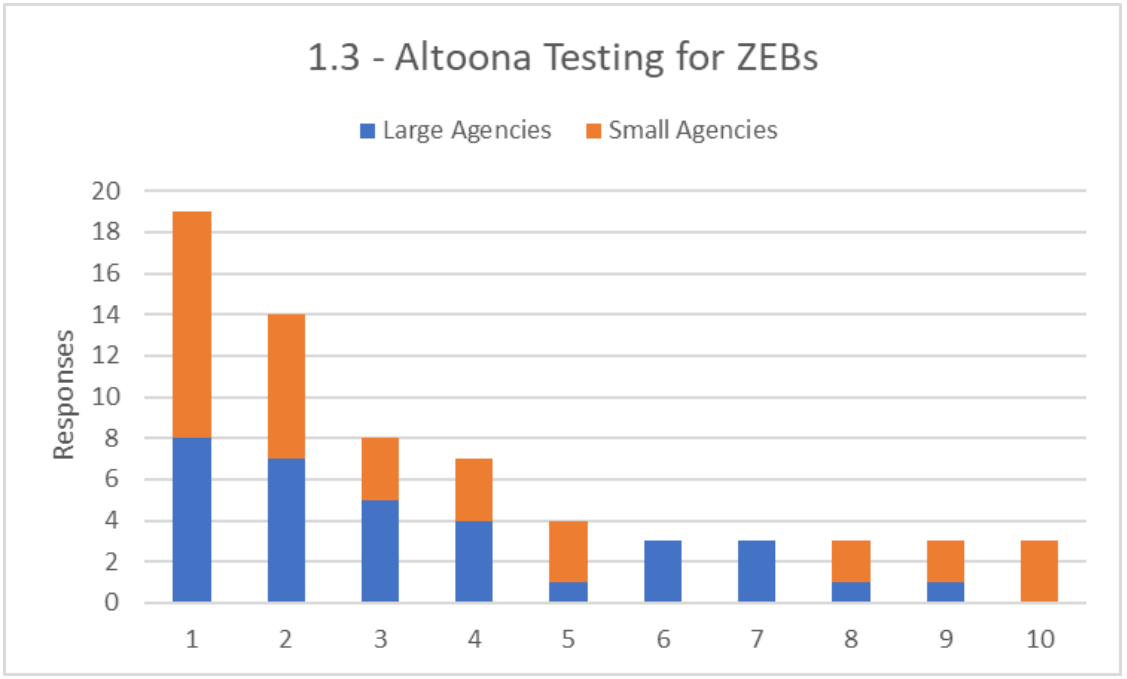
1.3 Should the Altoona testing include ZEB related tests?

☐ Yes | ☐ No

If yes, please identify the areas for ZEB testing:





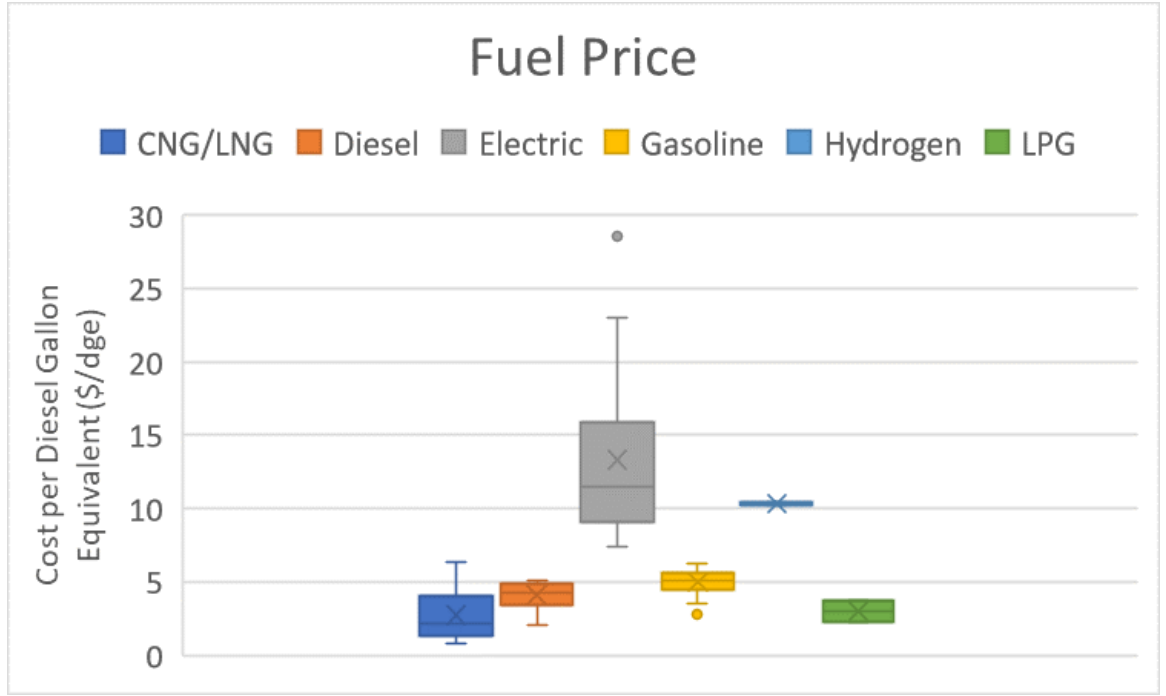


1	Vehicle range (real world efficiency/range, environmental impacts)
2	Safety (BTMS testing, fire detection/suppression for batteries & hydrogen)
3	Lifetime/longevity (vehicle/system/component degradation)
4	Performance (motor efficiency, regen braking efficiency, battery performance)
5	Other (noise, air brake systems, environmental impact)
6	Charging/fueling (system integrity, compatibility, charging/fueling time)
7	Chassis/weight/structural considerations
8	Maintainability
9	Reliability
10	"same as conventional"

Transit Survey – Fuel Price

Table 5. Average Fuel Price per Unit ($/dge, $/kg, etc.)

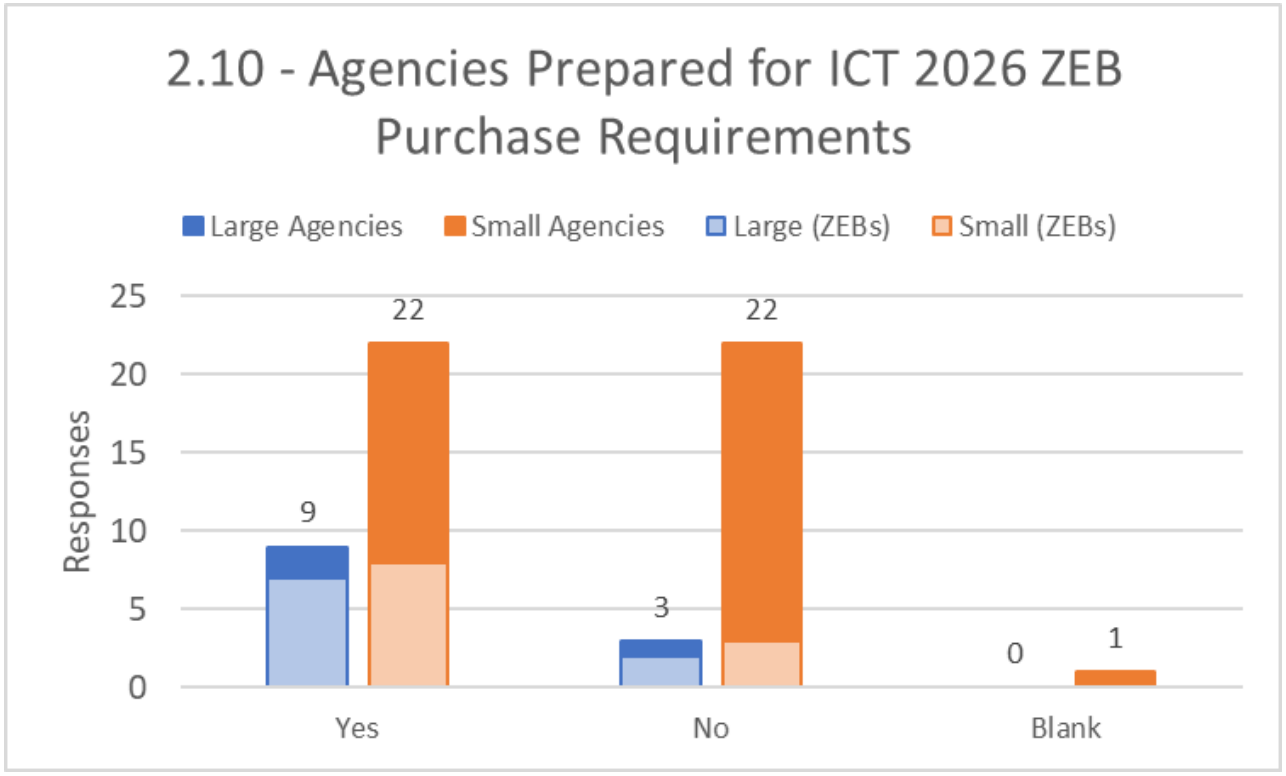
Powertrain/ Fuel Type	Preferred Units	Average Fuel Price per Unit
CNG/LNG	$/gge	
Diesel	$/dge	
Electricity (for BEBs)	$/kWh	
Gasoline	$/gge	
Hydrogen (for FCEBs)	$/kg	
Propane (LPG)	$/dge	



Transit Survey – Prepared to Meet ICT 2026 Req.

2.10 Does your agency feel ready to meet the ICT 2026 ZEB purchase requirements?
(i.e., for 2026–2028, new bus purchases must be 50% ZEB for large agencies and 25% ZEB for small agencies.)
☐ Yes | ☐ No

If no, what are your major concerns for meeting 2026 requirements?

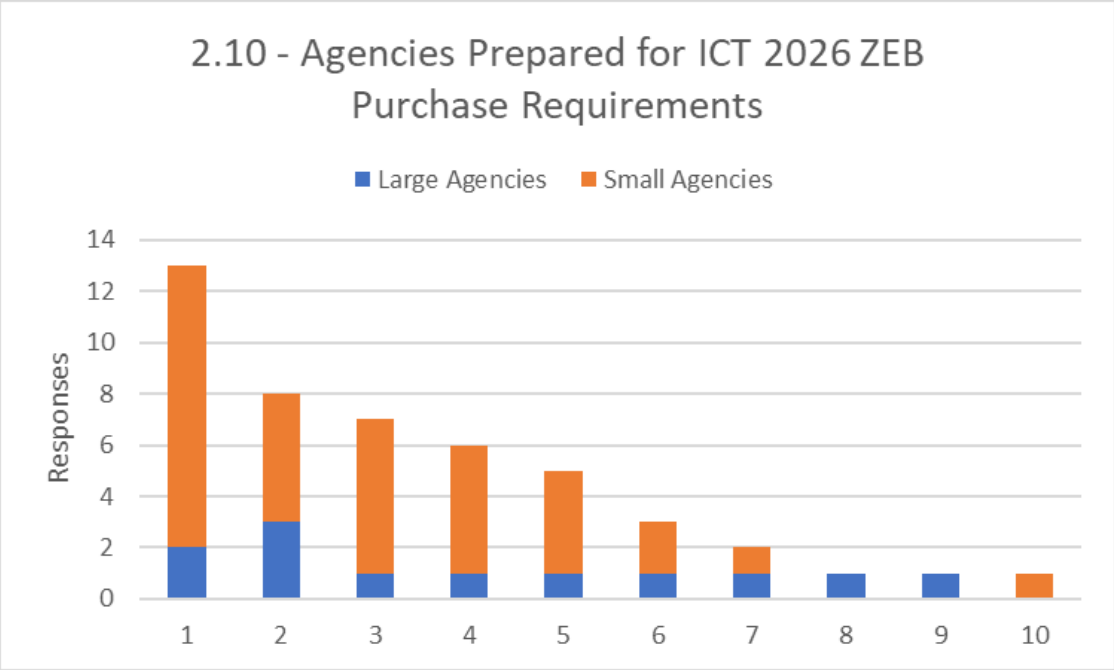


Transit Survey – Initial Results

2.10 Does your agency feel ready to meet the ICT 2026 ZEB purchase requirements? (i.e., For 2026–2028, new bus purchases must be 50% ZEB for large transit agencies and 25% ZEB for small transit agencies.)

☐ Yes | ☐ No

If no, what are your major concerns for meeting 2026 requirements?



1	Funding (high cost for vehicles and/or infrastructure)
2	Infrastructure availability/technology readiness
3	Vehicle availability/technology readiness
4	Vehicle performance or reliability
5	Infrastructure timeline/construction delays
6	Property/facility-related needs
7	Training/workforce development
8	Operations, fleet integration
9	Regulatory and policy uncertainties
10	Hydrogen availability

Phase 1 Summary of Key Needs Moving to 100% ZEB Fleets

To achieve a successful transition to 100% ZEB transit fleets in the coming years, some of the greatest needs include:

1. Sustained progress from the vehicle, equipment, and infrastructure manufacturing base is needed to continue ***driving down costs, improve reliability and optimize performance***.
2. ***Expansion of charging and fueling infrastructure*** is a fundamental need that will require coordinated efforts and forward-looking planning by transit agencies, utilities, and developers.
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4. ***Financial support*** for purchasing, installing, and operating ZEBs and the necessary fueling/charging equipment. Federal and State funding for ZEBs and related charging/fueling infrastructure are critical to achieving reasonable payback on the upfront costs, especially in the early years.

These "Key Needs" from Phase 1 assesment are consistent with preliminary results from Phase 2 Survey – but we seek to more fully document the current state of CA transit ZEB industry

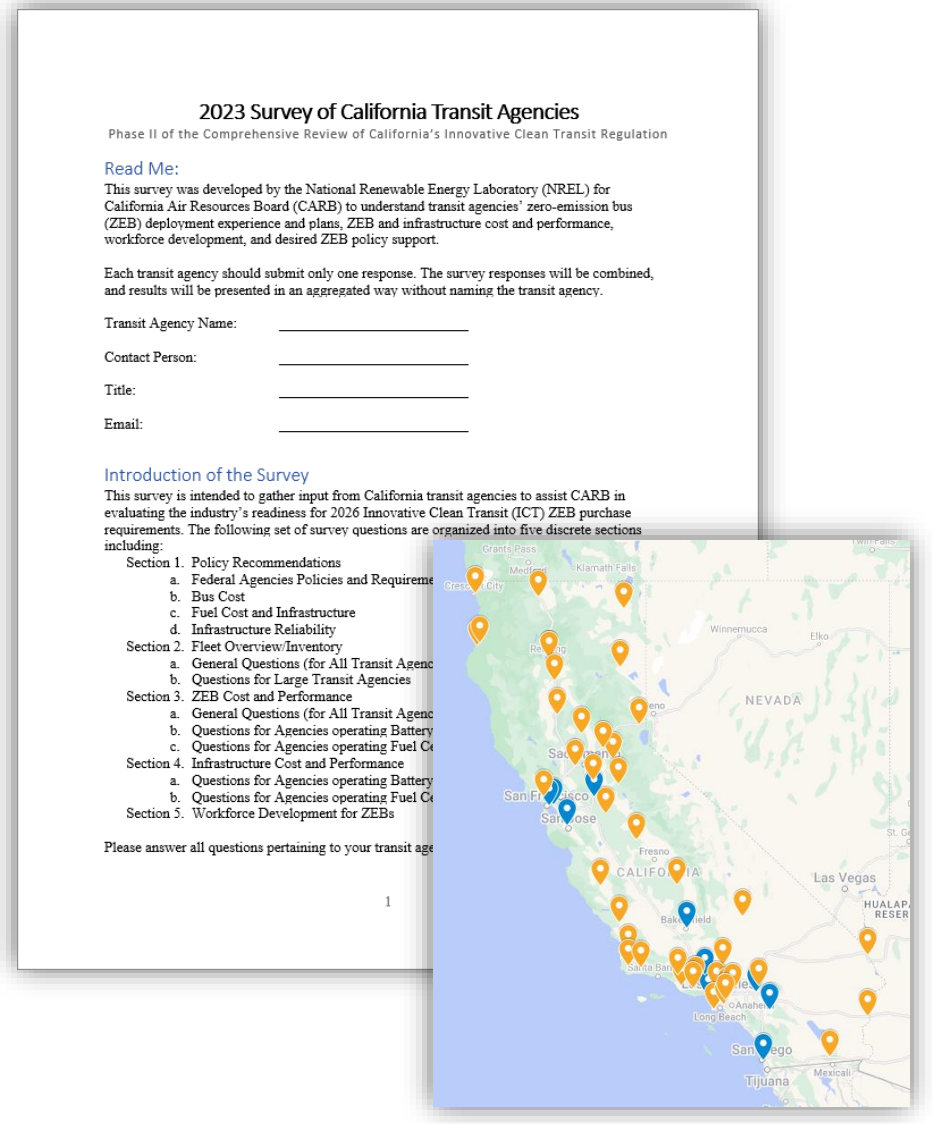
ICT Survey – your input is critical!

Phase 2 Objective: Provide comprehensive assessment of Innovative Clean Transit program readiness for ***2026 ZEB purchase requirements***.

ICT Survey is a chance to document input on a wide variety of topics critical to CA transit industry

Other data sources will be included… but we hope to increase industry representation in the survey

Not too late to provide your input!



2023 Survey of California Transit Agencies

Phase II of the Comprehensive Review of California's Innovative Clean Transit Regulation

Read Me:

This survey was developed by the National Renewable Energy Laboratory (NREL) for California Air Resources Board (CARB) to understand transit agencies' zero-emission bus (ZEB) deployment experience and plans, ZEB and infrastructure cost and performance, workforce development, and desired ZEB policy support.

Each transit agency should submit only one response. The survey responses will be combined, and results will be presented in an aggregated way without naming the transit agency.

Transit Agency Name: _____

Contact Person: _____

Title: _____

Email: _____

Introduction of the Survey

This survey is intended to gather input from California transit agencies to assist CARB in evaluating the industry's readiness for 2026 Innovative Clean Transit (ICT) ZEB purchase requirements. The following set of survey questions are organized into five discrete sections including:

Section 1. Policy Recommendations
- a. Federal Agencies Policies and Requirem
- b. Bus Cost
- c. Fuel Cost and Infrastructure
- d. Infrastructure Reliability

Section 2. Fleet Overview/Inventory
- a. General Questions (for All Transit Agenc
- b. Questions for Large Transit Agencies

Section 3. ZEB Cost and Performance
- a. General Questions (for All Transit Agenc
- b. Questions for Agencies operating Battery
- c. Questions for Agencies operating Fuel Ce

Section 4. Infrastructure Cost and Performance
- a. Questions for Agencies operating Battery
- b. Questions for Agencies operating Fuel Ce

Section 5. Workforce Development for ZEBs

Please answer all questions pertaining to your transit age

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Questions?

www.nrel.gov

NREL
Transforming ENERGY

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Backup slides

ZEB Performance and Operation

- ZEB capital costs and incentive funding programs utilized for ZEBs
- ZEB availability and use (daily mileage, routes)
- Energy/fuel consumption, range
- Fueling/charging time, fuel costs
- Reliability – roadcalls and miles between roadcall (MBRC)
- Performance issues encountered and solutions

ZEB Infrastructure

- Size, quantity, and type of fueling/charging equipment
- Costs – equipment, installation, construction costs and necessary infrastructure and/or facility upgrades
- Incentive funding programs utilized for ZEB infrastructure
- Total project timelines
- Warranty information and maintenance/service agreements
- Reliability, uptime of fueling/charging equipment
- Operational changes/impacts

Workforce Development

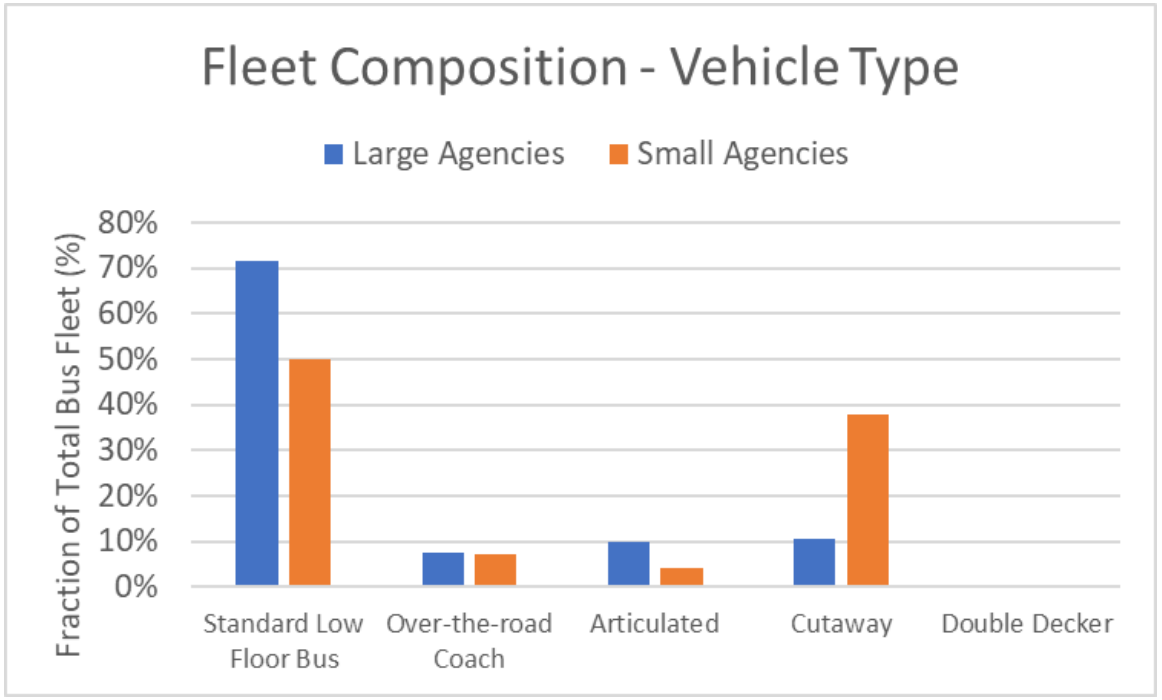
- New job creation for ZEBs
- Types of ZEB training programs/courses available
- Source of training (provided by OEM, developed in-house, 3rd party online training or local institution)
- Cost of new ZEB training and amount of incentive funding applied to training programs
- Percent of workforce trained for ZEBs
- Other tools/resources utilized

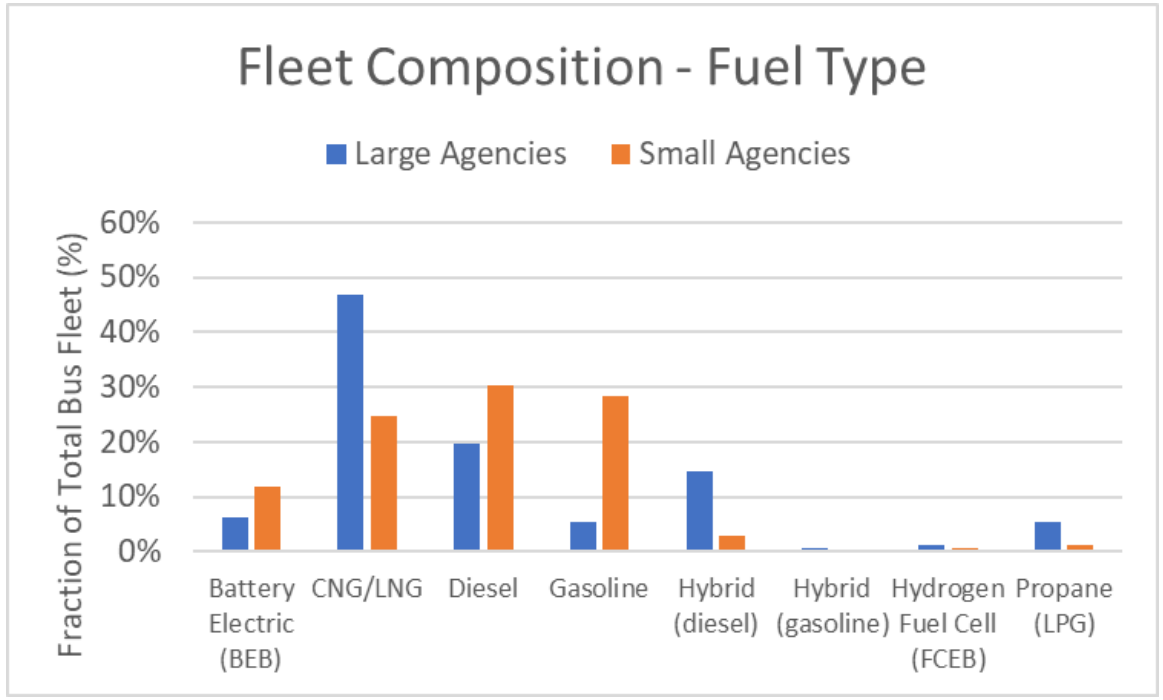
Transit Survey – Fleet Composition

Large Agencies	Standard Low Floor Bus	Over-the-road Coach	Articulated	Cutaway	Double Decker	Total
Battery Electric (BEB)	5.9%	0.0%	0.3%	0.0%	0.0%	6.2%
CNG/LNG	34.3%	4.2%	4.5%	3.9%	0.0%	46.9%
Diesel	14.1%	3.4%	1.7%	0.0%	0.4%	19.7%
Gasoline	2.6%	0.0%	0.0%	2.8%	0.0%	5.5%
Hybrid (diesel)	11.6%	0.0%	3.1%	0.0%	0.0%	14.7%
Hybrid (gasoline)	0.5%	0.0%	0.0%	0.0%	0.0%	0.5%
Hydrogen Fuel Cell (FCEB)	1.1%	0.0%	0.0%	0.0%	0.0%	1.1%
Propane (LPG)	1.4%	0.0%	0.0%	3.9%	0.0%	5.3%
Other: _____	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	71.6%	7.6%	9.7%	10.6%	0.4%	100.0%

Small Agencies	Standard Low Floor Bus	Over-the-road Coach	Articulated	Cutaway	Double Decker	Total
Battery Electric (BEB)	7.7%	1.7%	2.3%	0.2%	0.0%	11.8%
CNG/LNG	16.3%	0.2%	0.0%	8.2%	0.1%	24.8%
Diesel	21.9%	4.1%	0.0%	3.9%	0.3%	30.3%
Gasoline	0.1%	1.2%	1.9%	25.0%	0.0%	28.3%
Hybrid (diesel)	3.0%	0.0%	0.0%	0.0%	0.0%	3.0%
Hybrid (gasoline)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydrogen Fuel Cell (FCEB)	0.6%	0.0%	0.0%	0.0%	0.0%	0.6%
Propane (LPG)	0.5%	0.0%	0.0%	0.7%	0.0%	1.2%
Other: _____	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	50.1%	7.2%	4.2%	38.0%	0.4%	100.0%

Transit Survey – Fleet Composition





Transit Survey – Fuel Cost

Table 5. Average Fuel Price per Unit ($/dge, $/kg, etc.)

Powertrain/Fuel Type	Preferred Units	Average Fuel Price per Unit
CNG/LNG	$/gge	
Diesel	$/dge	
Electricity (for BEBs)	$/kWh	
Gasoline	$/gge	
Hydrogen (for FCEBs)	$/kg	
Propane (LPG)	$/dge