Mountains to Sea: Electrifying North Carolina's Transit Fleets

Zero Emission Bus Transition Plan

January 17,2023

Agenda

- Welcome –Sarah Searcy, Christopher Dodson (NCDOT)
- Project Overview
- CTE Introduction- Project Team
- CTE Overview
- ZEB Technology Overview
- Transition Plan Methodology
- North Carolina’s Transit Fleets Transition Planning Overview
  - AppalCART Transition Analysis (BEB)
  - HATS Transition Analysis (Cutaway)
- Questions

Project Overview

- FTA’s Helping Obtain Prosperity for Everyone (HOPE) program
  - Grant Awarded October 7, 2020
  - ***"Mountains to Sea: Electrifying North Carolina's Transit Fleets"***
- Objective - Develop ZEB Transition Plans for two transit agencies in rural areas with distinct climate and topographical differences
  - AppalCart – Watauga County, mountainous region
  - HATS – Hoke County, near southern coast
- Goal - ZEB Transition Plans to be used as case studies for NC transit agencies with similar characteristics

Project Team

HOPE Program Administrator and Project Sponsor

AppalCART

Sponsored Transit Agency

NORTH CAROLINA HOKE COUNTY

Sponsored Transit Agency

Consultant Project Manager

About CTE

WHO WE ARE

501(c)(3) nonprofit engineering and planning firm

OUR MISSION

Improve the health of our climate and communities by bringing people together to develop and commercialize clean, efficient, and sustainable transportation technologies

PORTFOLIO

$800+ million

- *Research, demonstration, deployment*
- *More than 100 active projects*

OUR FOCUS

Zero-Emission Transportation Technologies

NATIONAL PRESENCE

Atlanta, Berkeley, Los Angeles, St. Paul

Our Four Service Areas

Prototype Development & Demonstration

We support technology providers through technology research, development, and demonstration.

Smart Deployment

We support early adopters by providing the best technical solutions for initial deployments.

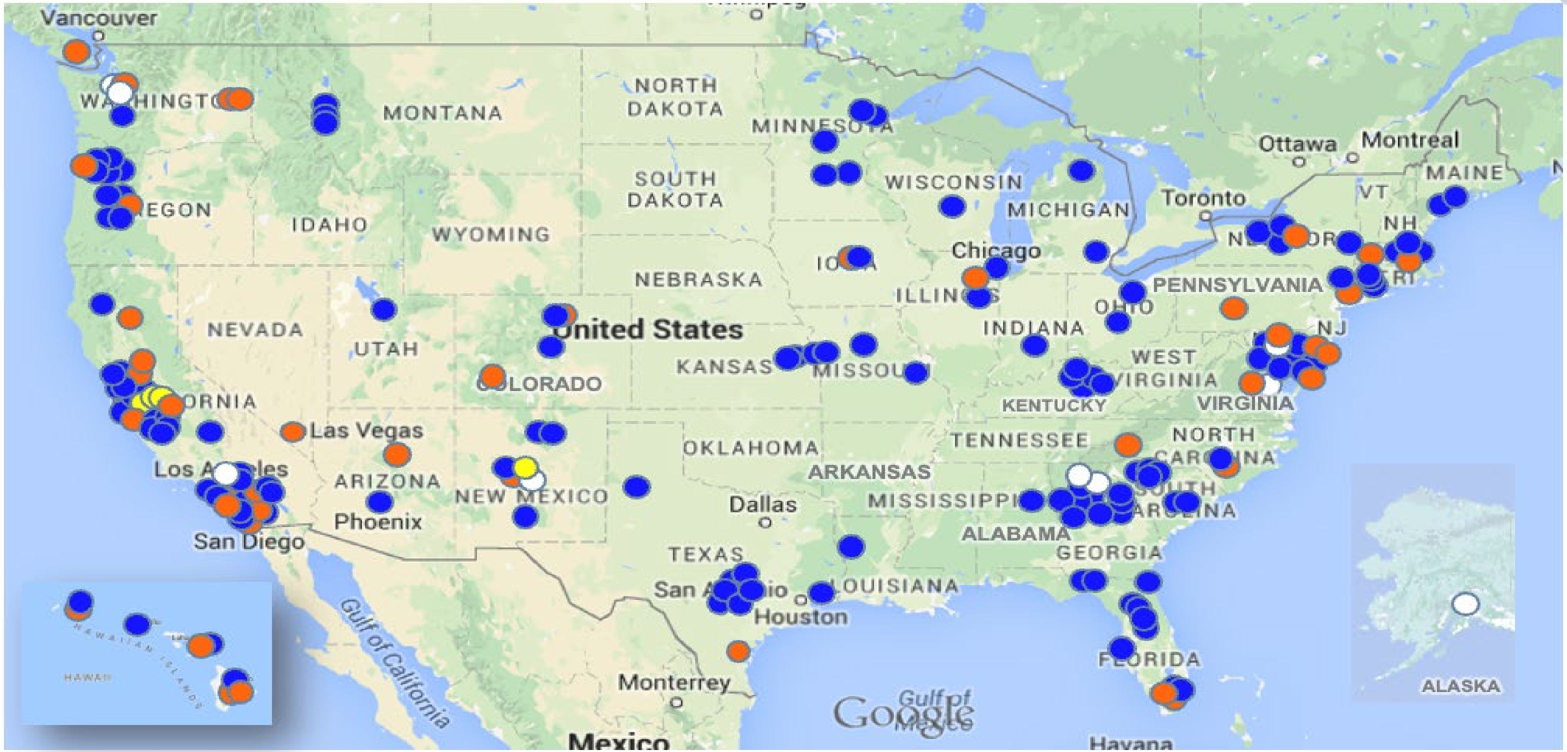
Fleet Transition

We help fleet operators implement strategic plans for full electrification.

Education & Outreach

We help organizations of all shapes and sizes stay ahead of the technology curve.

CTE Zero Emission Bus Projects

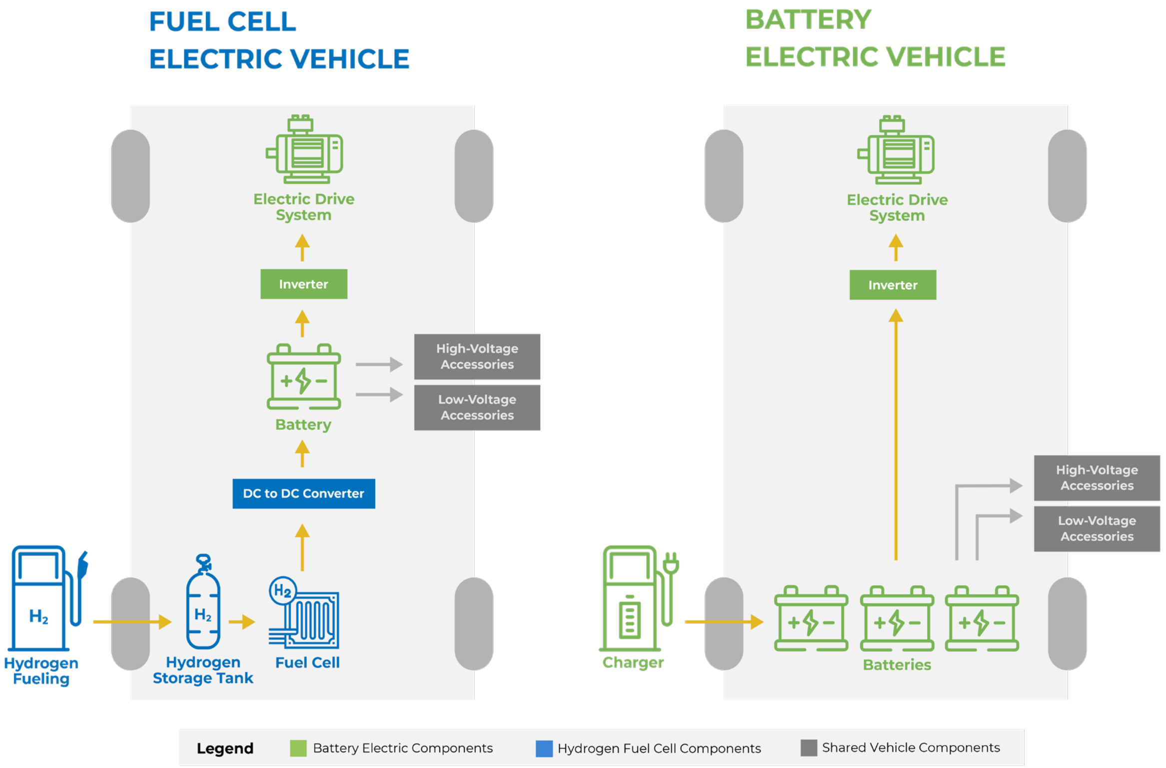


ZEB Deployment Projects
ZEB Planning Projects
ESB Planning Projects
E-Fleet Planning Projects

Zero Emission Bus Technology

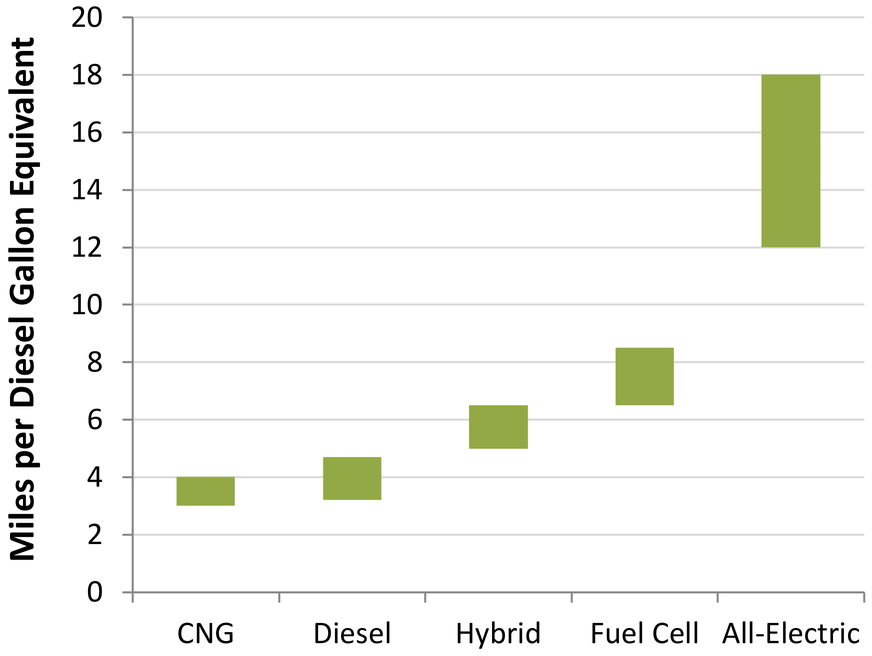
Zero Emission Buses —What's Different?

- Propulsion System
  - *Traction Motor instead of engine*
- Energy Storage System
  - *Battery instead of fuel tank*
- HVAC
  - *No "free" heat*
  - *Electric heater*
- Time to "Re-fuel"
  - *FCEB: 10 minutes*
  - *BEB: ~3 hours*



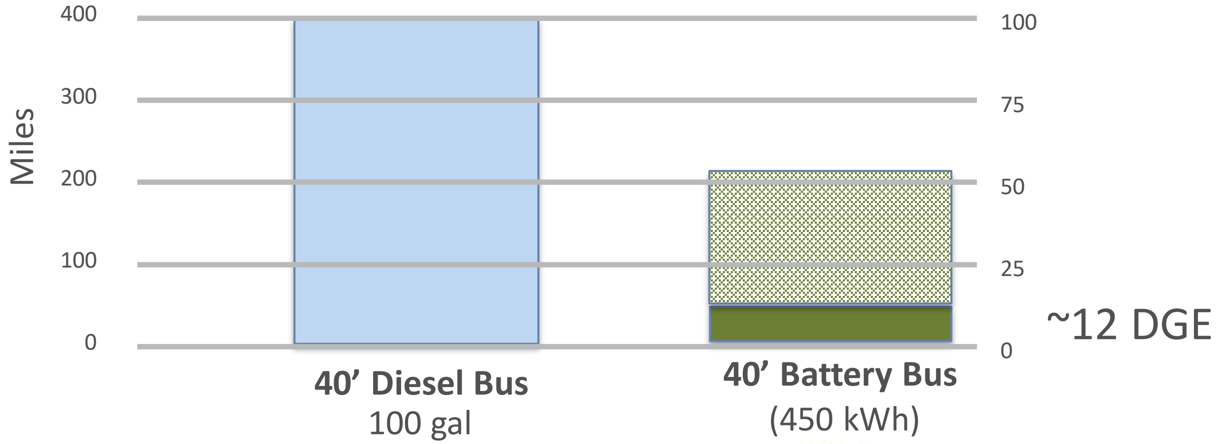
Efficiency Comparison

- Battery-electric buses are ~4x more efficient than diesel
- BEB efficiency (and range) changes with local conditions and driving habits more than diesel and CNG buses.



BEB vs Diesel Range

Different methods of storing energy require different deployment plans.



Electric drive is four times as efficient as a diesel engine!!!

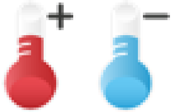
U.S. Department of Energy: 38 kWh is equivalent to 1 gallon of diesel

Source: Center for Transportation & the Environment

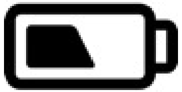
Factors Affecting ZEB Range

- **Route characteristics:** speed, stops, grade

- **Ridership**



- **Climate: Heating and cooling**

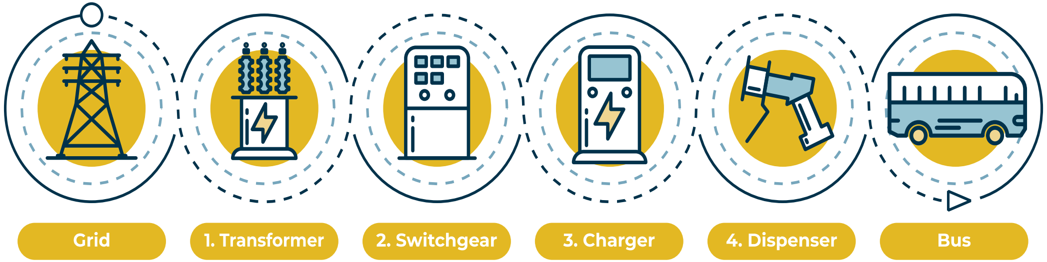


- **Battery degradation**

- **Operator**

Charging Infrastructure Terms

- **Chargers.** Charging projects include purchase and installation of 150 kW chargers and dispensers.
- **Dispensers.** There can be up to 2 dispensers for each charger and each dispenser project assumes the cost of plug-in dispensers and cable reels.

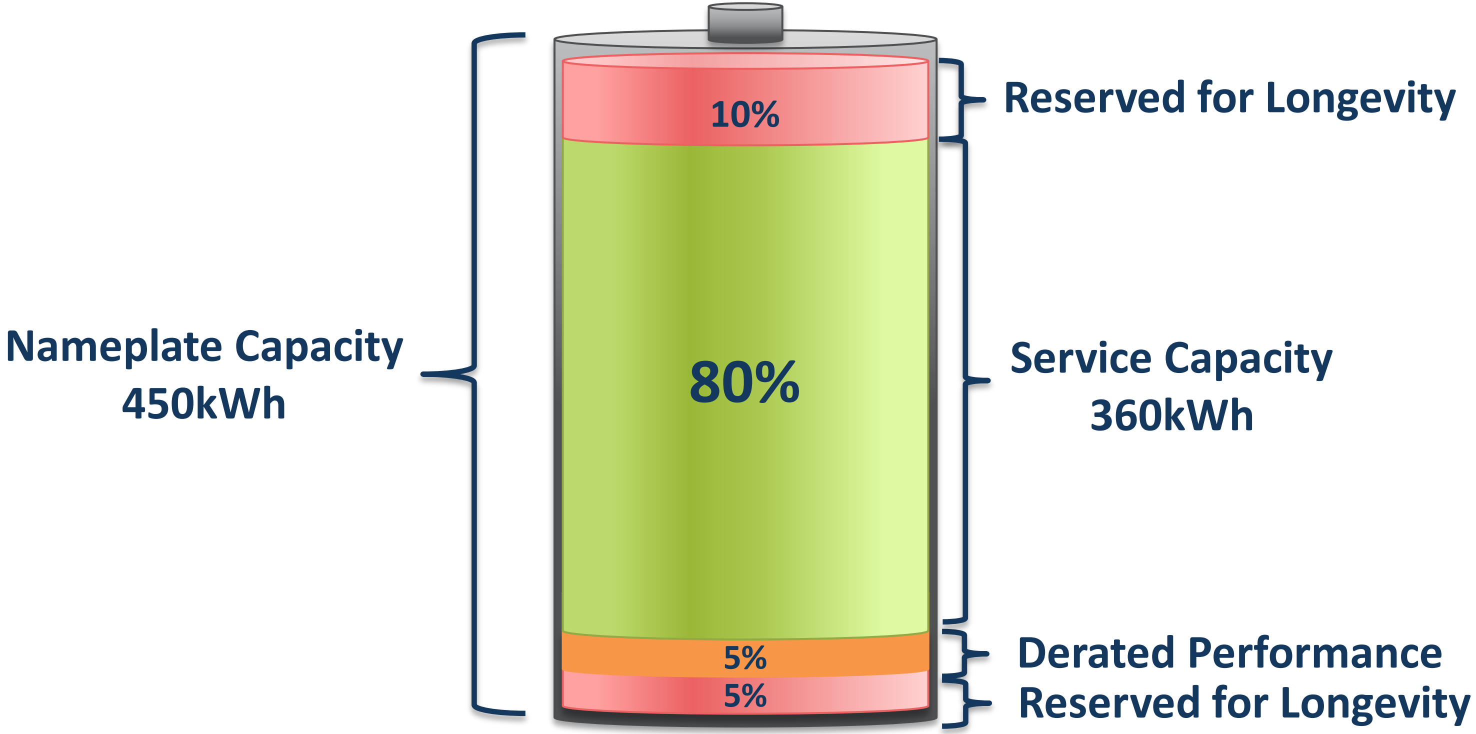


Generalized battery charging station schematic

Wall-mounted dispenser

Ceiling-mounted dispenser

Lithium-Ion Battery Overview



ZEB Transition Planning

Why is ZEB Transition Planning Important

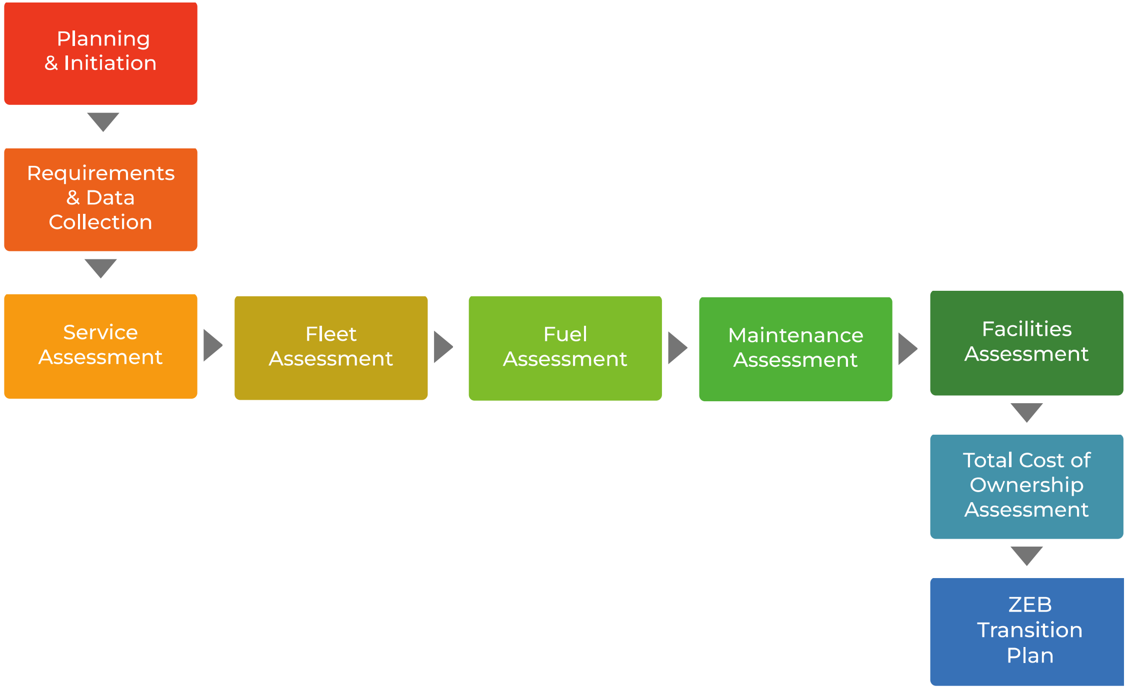
- Helps to identify types of vehicles and when to purchase
- Helps to identify funding requirements
- Helps to understand new policy requirements
- Helps to identify facility modifications
- Helps to understand stakeholder engagement
- Helps to understand the Impacts on the workforce

Objectives of Transition Planning

- Determine feasibility of replacing existing buses with zero emissions buses
- Determine what alternatives would work best for specific transit service
- Understand incremental costs for buses and fueling infrastructure
- Develop a Transition Master Plan

North Carolina's Transit Fleets Transition Planning Overview

CTE's ZEB Transition Planning Methodology



Planning, Requirements & Data Collection

Requirements & Data Collection

- Collect route, block, fleet operational, maintenance, and facilities information to define current scenario
- For demand-response service, collect any fixed stops and common lay-over locations

Fleet

- Vehicle Characteristics
  - Garage
  - Make/Model
  - Size/Capacity
  - Age & Odometer
- Scheduled Replacement
- Fuel & Maintenance Costs

Block

- Division/Garage
- Operating Days
- Bus Type(s)
- Pull-in/Pull-out Times
- Distance
- Deadhead
- Routes Included

Route

- Distance
- Duration
- Topology
- Service Type
- Bus Type(s)

Service and Fleet Assessments

Service Assessment

- Evaluate service blocks to determine if current ZEB technologies have sufficient range to replace fleet on 1:1 basis
- Analyze feasibility of alternative solutions that allow for 100% fleet transition

Fleet Assessment

- Develop timeline for replacement of current buses with ZEBs consistent with agency's fleet replacement plan and results of service assessment
- Project fleet capital costs over the transition period

Fuel and Maintenance Assessments

Fuel Assessment

- Analyze daily, monthly, and annual fuel consumption and demand requirements
- Develop forecasts for annual electricity costs based on current utility rate structure

Maintenance Assessment

- Analyze labor and materials costs for ZEB maintenance over the transition period
- Analyze expected major component replacements for each technology type

Facilities Assessment

Facilities Assessment

- Identify infrastructure requirements for each of the technology scenarios, including electric charging equipment and maintenance facility modifications
- Determine utility upgrades necessary to support charging infrastructure
- Develop phasing plans and sequencing for future build-out of infrastructure to match ZEB procurements
- Project capital costs for infrastructure construction and facilities modifications for each technology option
- Coordination with agency’s selected Energy Service Company (ESCO)

Total Cost of Ownership Assessment

Total Cost of Ownership Assessment

- Develop life cycle cost analysis for all transition scenarios including major capital and operating cost components on an annualized basis over the transition period
- Includes bus procurements; fuel; maintenance and equipment; infrastructure; facility upgrades; and design, construction, and installation services

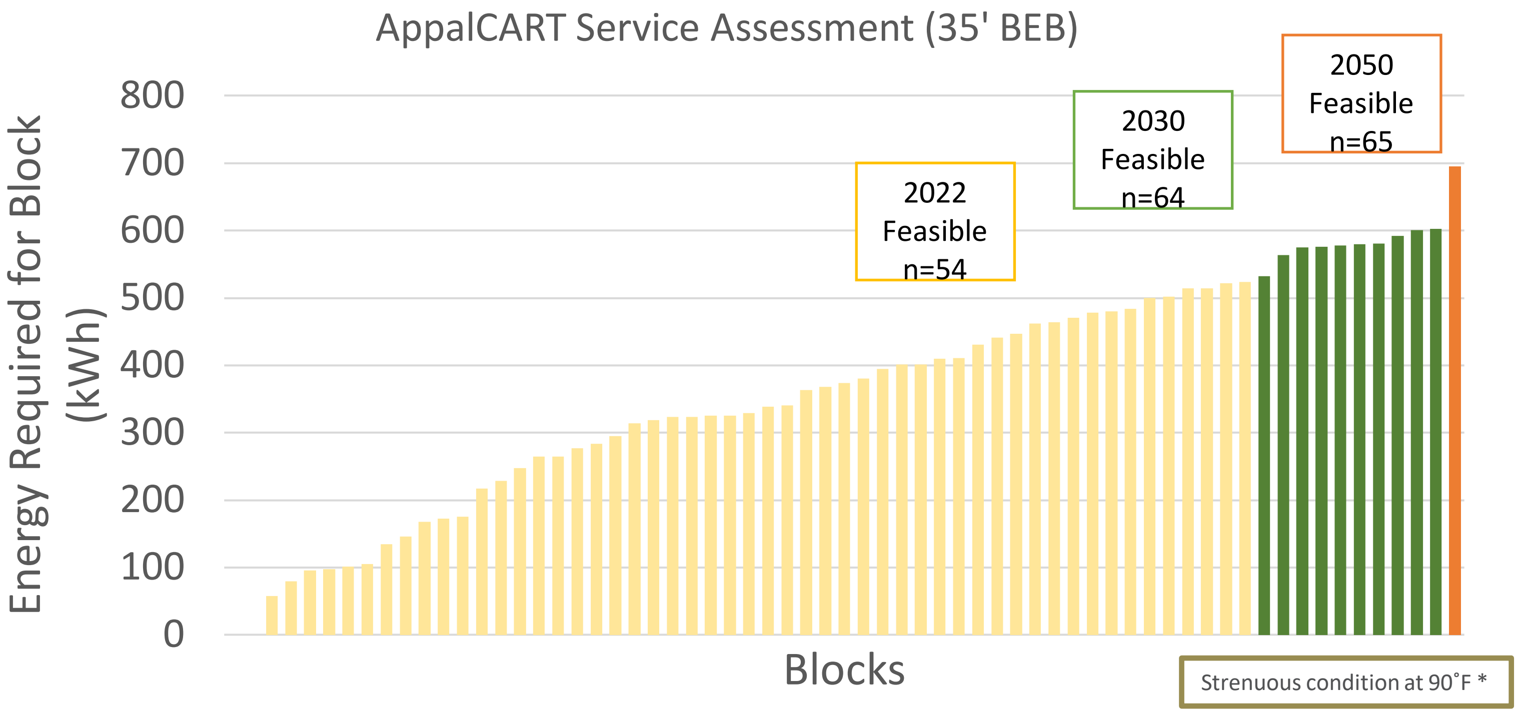
Case Study: AppalCART

AppalCart Agency Summary

- Operates in Boone, Watauga County
- Fleet compromised twenty five (25) GILLIG diesel buses, two (2) GILLIG diesel hybrid buses, and one (1) Proterra electric bus for a total of twenty-eight (28) buses
- Provides 13 fare-free, fixed bus routes, and 10 routes via our van services (Paratransit, Rural General Public, and Project on Aging)
- Mission: to provide sustainable, high-quality transportation services

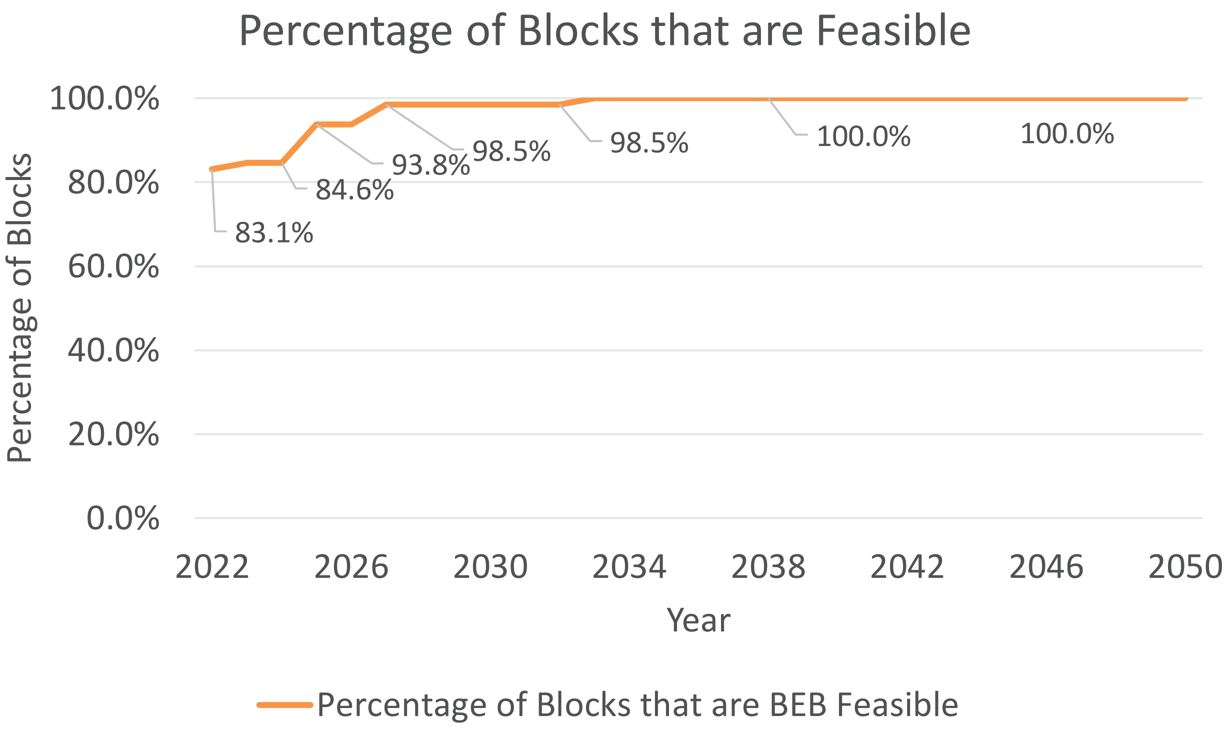
AppalCart Service Assessment

AppalCART Preliminary Results: 35’ BEB



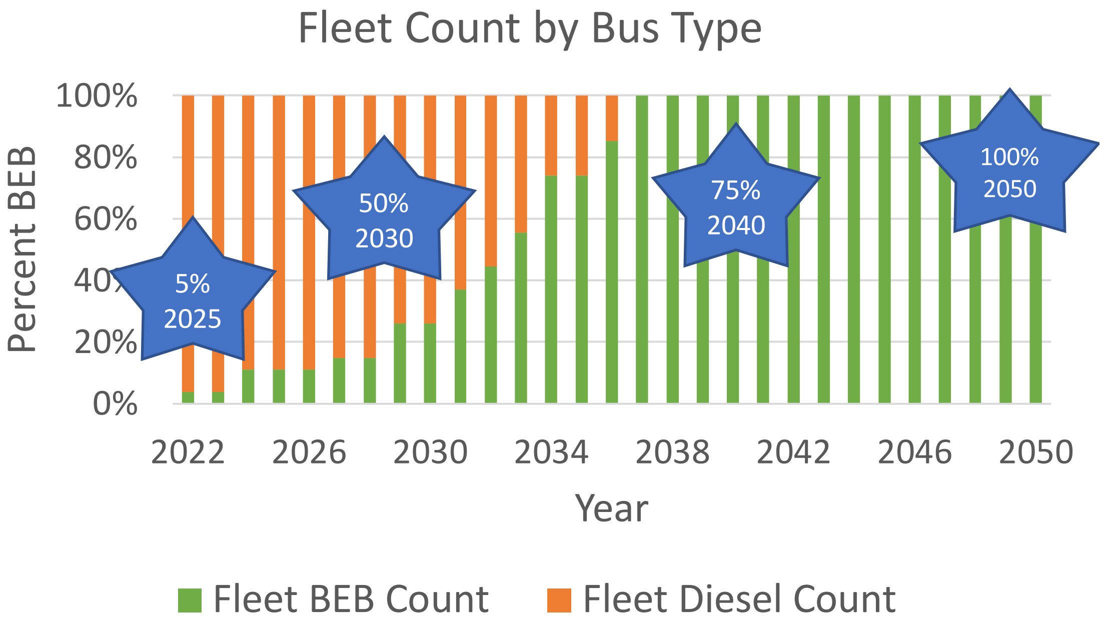
* Assumes use of diesel fired heater in cold conditions, therefore AC load is higher than heating load and defines “strenuous” condition

AppalCART Service Assessment – 35’



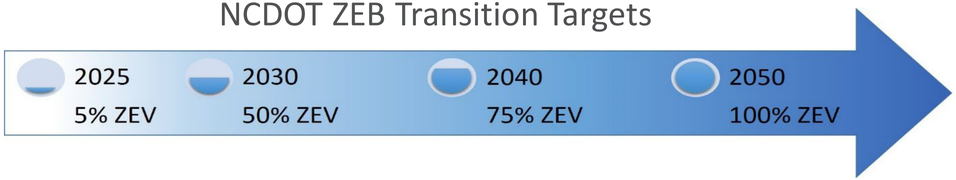
AppalCart Fleet Assessment

Fleet Transition Timeline and Goal



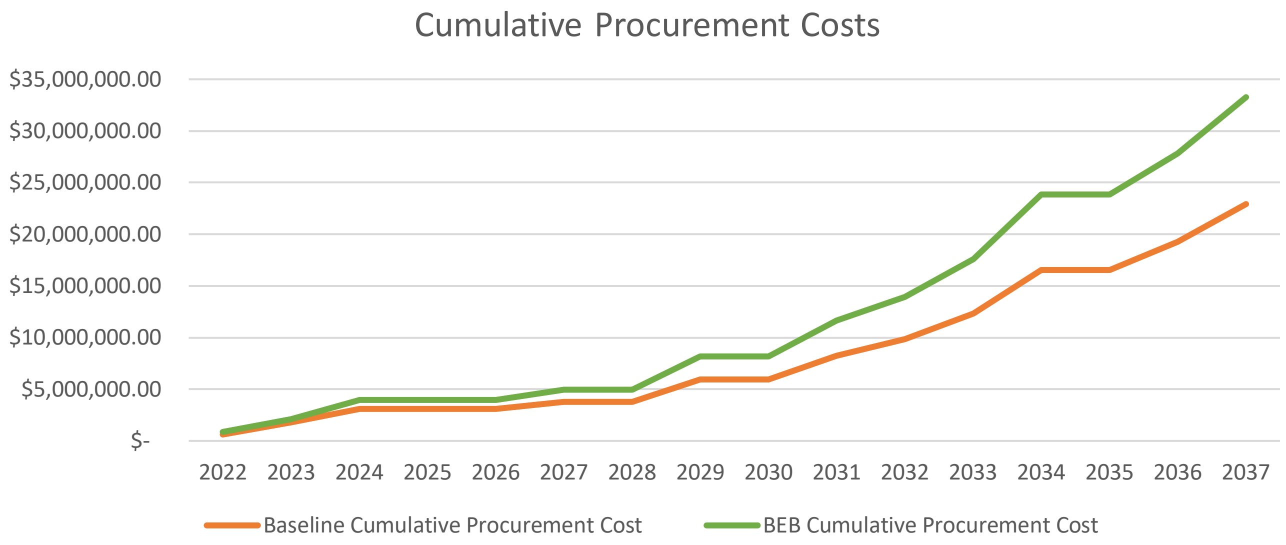
Fleet Assessment Review

NCDOT ZEB Transition Targets



- 50% Transition by 2030 is not feasible based on current replacement schedule
  - ***Requires early (< 500,000mi) replacements***
  - *Requires on-route charging to support*
    - *Projections show not enough depot-feasible blocks by 2030*
    - *Following current procurement, on-route charging not needed*
- 100% Transition by 2050 is feasible
  - 35' buses
  - Depot only charging

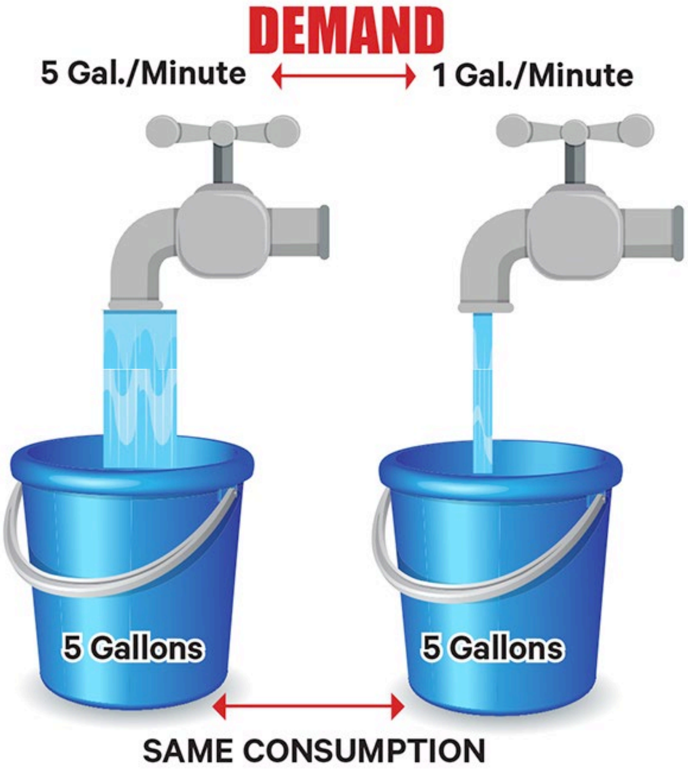
Vehicle Procurement Costs



Scenario	Cumulative Procurement Cost (2022-2037)	2050 Total Fleet ZEB
Baseline Cost	$ 22,939,608	0%
BEB Transition Cost	$ 33,261,458	100%

AppalCart Fuel Assessment

Demand vs Energy



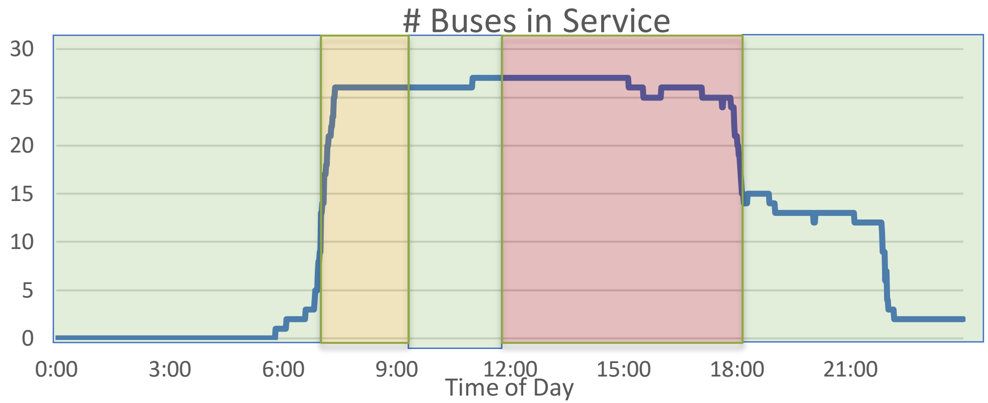
https://www.slvrec.com/rate-education-five-gallon-bucket-example-0

Demand is a **rate** (gal/min or kW)
Consumption is a **volume** (gal or kWh)

Electricity Bills consist of:

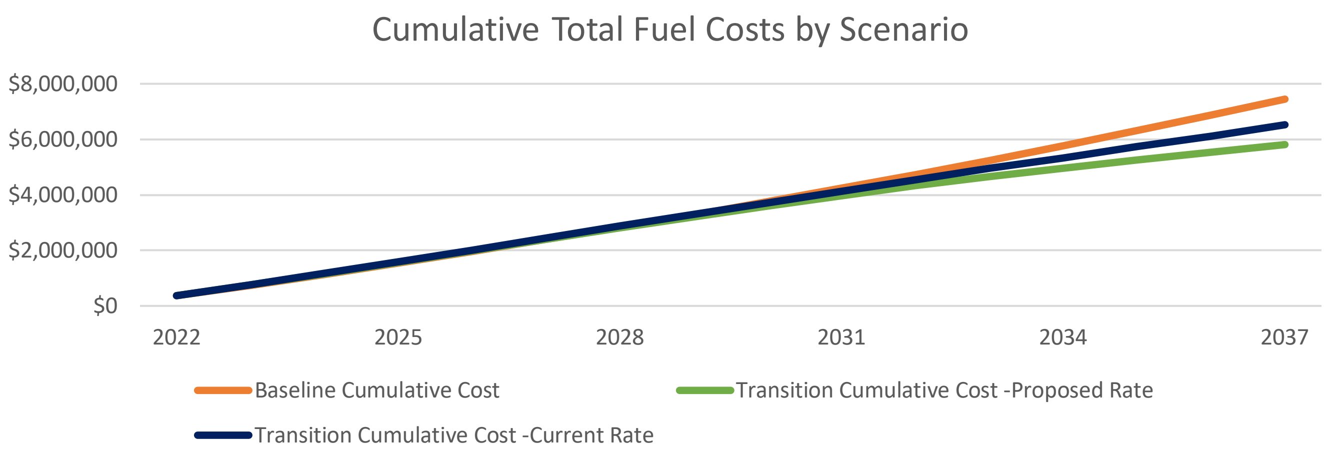
- "Demand" cost
  - Month's fastest draw of power (kW)
- "Energy" cost
  - Total amount consumed (kWh)

Buses in Service vs. Time of Use Rates



- Critical Peak Hours:
  - Monday – Friday from noon to 6:00 P.M. during the months of June through September, excluding July 4th and Labor Day
- On Peak Hours:
  - Monday – Friday from 7:00 a.m. to 9:00 a.m. during the months of November through March, excluding Thanksgiving Day, Christmas Day, and New Year's Day 2. Monday – Friday from 3:00 p.m. to 6:00 p.m. during the months of April, May, and October, excluding Memorial Day
- Off-Peak Hours:
  - All other times

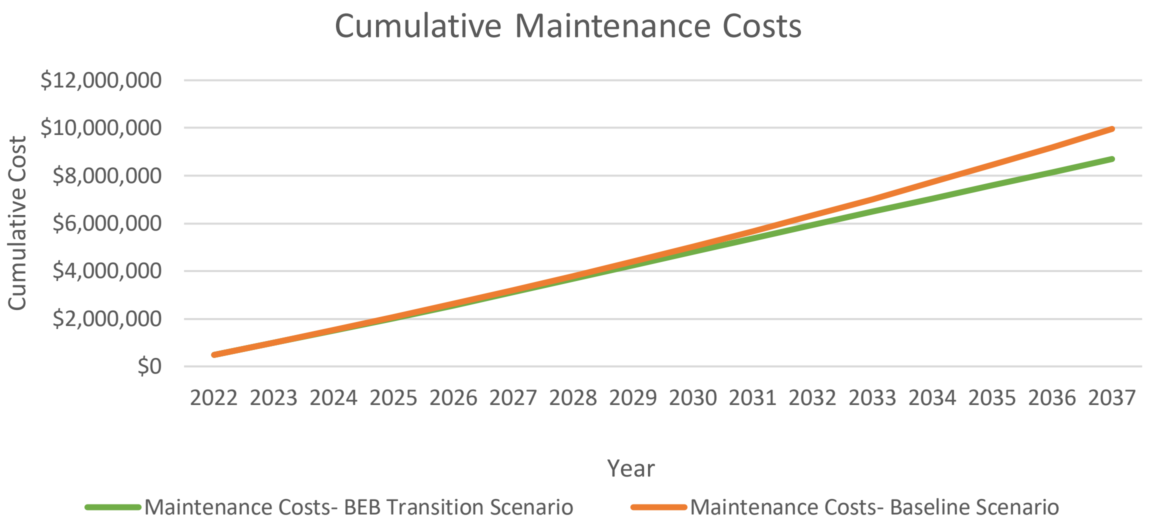
Cumulative Fuel Cost Summary



Scenario	Cumulative Cost (2022-2037)
Baseline	$ 7,444,198
Transition- *Current Rate*	$ 6,541,171
Transition- *Proposed Rate*	$ 5,798,534
2022-2037 Fuel Savings	$ 1,645,664

AppalCart Maintenance Assessment

Cumulative Maintenance Cost Summary



Scenario	2022-2037 Cumulative Cost
Baseline	$ 9,964,338
Depot Only	$ 8,684,733
Potential Maintenance Savings (2022-2037)	***$ 1,279,605***

AppalCart Facilities Assessment

Facilities Cost Assumptions

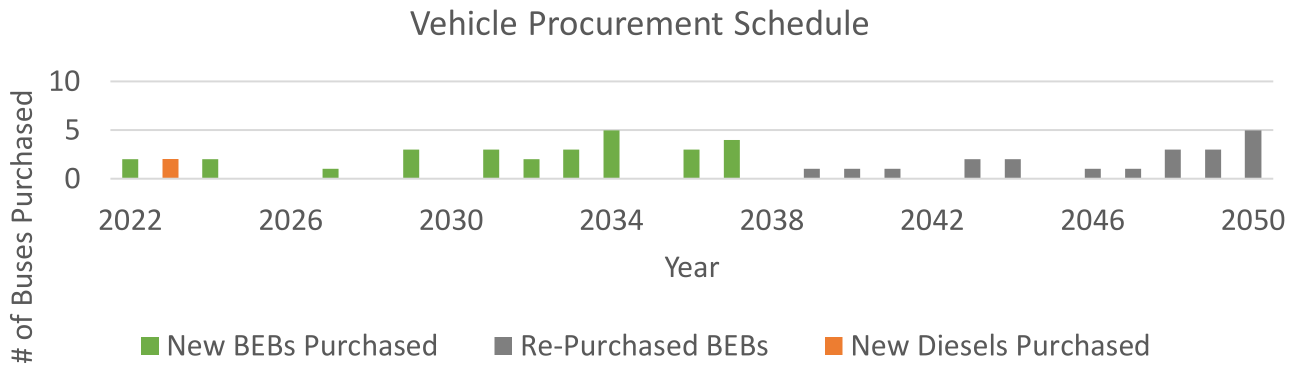
AppalCART cte

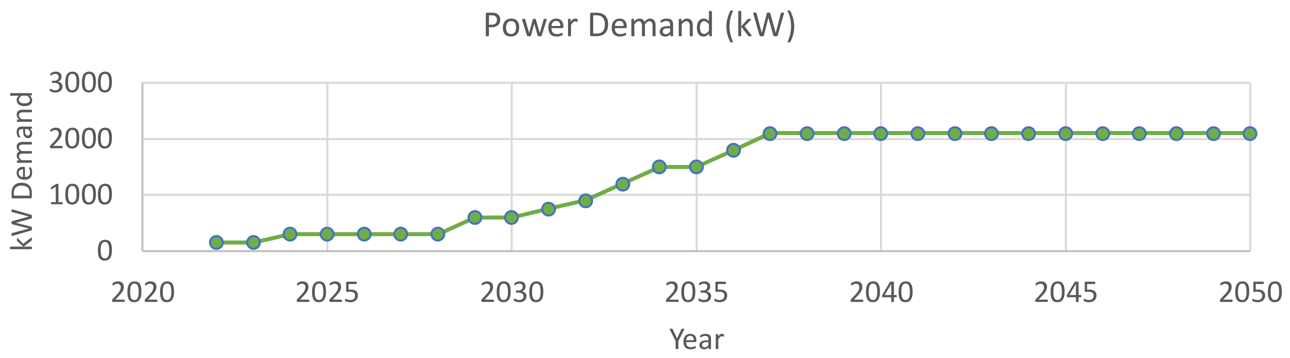
Plug-In Style Infrastructure	Cost	Description/Unit
Electrical Upgrades (Panel/switchgear, trenching/patchwork, etc.)	$300,000	For initial work (first installation)
	$50,000	For additional work (per additional build)
Contingency	20%	on project costs
Design Oversight	7%	on project costs and contingency
Dispenser and Cable Reel	$25,000	each
Dispenser Installation	$5,000	each
Infrastructure Planning	$200,000	For initial work
150 kW Charger	$100,000	each
Charger Installation	$5,000	each
1.44 MW Charging Cabinet	$667,500	90-180kWh DPS, 16 charge points with dynamic power sharing; cost from Proterra Low-No 2022 estimate

Source:

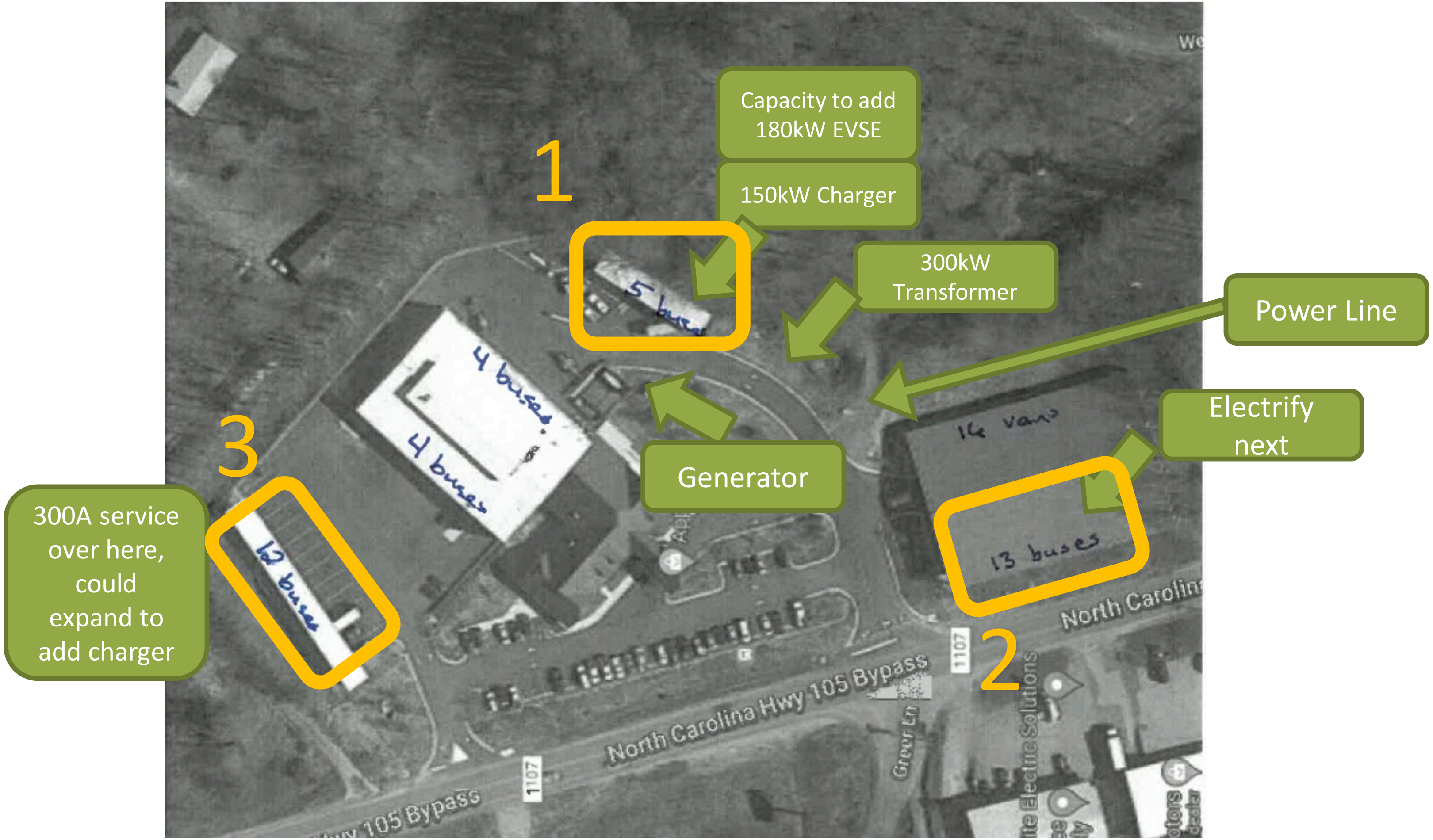
Cost assumptions are based on industry averages.

Vehicle Procurement and Power Demand Review



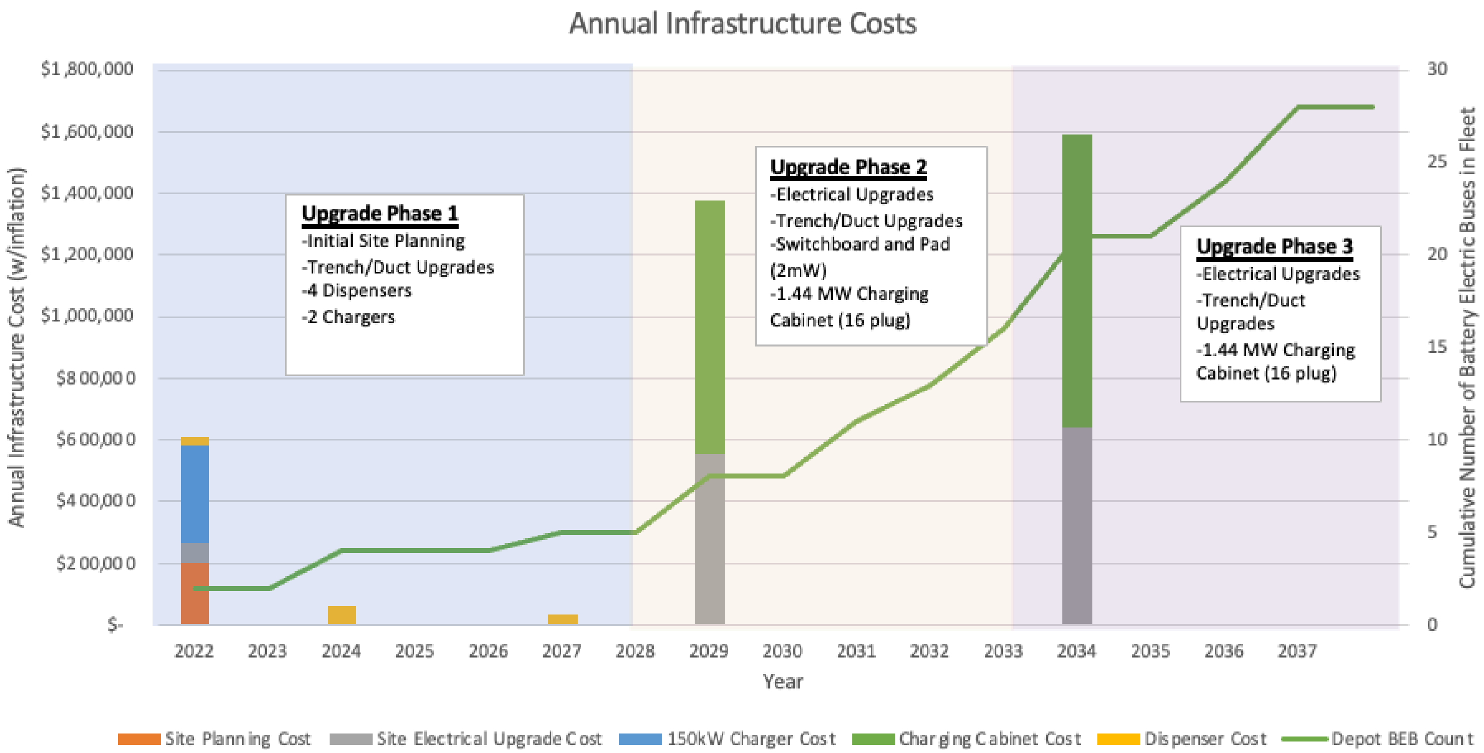


Site Designs and Upgrades



Annual Facilities Cost

- BEB Depot-Only Charging



AppalCart Total Cost of Ownership

TCO Assumptions Review

AppalCART

cte

Fleet Cost Assumptions

ICE Vehicle Type	Procurement Cost Estimate (Per Mile)
Diesel Bus	$ 593,000[1]
Electric Bus	$ 874,833[2]

- Initial 2022 cost; subsequent estimates include inflation rates
- Inflation rate of 3% from 2022-2050

Source:

[1] AppalCART provided data.

[2] AppalCART provided data for 2022 purchase.

Maintenance Cost Assumptions

ICE Vehicle Type	Maintenance Cost Estimate (Per Mile)
Diesel Bus	$ 0.69 [3]
Electric Bus	$ 0.48 [4]

Maintenance cost per mile=

$$\frac{\text{Total labor costs (in USD)} + \text{Total material costs (in USD)}}{\text{Total no. of miles}}$$

- Initial 2022 cost; subsequent estimates include inflation rates
- Inflation rate of 3% from 2022-2037

Source:

[3] $/mi calculated with agency-provided 2021 maintenance costs and long-term annual average fleet miles

[4] 30% reduction of maintenance cost for a 30'/35'/40' Diesel Bus

TCO Assumptions Review

Fuel Cost Assumptions

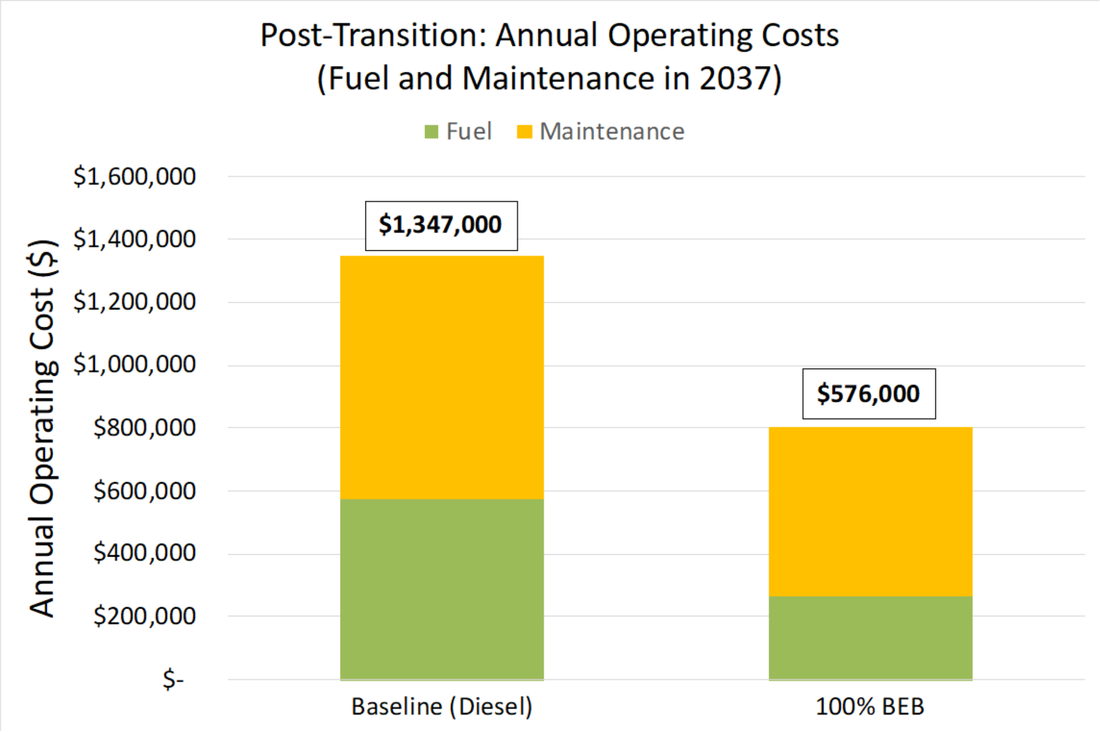
Fuel Type	Cost per unit	Notes
Diesel	$0.51/mi	• Based on AppalCART's annual fuel cost over annual mileage
Electricity- Commercial EV Rate (proposed)	Demand*: • $6.15/kW for the first 25kW • $5.18/kW for the remaining Energy: $0.0025/kWh	• Used Blue Ridge 2.2.1 -GSSC-CEV Rate Schedule
Fixed Fee	$62.87/month	• Three- phase grid service charge, per meter
Additional Assumptions		
Energy Used (kWh)	2.1 kWh/mi	• Assumes a strenuous driving efficiency without HVAC load • Source: CTE historical data
Demand (kW)	150kW per Charging Station	• 2 Buses to 1 Charging Station, average 75 kW per bus

- 3% yearly inflation increase for electricity
- EIA yearly transportation diesel fuel projection increase

Transition Cost Summary

	Transition Scenario (2022-2037)	Baseline Scenario (2022-2037)	Total Cost Difference
Fleet Assessment	$ 33,261,500	$ 22,939,600	$ 10,321,900
Fuel Assessment	$ 5,798,500	$ 7,444,200	- $ 1,645,700
Maintenance Assessment	$ 8,684,700	$ 9,964,300	- $ 1,279,600
Infrastructure Assessment	$ 3,568,700	N/A	$ 3,568,700
Total Cost of Ownership	$ 51,313,400	$ 40,348,100	**$ 10,965,300**

Post-Transition Operating Costs



Projected Operating Costs (Fuel & Maintenance) in first 100% ZEB year (2037).
2037 Dollars inflation adjusted.

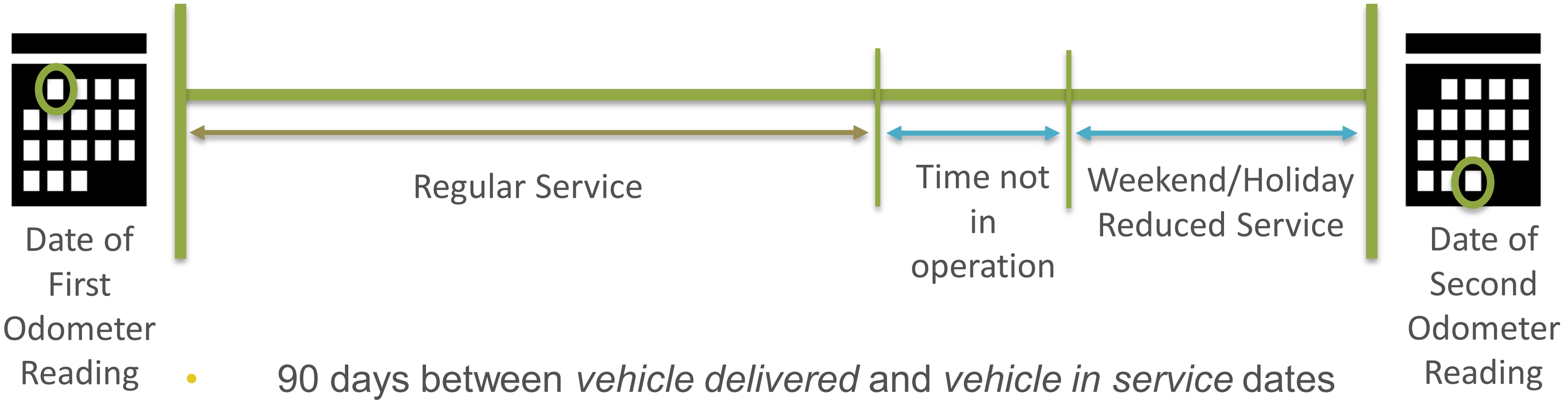
Case Study: HATS

HATS Agency Summary

- Operates in Raeford, Hoke County
- Fleet is comprised of two (2) minivans, four (4) full size vans and fifteen (15) 20-28 ft cutaways
- Service
  - Provides intra-county on-demand services
  - Routine service to inter-county medical facilities
- Mission: to provide safe and dependable transportation to the Hoke County Community and is committed to ensuring that no person is excluded from participating in the benefits of the transit services they offer

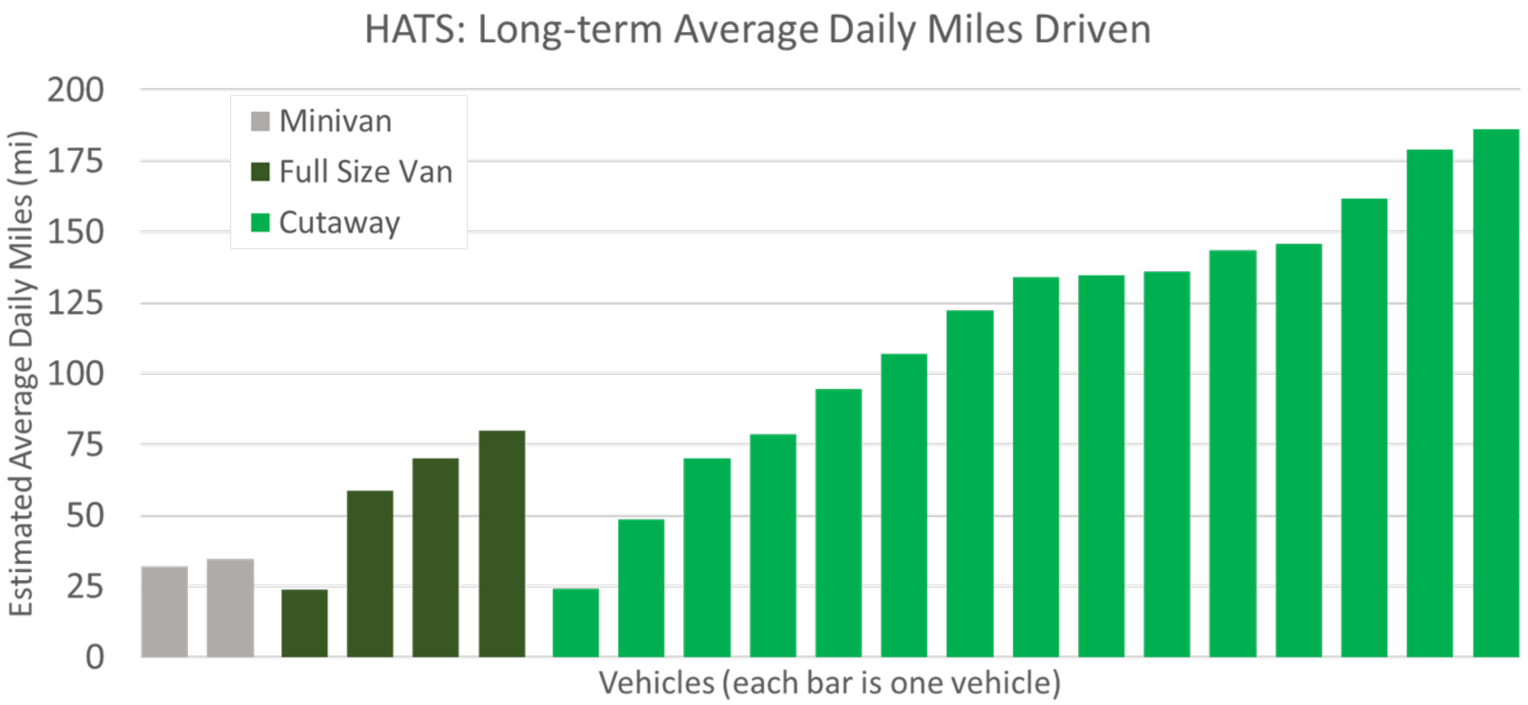
HATS Service Assessment

Odometer-Based Approach Assumptions



- 90 days between *vehicle delivered* and *vehicle in service* dates
- Time between odometer readings includes *Time not in Operation* and *Reduced Service* days
- Goal: Adjust days between odometer readings to reflect Time in Operation
- Parameters used for Analysis:
  - Time In Operation: 95% (10 operating days off per year)
  - Weekend/Holiday Reduced Service: 81% (based on federal holidays)

Odometer-based Approach Results



Results are long-term average daily miles.
Odometer-based Approach is an approximation and assumes even distribution of miles across operating days.
Does not consider energy used for extended idle times.

Strengths and Limitations of Odometer-based Service Assessment

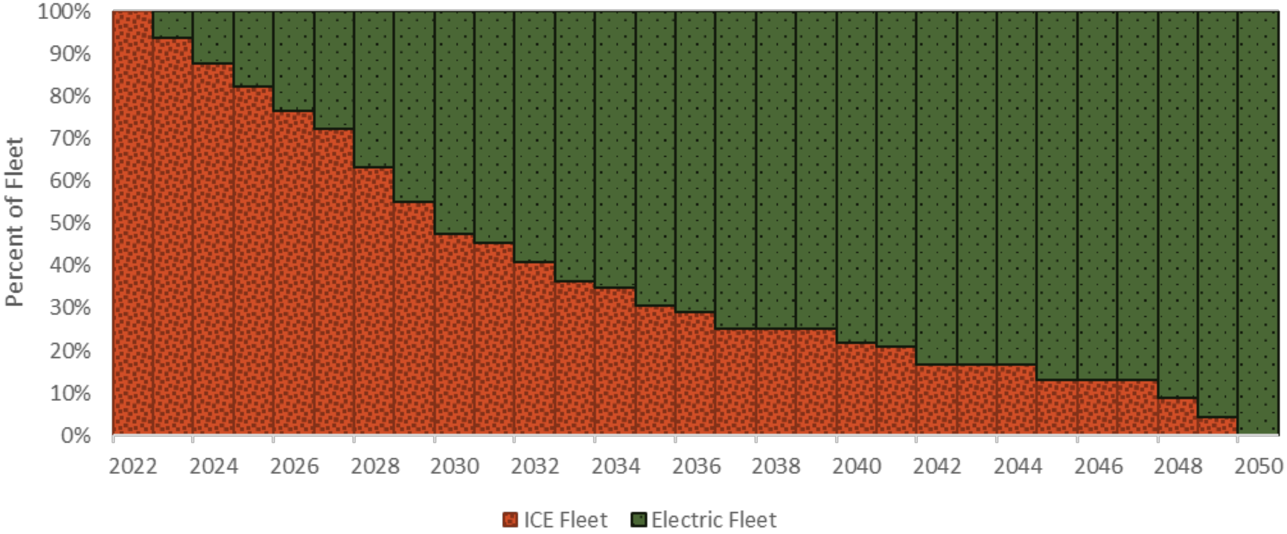
- Strengths
  - Long-term daily average miles baseline
  - Estimate for systems without fixed route service
- Limitations
  - Does not provide minimum or maximums experienced
    - Days above average will challenge battery technology
  - Daily miles dependent on service days assumptions
    - If estimate is low, daily miles will be higher

Service Assessment Assumptions

- Service Assumptions: Plan for Strenuous Case
  - 1.1 mi/kWh Strenuous Tractive Efficiency
  - 8 Hours in Service
  - 26 kW Strenuous HVAC Power
  - Depot Only Charging
  - Uses Full Service Energy Each Day
- Distribute total fleet daily miles between all vehicles
  - Results in 23 vehicles replacing the existing 15
- Replace vehicles at minimum pace to meet NCDOT goals
  - Due to current market short EV range, vehicles age out (do not mile out)
  - Assumed 10 year replacement schedule
- Market Improvement: 5% battery capacity increase every two years

HATS Fleet Assessment

Fleet Composition By Year



Year	% Electric
2025	18%
2030	52%
2040	78%
2050	100%

Fleet Assessment Summary

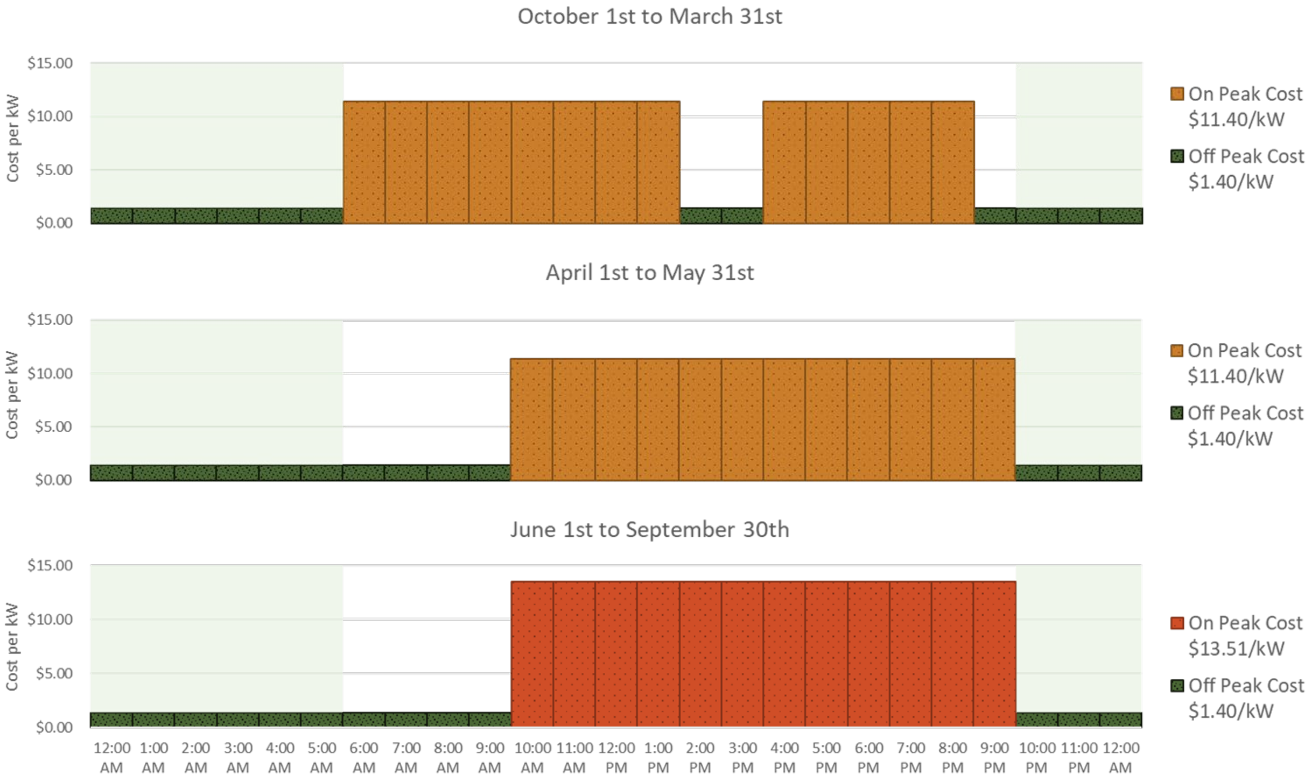
- 8 Hours of operation not feasible at 20°F
  - HVAC load exceeds current market battery capacity
- Solutions to increase BEV Service:
  - Mid-day Charging
  - Diesel Fired Cabin Heaters
  - Use Dial-a-Ride Best Practices
- Increasing fleet size from 15 to 23 allows NCDOT goals to be met under strenuous conditions for all duty cycles
  - Assumptions allow for shifting mileage between vehicles to maximize electric miles travelled

HATS Dial-A-Ride Best Practices

- Range Limitations
  - Less range than a day of operation
- Range Prediction Limitations
  - Small battery & imprecise predictions
- Seasonal Variations
  - Fixed route: plan around strenuous condition
  - Dial-a-ride: can factor seasonal variations
- Charging Limitations
  - Current models need an hour charge session to increase range by a useful amount
- Fitting Pre-Scheduled Dial-a-Ride Service
  - Use on a known route (such as inter-county service)
  - Keep range limit in mind when pre-scheduling local dial-a-ride service
- Idle Time
  - HVAC use is large consumer of energy.
  - Educate drivers on how hours in operation impacts battery use

HATS Fuel Assessment

Time of Use Breakdown: Demand

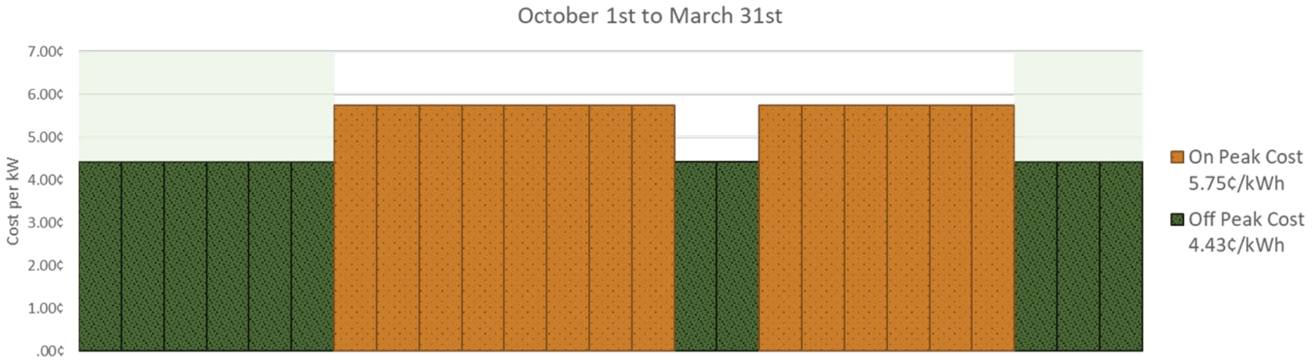


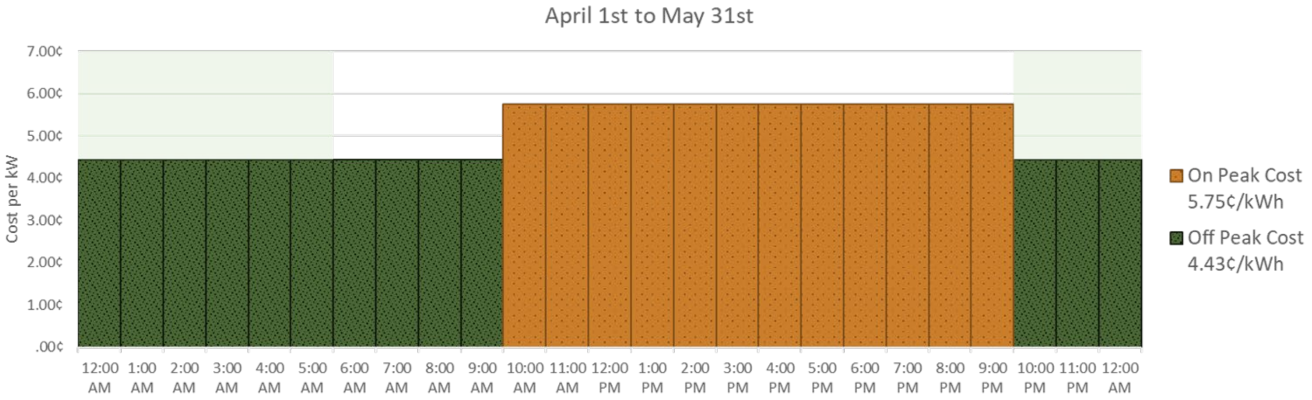
Notes:

10:00 pm to 6:00 am is considered Off-Peak regardless of the time of year

Demand is 7 to 9 times more expensive during On-Peak hours depending on the time of year

Time of Use Breakdown: Energy



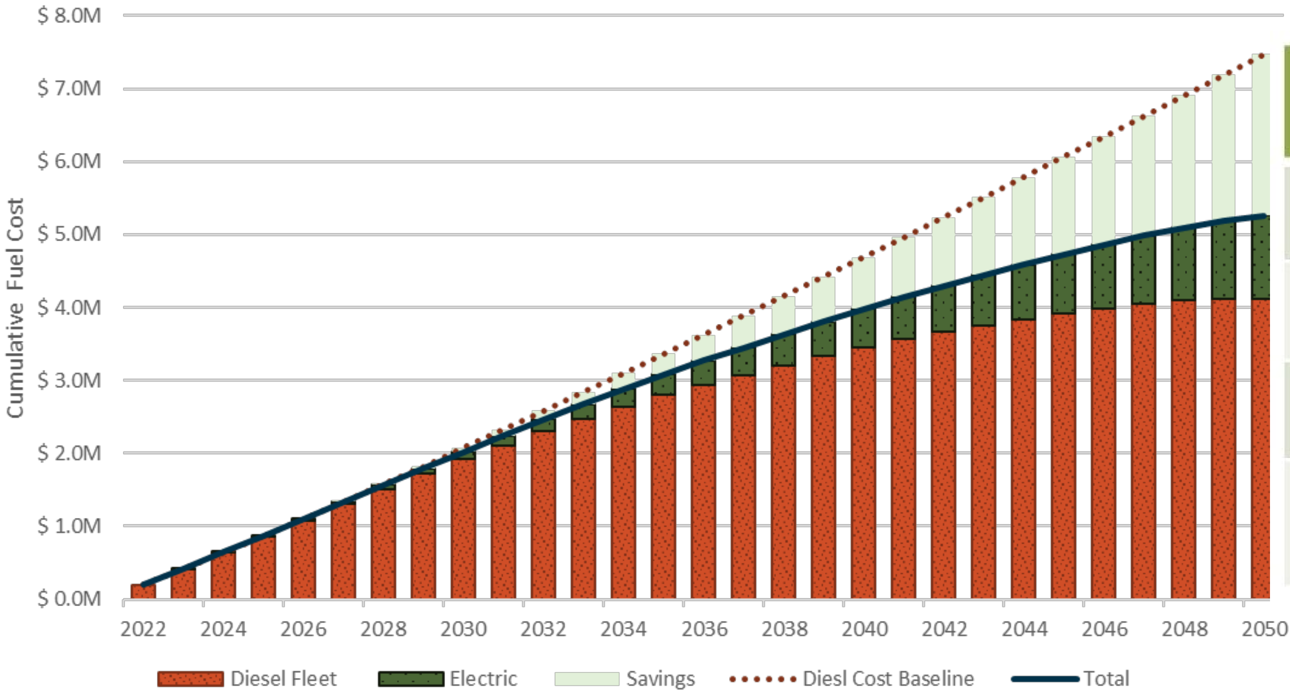


Notes:

10:00 pm to 6:00 am is considered Off-Peak regardless of the time of year

Energy is 30% more expensive during On-Peak Hours

Cumulative Fuel Cost



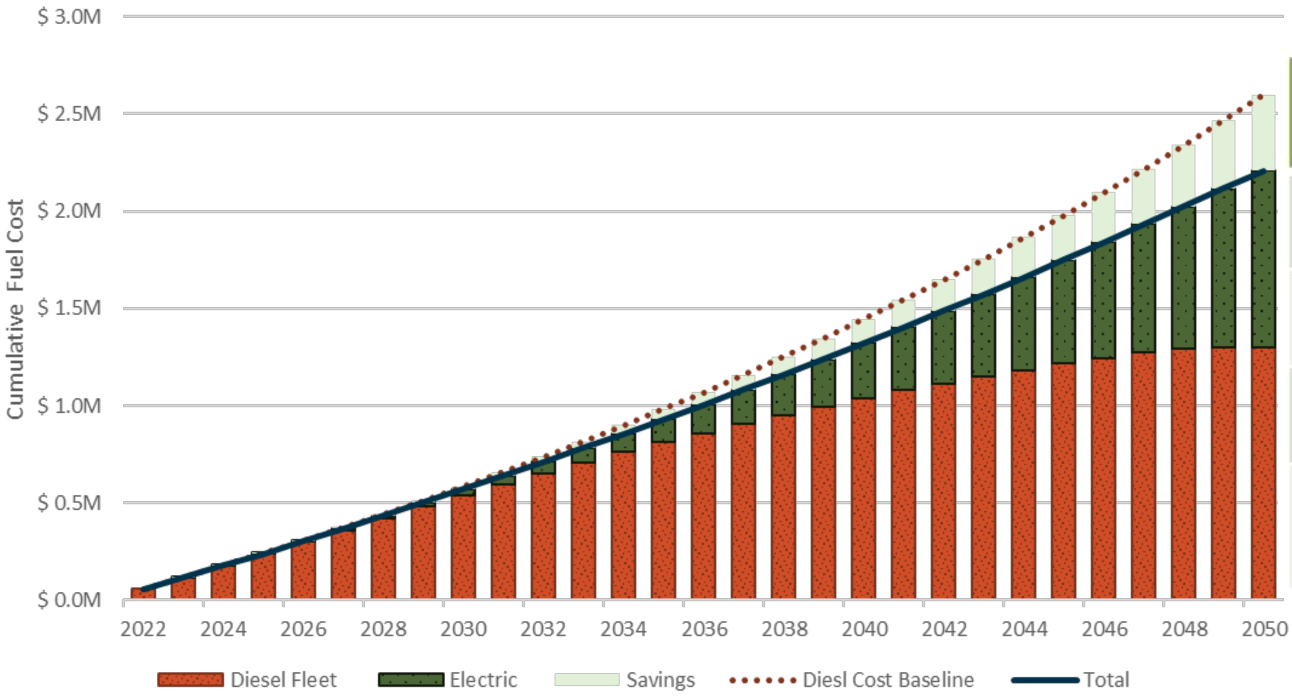
Year	Cumulative Savings
2025	$0
2030	$51,300
2040	$708,800
2050	$2,210,400

Conclusion

- Time-Of-Use rates incentivize off-peak charging
  - CTE analysis shows that current service capacity can accommodate
- Increased electric fleet mileage lowers cost per mile
- Financial Benefits:
  - CTE Transition Plan estimates up to $2,210,400 fuel savings realized from 2022 to 2050
  - Annual fuel savings up to $207,000 after transition
- CTE recommends maintaining an ongoing relationship with the utility to find the best rate
  - Future rates may include further incentives for Off-Peak operation
  - EV specific rates may be created

HATS Maintenance Assessment

Cumulative Maintenance Cost



Year	Cumulative Savings
2025	$1,000
2030	$13,300
2040	$121,300
2050	$388,800

Maintenance Assessment Conclusions

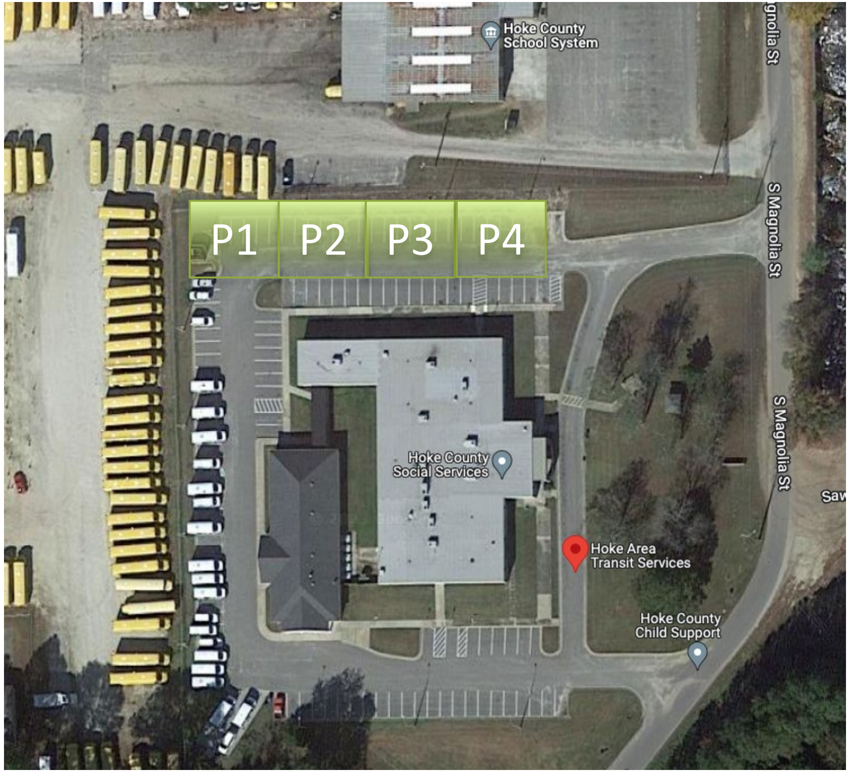
- Increased electric fleet mileage lowers cost per mile
  - Electric fleet offers a 30% reduction in maintenance costs per mile
  - Assumes all maintenance is odometer based
- Financial Benefits:
  - CTE Transition Plan estimates up to $388,800 in maintenance savings realized from 2022-2050
  - Annual fuel savings up to $39,400 after transition

HATS Facilities Assessment

Charger Location and Procurement Schedule

NORTH CAROLINA HOKE COUNTY

cte



Phase	Year	Number of Chargers Procured
1	2023	2
2	2025	4
3	2030	4
4	2040	2
Total		12

2025 5% ZEV
2030 50% ZEV
2040 75% ZEV
2050 100% ZEV

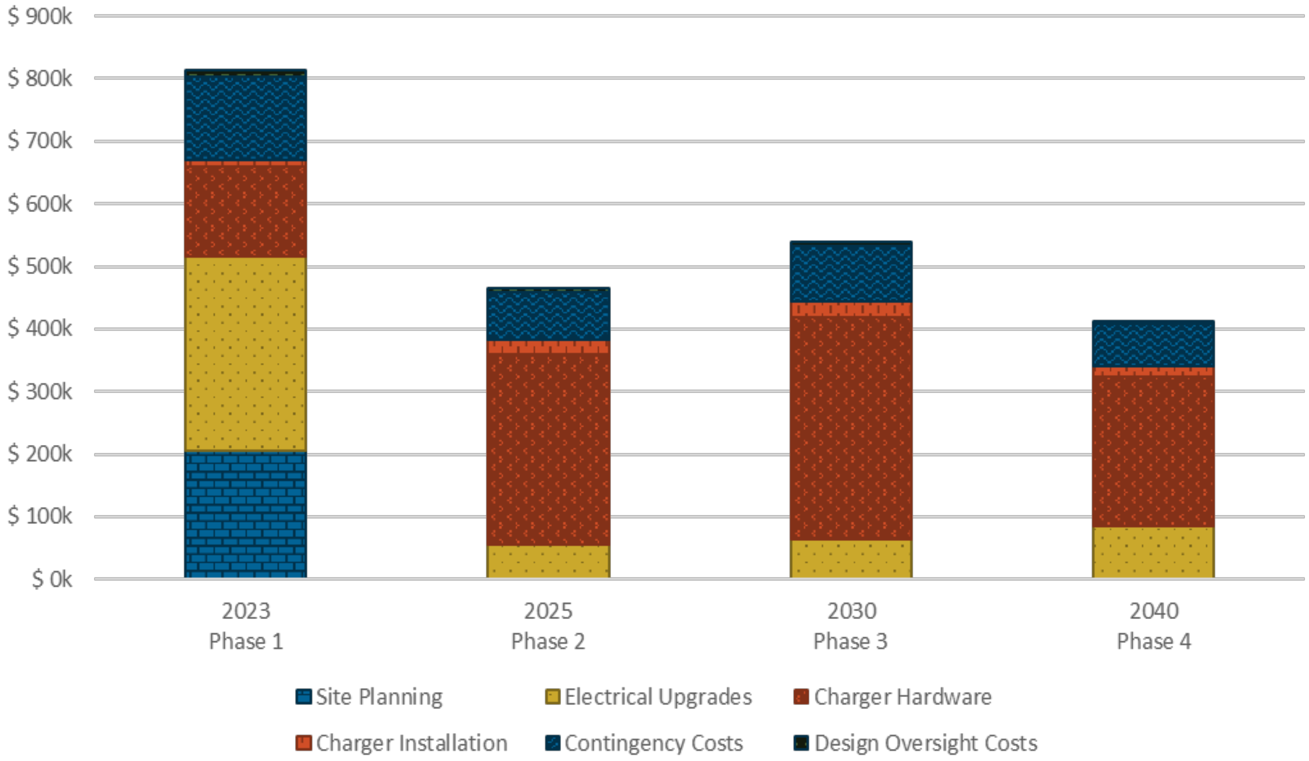
Facilities Cost Assumptions

Plug-In Style Infrastructure	*Cost*	*Description/Unit*
Electrical Upgrades (Panel/switchgear, trenching/patchwork, etc.)	$300,000	For initial work (first installation)
	$50,000	For additional work (per additional build)
Contingency	20%	on project costs
Design Oversight	7%	on project costs and contingency
Infrastructure Planning	$200,000	For initial work
60 kW Charger	$70,000	each
Charger Installation	$5,000	each
Inflation Rate	3%	Per year

Source:

Cost assumptions are based on industry averages.

Facilities Costs By Phase



Year	Total Costs
2023	$813,000
2025	$464,000
2030	$538,000
2040	$413,000
Total	$2,229,000

HATS Total Cost of Ownership

TCO Assumptions Review

Fleet Cost Assumptions

Vehicle Type	Procurement Cost Estimate (Per Vehicle)
Diesel Cutaway	$ 75,000[1]
Electric Cutaway	$ 250,000[2]

- Initial 2022 cost; subsequent estimates include inflation rates
- Inflation rate of 3% from 2022-2050

Source:

[1] HATS provided data

[2] CTE market research 2022

Maintenance Cost Assumptions

Vehicle Type	Maintenance Cost Estimate (Per Mile)
Diesel Cutaway	$ 0.13[3]
Electric Cutaway	$ 0.09[4]

Maintenance cost per mile=

$$\frac{\text{Total labor costs (in USD)} + \text{Total material costs (in USD)}}{\text{Total no. of miles}}$$

- Initial 2022 cost; subsequent estimates include inflation rates
- Inflation rate of 3% from 2022-2050

Source:

[3] $/mi calculated with agency-provided 2021 maintenance costs and long-term annual average fleet miles

[4] 30% reduction of maintenance cost based on CTE historical data

TCO Assumptions Review

Fuel Cost Assumptions

Fuel Type	Cost per unit	Notes
Diesel	$0.47/mi	• Based on HATS estimated annual fuel cost over estimated annual mileage
Electricity	Demand: $1.40/kW Energy: $0.04/kWh Other Charges - $42.90/month	• Rates for off-peak usage[1] • See rate schedule document for more details
Additional Assumptions		
Energy Used (kWh)	2.9 kWh/mi	• Average across all routes • Assumes a strenuous driving efficiency with 8 hours of strenuous HVAC load • Source: CTE historical data
Demand (kW)	60 kW per Charging Station	• 2 Buses to 1 Charging Station, average 30 kW per bus
Annual Price Change	U.S. Energy Information Administration Annual Projections to 2050	• See following slide

All costs displayed in 2022 dollars
[1]See Time of Use Breakdown slides for more information on how rates vary with time

Transition Cost Summary

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	Transition	Baseline	Total Cost Difference
Fleet	$ 24,690,000	$ 5,900,000	$ 18,780,000
Infrastructure	$ 2,230,000	N/A	$ 2,230,000
Fuel	$ 5,260,000	$ 7,470,000	- $ 2,210,000
Maintenance	$ 2,210,000	$ 2,600,000	- $ 390,000
Total Cost of Ownership	$ 34,380,000	$ 15,970,000	**$ 18,410,000**

Wrap-Up

- AppalCART can feasibly convert their current diesel fleet to 100% BEBs by 2037 following their current projected procurement schedule.
- To achieve this goal, CTE projects an additional $13.9 million investment in capital for BEBs and subsequent charging infrastructure as compared to AppalCART's baseline cost of not transitioning to ZEBs over the same time period.

Wrap-Up

- HATS can feasibly convert their current fleet to 100% BEVs by 2050 by increasing their fleet size from 15-23.
- To achieve this goal, It will be necessary to invest an additional $21 million in capital for BEVs and subsequent charging infrastructure as compared to HATS' baseline cost of not transitioning to ZEVs over the same time period.

Additional Considerations

- On-Route Charging Options
  - Enables earlier transition on energy-intensive blocks
- Resilience and Redundancy
  - Backup generator
- Workforce Development
  - Maintenance Training
  - Operator Training
  - First Responder Training
- Revisit ZEB Transition Plan every ~2 years
  - ZEB technology and market is developing rapidly
  - Battery energy storage capacity and charge rates expected to improve

Questions