INTERcity
TRANSIT

Zero-Emission Fleet Analysis

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HATCH LTK
Positive Change for the Next Century

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Executive Summary

Intercity Transit (Intercity) contracted the Center for Transportation and the Environment (CTE) to conduct a fleet analysis for Intercity's fixed-route, Dial-A-Lift, Vanpool, and non-revenue services that considers the feasibility of transitioning to zero-emission technology by 2050. Zero-emission technologies considered in this study include both battery electric buses (BEBs) and hydrogen fuel cell-electric buses (FCEBs). CTE was supported in this effort by Nelson/Nygard and Hatch LTK.

CTE worked closely with Intercity's staff throughout the project to develop the approach, define the assumptions, and confirm the results of the analysis. For the non-revenue vehicle fleet, a full analysis was not conducted and focus was placed on the fixed route, Dial-A-Lift, and Vanpool fleets for this report; however, a brief summary of the zero emission non-revenue vehicle market is provided in Section 9. The approach for the study is based on the development and analysis of five transition scenarios:

- **Baseline:** Intercity's current fixed-route service is operated with diesel vehicles; No changes to Intercity's current procurement schedule during the transition timeline (2023 – 2050).
- **BEB Depot Charging Only:** Transitions Intercity's existing vehicles to BEBs based on block feasibility assuming overnight depot charging only.
- **BEB Depot and On-Route Charging:** Transitions Intercity's existing vehicles to BEBs based on block feasibility assuming overnight depot charging and on-route charging.
- **Mixed Fleet (BEB/FCEB):** Transitions Intercity's existing vehicles to a mixed FCEB and BEB fleet, with BEBs utilizing overnight depot charging. Blocks not feasible with BEBs utilizing overnight depot charging are transitioned to FCEBs.
- **FCEB Only Fleet:** Transitions Intercity's existing vehicles to FCEBs based on block feasibility.

The Baseline scenario assumes that no change is made from currently planned technologies and is used to evaluate impacts and changes considered for the other zero-emission technologies. Each scenario uses a set of assumptions for improvements in battery storage capacity and efficiency, ultimately yielding improvements in bus range.

The underlying basis for the assessment is CTE's ZEB Transition Planning Methodology. CTE first applied the methodology to conduct a Service Assessment on Intercity's routes and blocks to assess efficiency, energy consumption, and range. CTE analyzed the feasibility and energy consumption of operating Intercity's current blocking using BEBs and FCEBs. CTE collected blocking and bus assignment information and evaluated the potential year-to-year changes in their blocking approach to ensure the results are reflective of future operations. The analysis was conducted using a screening model developed by CTE based on years of observed operations of ZEBs in a variety of operational scenarios. CTE's screening model utilizes CTE's BEB and FCEB operational database to predict the energy consumption and range of various classes of zero-emission buses, and industry research to gauge future BEB/FCEB technology improvements that would influence feasibility and energy use. The model considers the variability of range resulting from differences in route type, loading, temperature conditions, driver behavior, and duty cycle. Inputs to the model specific to Intercity included duration and mileage of each current and future block, and anticipated operational conditions. The model also reflects projected changes in feasibility in future years as anticipated improvements in bus efficiency and energy storage capacity are realized.

The results of this analysis include minimum and maximum anticipated energy consumption and range on each service block with consideration for weather conditions, use of auxiliary fossil-fueled heating systems, duty cycle, and battery degradation scenarios specific to Intercity's blocking approach, fleet composition, and operating environment.

Once estimates for vehicle efficiency, range, and energy consumption were established, CTE completed the following assessments to develop cost estimates for each transition scenario.

1. Service Assessment
2. Fleet Assessment
3. Fuel Assessment
4. Maintenance Assessment
5. Facilities Assessment

These assessment results yield a total cost of ownership for each transition scenario.

The total cost of ownership over the transition period (2023 – 2050) for Intercity's fixed route fleet is summarized in the table below.

Total Cost of Ownership for ZEB Transition (2023-2050) for Intercity's Fixed Route Fleet

Category	Baseline	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet	FCEB Only Fleet
Fleet	$270.3M	$408.8M	$468.6M	$477.5M	$493.5M
Fuel	$109.3M	$71.2M	$50.5M	$71.3	$102M
Maintenance	$95.7M	$81.5M	$74M	$78M	$88.2M
Infrastructure	$-	$10.6M	$21.6M	$17.7M	$11.6M
Total	**$475.3M**	**$572M**	**$614.8M**	**$646.5M**	**$695.4M**
Compared to Baseline	$-	+$96.7M	+$139.5M	+$171.2M	+$220.1M
% of Blocks Achievable with ZEBs by 2050	0%	83%	100%	100%	100%

The total cost of ownership over the transition period (2023 – 2050) for Intercity's Dial-a-Lift fleet is summarized in the table below.

Total Cost of Ownership for ZEB Transition (2023-2050) for Intercity's Dial-a-Lift Fleet

Category	Baseline	BEB Overnight Charging Only	BEB Overnight and Midday Charging	Mixed Fleet	FCEB Only Fleet
Fleet	$75.3M	$79.2M	$79.3M	$80.3M	$111.7M
Fuel	$13.9M	$8.9M	$8.7M	$9.1M	$16.3M
Maintenance	$38.6M	$32.8M	$32.6M	$32.7M	$34.0M
Infrastructure	$-	$2.5M	$2.6M	$4.8M	$1.9M
Total	$127.8M	$123.4M	$123.1M	$126.8M	$163.9M
Compared to Baseline	$-	-$4.4M	-$4.6M	-$951k	+$36.1M
% of Blocks Achievable with ZEBs by 2050	0%	96%	100%	100%	100%

Intercity's largest van service, Vanpool, will face a difficult challenge with electrification, as these vans are parked overnight at private residences instead of the centralized Intercity depot, making fueling a difficult task. Determining how the Vanpool vehicles can be fueled will be one of the biggest obstacles that Intercity will need to address before the vanpool fleet can be feasibly transitioned to zero-emission technology. The Community Van and Village Van vehicles typically stay at Intercity's Pattison Street facility overnight, so charging at the depot similar to the Dial-A-Lift service is feasible.

Overall, ZEB technologies are in a period of rapid development and change and all available options will require significant investment in facilities and infrastructure. The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. As Intercity continues to move towards a zero-emissions fleet, it will be important to consider and plan for operational adjustments around operations, maintenance, planning and scheduling, administration, and customer sentiment. It is expected that the results from this analysis will be used by Intercity Transit Leadership and the Board of Directors to identify an approach for fleet electrification. Once the approach has been determined, a formal Zero Emission Transition and Implementation Plan will be prepared.

Section 1 - Introduction

Intercity Transit (Intercity) is a municipal corporation offering public transit services to residents and workers in the Public Transportation Benefit Area that includes Olympia, Lacey, Tumwater, and Yelm in Washington state. This service area extends across an area spanning 101 square miles and includes 22 bus routes. However, during the COVID-19 global pandemic some of Intercity's fixed route and corresponding Dial-A-Lift service was suspended. Intercity plans to restore service to these routes and also expects growth and expansion in the coming years. Along the fixed-route service, customers can access connections to neighboring transit systems such as Pierce, Grays Harbor, and Mason. Intercity also provides a door-to-door service for individuals with disabilities, vanpool and specialized van programs. The vanpool services are offered to groups of three or more commuters who share a commute and vanpool participants pay a low monthly fare that covers operating costs. The Dial-A-Lift service is compliant with the Americans with Disabilities Act and provides door-to-door transportation to riders with disabilities. All of Intercity's buses are equipped with lifts and can accommodate wheelchairs [1].

Intercity contracted the Center for Transportation and the Environment (CTE) to conduct a fleet analysis for Intercity's fixed-route, dial-a-lift, and vanpool services that considers the feasibility of transitioning to zero-emission technology by 2050. CTE was supported by Nelson\Nygaard and Hatch in completing this analysis. Zero-emission technologies considered in this study include both battery-electric buses (BEBs) and fuel cell-electric buses (FCEBs). BEBs and FCEBs have similar electric drive systems that feature a traction motor powered by a battery. The primary difference between BEBs and FCEBs, however, is the amount of battery storage and how the batteries are recharged. The energy supply in a BEB comes from electricity provided by an external source, typically the local utility grid, which is used to recharge the batteries. The energy supply for an FCEB is completely on-board, where hydrogen is converted to electricity using a fuel cell. The electricity from the fuel cell is used to recharge the batteries. Illustrated below is the electric drive components and energy source for a BEB and FCEB.

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[1] https://www.intercitytransit.com/about-us

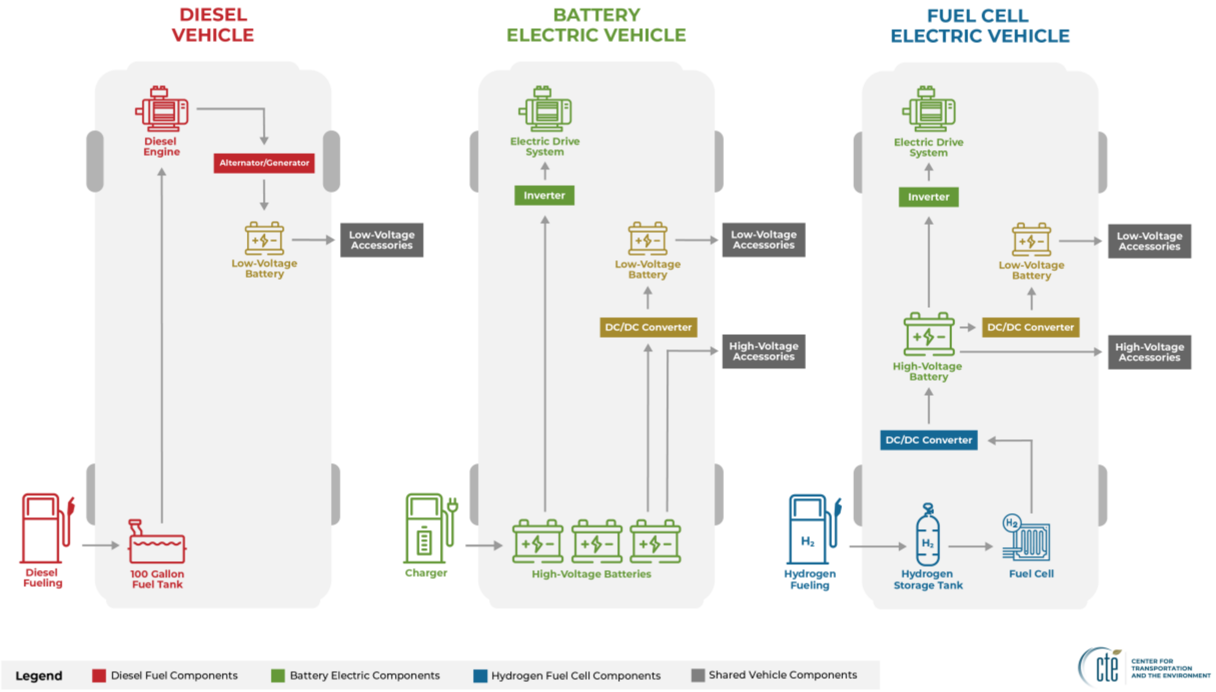

Figure 1: Schematic of ZEB Technologies

There are considerations and limitations associated with each technology. One of the primary limitations of BEBs is overall energy storage capacity. Although BEBs are approximately four times more efficient than diesel vehicles, the total amount of energy that can be stored on board without adding excessive weight is still less than diesel. That means that using current technology, the overall BEB range on one charge is less than the range of a diesel vehicle on one tank of fuel. Range limitations can be mitigated by the use of the appropriate charging technologies and strategies, and this is a very important element in the planning for any BEB deployment, especially when considering a full fleet transition.

Furthermore, battery and charging technologies are changing at a rapid pace. The trends toward higher battery energy densities and increasingly sophisticated software-based charge management methodologies are expected to improve the range of BEBs to levels more comparable with traditional diesel vehicles over time. New charging vendors continue to enter the marketplace, offering various charger configurations and charge rates that help agencies customize a charging strategy and reduce operational risk associated with BEB deployments. Regardless of which battery technology or chemistry is utilized, all high voltage vehicle batteries in the market today degrade over time. Therefore, the impact on performance over time and associated battery warranties should be reviewed to optimize operations and further reduce risk.

Finally, lifecycle costs of electricity and overall infrastructure represent significant investments. Charging an entire fleet of buses can require a substantial real estate footprint and associated upfront cost to purchase and install the required equipment, not to mention the appropriate training and ongoing operational requirements.

There are similar considerations in FCEB deployment in that the infrastructure footprint can be substantial and since battery technology is also utilized there are similar concerns with degradation and end-of-life performance. Current FCEBs do have a range that is longer than BEBs and more similar to traditional diesel or CNG buses, so theoretically there will be less operational risk due to fueling strategies when incorporating FCEBs into a fleet. However, both the upfront cost of FCEB vehicles and the cost of fuel are currently higher than with their BEB counterparts (hydrogen vs. electricity). Finally, there are still a limited number of demonstrations of FCEBs to learn from partly because BEB charging technology is easier to scale and deploy to small fleets (which has been a large part of BEB deployment activity to date).

This analysis reflects the state of technology at the time that it was prepared whereas the transition to a full zero-emission bus fleet is expected to take decades to complete. Furthermore, it reflects an abbreviated version of CTE's transition planning methodology. Additional data collection and modeling could be used to create more accurate predictions to aid Intercity's planning for future service and transition to zero emission technologies. Intercity will use the results of this analysis to prepare a Zero-Emission Transition Plan to guide the process for a full-fleet transition to zero-emission technology. Throughout the transition period, the state of technology development, costs, regulatory environment, service requirements, and supply chain will all evolve, requiring Intercity to reassess and update the Zero-Emission Transition Plan and ensure that Intercity continues to meet their mission in the most effective and efficient way possible.

Section 2 - Transition Planning Methodology

This analysis was completed using a modified version of CTE's Transition Planning Methodology. The standard transition planning methodology is a complete set of analyses used to inform agencies in converting their fleets to zero-emission and consists of data collection, analysis and assessment stages; these stages are sequential and build upon findings in previous steps. However, in this fleet assessment, the analysis was conducted using a screening model developed by CTE. This screening model is based on years of observed operations of ZEBs in a variety of operational scenarios. CTE's screening model utilizes CTE's BEB and FCEB operational database to predict the energy consumption and range of various classes of zero-emission buses, and industry research to gauge future BEB/FCEB technology improvements that would influence feasibility and energy use. The model considers the variability of range resulting from differences in route type, loading, temperature conditions, driver behavior, and duty cycle. The agency-specific inputs to the model include duration and mileage of each current and future block, and anticipated operational conditions. The model also reflects projected changes in feasibility in future years as anticipated improvements in bus efficiency and energy storage capacity are realized.

Steps specific to this screening level fleet assessment are outlined below:

1. Planning and Initiation
2. Service Assessment
3. Fleet Assessment
4. Fuel Assessment
5. Maintenance Assessment
6. Facilities Assessment
7. Total Cost of Ownership Assessment

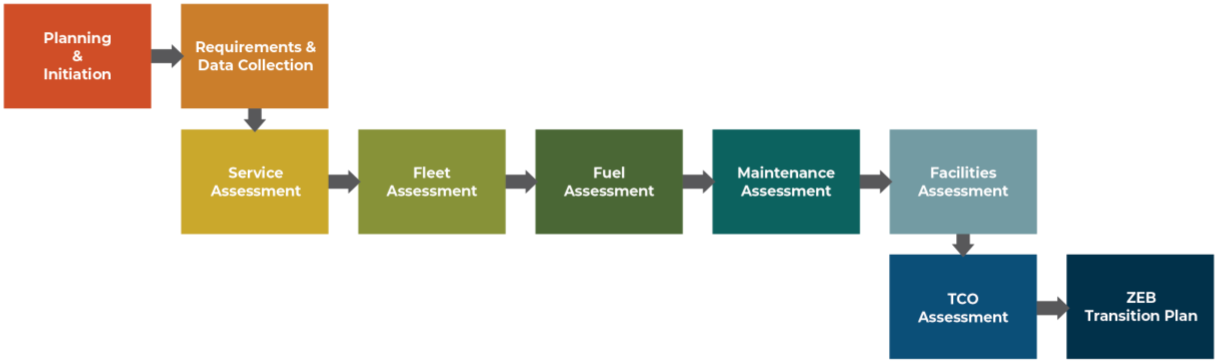

Figure 2: ZEB Transition Study Methodology

The **Planning and Initiation** phase builds the administrative framework for the transition analysis. During this phase, the project team drafted the scope, approach, tasks, assignments and timeline for the project. CTE worked with Intercity staff to plan the overall project scope and all deliverables throughout the full life of the study. During the kickoff meeting, the CTE team met with stakeholders and collected route, block, fleet, operational, maintenance, and facilities information from Intercity staff to form the baseline scenario. CTE conducted a route modeling workshop to determine the blocks that were used as the basis for the Service Assessment.

The **Service Assessment** phase evaluated the expected energy needs for each bus to determine if zero-emission technologies have sufficient range to replace current buses on a 1:1 basis and complete every scheduled service day or route assignment. During the Planning and Initiation phase, the CTE team met with Intercity to define assumptions and requirements used throughout the study and to collect operational data. Results from modeling were used to estimate achievability of every block in Intercity's network using BEBs and FCEBs. The results from the Service Assessment were used to guide ZEB procurements in the Fleet Assessment and determine energy requirements for the Fuel Assessment.

The **Fleet Assessment** analyzed the capabilities of current ZEB technologies to meet Intercity's service requirements. The analysis projected the timeline for replacement of diesel, diesel-hybrid, gasoline, and propane buses with BEBs and FCEBs. The Fleet Assessment also includes an assessment of projected fleet procurement costs over the transition lifetime.

The **Fuel Assessment** used the outputs from the Fleet Assessment to create a projected timeline for replacement of current vehicles consistent with Intercity's existing fleet replacement plan. Technology constraints and alternative fleet compositions determined by the Service Assessment were considered in the creation of this projected timeline and CTE ensured the timeline was in alignment with Intercity's sustainability and transition goals.

The **Maintenance Assessment** analyzed labor and materials costs for zero-emission vehicle (ZEV) maintenance over the transition period as well as major component replacements for each technology type.

The **Facilities Assessment** defined the requirements for charging and hydrogen fueling infrastructure including operational impact and utility service requirements. The CTE team developed estimates for equipment and infrastructure, design, construction, and installation costs, space and siting requirements. CTE evaluated the requirements for a hydrogen refueling station needed to support the fleet.

The **Total Cost of Ownership Assessment** summarizes the costs of annual bus procurements, annual fuel cost, annual maintenance costs, as well as the costs of charging equipment, supporting infrastructure, facility upgrades, and design, construction and installation over the vehicle lifecycle.

Section 3 - Transition Scenarios

The following scenarios were assumed for the transition assessment:

- **Baseline:** Intercity's current fixed-route service composed of both diesel and diesel-hybrid vehicles. No changes to Intercity's current procurement schedule during the transition timeline (2023 – 2050).
- **BEB Depot Charging Only:** Transitions Intercity's existing vehicles to BEBs based on block feasibility assuming overnight depot charging only.
- **BEB Depot and On-Route Charging:** Transitions Intercity's existing vehicles to BEBs based on block feasibility assuming overnight depot charging and on-route charging.
- **Mixed Fleet (BEB/FCEB):** Transitions Intercity's existing vehicles to a mixed BEB and FCEB fleet, with BEBs utilizing overnight depot charging where feasible. Blocks not feasible with BEBs utilizing overnight depot charging are transitioned to FCEBs.
- **FCEB Only Fleet:** Transitions Intercity's existing vehicles to FCEBs based on block feasibility.

Section 4 – Fixed Route Fleet Analysis

4.1 –Assumptions

Due to the inherent nature of varying conditions over the period of a long-term fleet transition, it is necessary to establish a number of simplifying assumptions in an analysis such as this. These fixed-route analysis assumptions were developed based on discussions between the CTE team and Intercity during the **Planning & Initiation** stage of this project and include the following:

- Transition to a 100% ZEB fleet by 2050
- Current fleet composition (as of the time of this analysis) used for the baseline scenario
- Currently planned fleet replacement cycles
- 12-year lifespan assumed for heavy duty buses
- Current battery sizes for BEBs and fuel tank sizes for FCEBs are based on existing specifications for vehicles that have completed Altoona testing
- A 5% improvement in battery capacity (for BEB) and efficiency (FCEB) every two years
- A battery warranty is purchased at the time of vehicle purchase
- 10% of battery capacity is assumed to be unusable
- A fuel-cell overhaul will occur at the mid-life of each heavy-duty transit FCEB (6 years)
- 35' and 40' BEB efficiencies based on screening level analysis of Intercity Transit's 115 fixed route blocks
- Hydrogen efficiency obtained from CTE data sources
- 17 kWh/kg conversion metric to calculate FCEB efficiencies from Intercity's BEB efficiencies (e.g., 2.08 kWh/mi for 35/40' BEBs translates to 0.12 kg/mi for 35/40' FCEBs)

Current BEB technologies have range limitations relative to diesel vehicles, and as a result, it is not always possible to replace an agency's current fleet one to one using BEBs. Improvements are expected to be made over time, but there are significant challenges to overcome, and the timeline to achieve the goal is uncertain. In addition to the uncertainty of technology improvements, there are other risks to consider. Although current BEB range limitations may be remedied over time as a result of advancements in battery energy density and more efficient components, battery degradation may re-introduce range limitations as a risk to an all-BEB fleet over time. In emergency scenarios that require use of BEBs, agencies may face challenges supporting long-range evacuations and providing temporary shelters in support of fire and police operations. Furthermore, fleetwide energy service requirements and power redundancy and resiliency may be difficult to achieve at any given depot in an all-BEB scenario. Higher capital equipment costs and availability of hydrogen may constrain FCEB solutions.

4.2 – Baseline Data

It is essential to understand the key elements of Intercity's service to evaluate the costs associated with a full-ZEB transition. Key data elements of the existing Intercity service were provided by Intercity staff and include the following:

- Fleet composition
- Routes and blocks
- Mileage, fuel consumption, and fuel efficiency
- Annual maintenance costs
- Annual fleet capital costs

Fleet

At the time of this study, Intercity's fixed-route bus fleet consisted of 86 vehicles of various lengths and fuel types that provide service for 22 fixed-routes. The following table provides a breakdown of the existing fleet vehicles by length and fuel type.

Table 1: Current Bus Quantity by Length and Fuel Type

Vehicle Length	Fuel Type	Total Vehicles
35'	Diesel	31
40'	Diesel	55
TOTAL		***86***

Figure 3 depicts Intercity's existing bus replacement schedule through the end of the transition period.

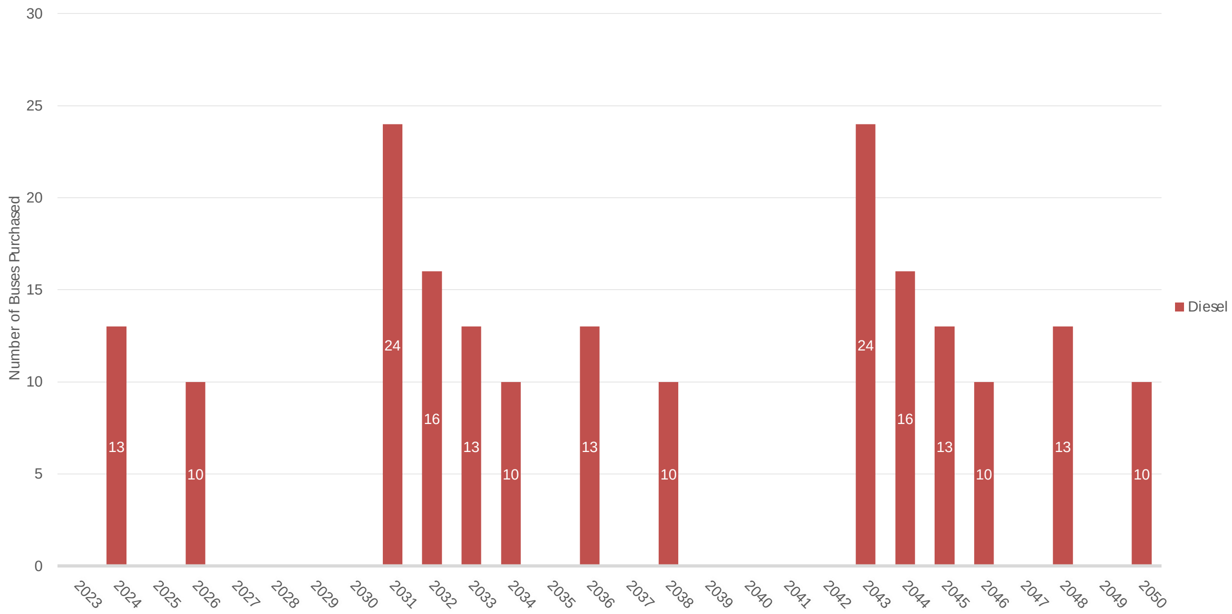

***Figure 3*: Bus Replacement Schedule**

Routes and Blocks

Intercity's service currently consists of 22 routes. Intercity operates a total of 115 blocks including 76 weekday blocks and 39 blocks operating on Saturday and Sunday. Routes 100, 101, and 411 were operational prior to the Covid pandemic; however, the service is no longer operational post-Covid. Route 620 now runs a limited service post-Covid. The pre-Covid 2019 service levels were projected through 2050 as Routes 100, 102, 411, and 620 are expected to eventually return to full service. This transition analysis only evaluated data from Intercity's pre-Covid service.

Table 2: Number of Blocks by Bus Length (Pre-Covid)

Vehicle Length	Blocks
35'	19
40'	96
TOTAL	***115***

Fuel

Intercity's current fuel use was collected and used to estimate energy costs throughout the study life. A fluctuating inflation rate was applied through 2050 based on the projection for diesel, natural gas, and electricity as transportation fuels from the 2023 *EIA Annual Energy Outlook*[2]. The assumption for the price for diesel was based on the 2022 costs report by Intercity: $4.80 diesel gallon equivalent (DGE). Electricity costs were assumed to be driven by

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[2] https://www.eia.gov/outlooks/aeo/

Puget Sound Energy's (PSE) Schedule 26 for Large Demand General Service (>350 kW). The 2023 price for hydrogen used was $8.61/kg based on the average Year 1 and Year 2 costs outlined in the GETBus and PlugPower temporary hydrogen fueling contract with SamTrans (San Mateo, CA), dated March 2023.

When vehicles are added to the fleet, all vehicles of the same length that are acquired in that year to replace retiring vehicles are assumed to operate the average annual mileage of that vehicle size and, for diesels, are assumed to consume the same amount of fuel as other vehicles of the same length and fuel type.

***Table 3**: Annual Mileage by Bus Length and Group*

Vehicle Length	Average Annual Mileage per Vehicle
35'	25,367
40'	53,324

Baseline fuel economy based on historical operations is provided below.

Table 4: Fuel Economy by Bus Length

Vehicle Length	Fuel Efficiency (mpdge)
35'	5.49
40'	4.70

mpdge = miles per diesel gallon equivalent

Maintenance

Historical maintenance costs reported by Intercity were used to project future maintenance costs for all legacy fuel types.

***Table 5**: Average Maintenance Cost per Mile by Vehicle Length*

Vehicle Length	Diesel ($/mi)
35'	$0.59
40'	$0.59

Major services such as engine and transmission rebuilds are already included in the per mile maintenance costs provided by Intercity.

4.3 – Service Assessment

Bus efficiency and range are primarily driven by vehicle specifications; however, it can be impacted by a number of variables including the route profile (i.e., distance, dwell time, acceleration, sustained top speed over distance, average speed, traffic conditions, etc.), topography (i.e., grades), climate (i.e., temperature), driver behavior, and operational conditions such as passenger loads and auxiliary loads. As such, ZEB efficiency and range can vary dramatically from one agency to another. Therefore, it is critical to determine efficiency and range estimates that are based on an accurate representation of the operating conditions associated with Intercity's system to complete the assessment. Strenuous operating conditions were used to determine energy demand.

The first task in the Service Assessment is to develop a model to run operating simulations for each of Intercity's routes. CTE uses *Autonomie*, a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE has modified software parameters specifically for electric buses to assess energy efficiencies, energy consumption, and range projections.

As discussed earlier in this report, the Service Assessment was conducted using a screening model developed by CTE. CTE's screening model utilizes CTE's BEB and FCEB operational database to predict the energy consumption and range of various classes of ZEBs, and industry research to gauge future ZEB technology improvements that would influence feasibility and energy use. The model considers the variability of range resulting from differences in route type, loading, temperature conditions, driver behavior, and duty cycle. The agency-specific inputs to the model include duration and mileage of each current and future block, and anticipated operational conditions. The model also reflects projected changes in feasibility in future years as anticipated improvements in bus efficiency and energy storage capacity are realized.

The data from the routes, as well as the specifications for each of the bus types selected, was used to simulate operation of each type of bus on each type of route. As Routes 100, 102, 411, and 620 are expected to return to full service after being suspended during the COVID-19 pandemic, 2019 service levels were projected through 2050. Blocking and annual mileage of the 86 fixed-route vehicles are not expected to change and block assignments by vehicle length are consistent throughout the transition period. Block assignments are defined by peak pull-out which in this case is weekday service. Feasibility is defined by the energy on-board from a single depot charge.

The models were run with varying loads to represent "nominal" and "strenuous" loading conditions. Nominal loading conditions assume average passenger loads and moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditioning (HVAC) system. Strenuous loading conditions assume high or maximum passenger loading and either very low or very high temperature (based on agency's latitude) that requires near maximum output of the HVAC system. This nominal/strenuous approach offers a range of operating efficiencies to use in estimating average annual energy use (nominal) or planning minimum service demands (strenuous).

Additional details for the assumptions used to complete the Service Assessment are included in **Table 6** below. **Figure 4** provides an outline of the data streams used to create the service modeling and simulation that form the Service Assessment results.

Table 6: Service Assessment Assumptions

Vehicle Class	Avg. Battery Capacity	Auxiliary Load (Nominal)	Auxiliary Load (Strenuous)
35’ BEB	491 kWh	6 kW	20 kW
40’ BEB	523 kWh	6 kW	20 kW

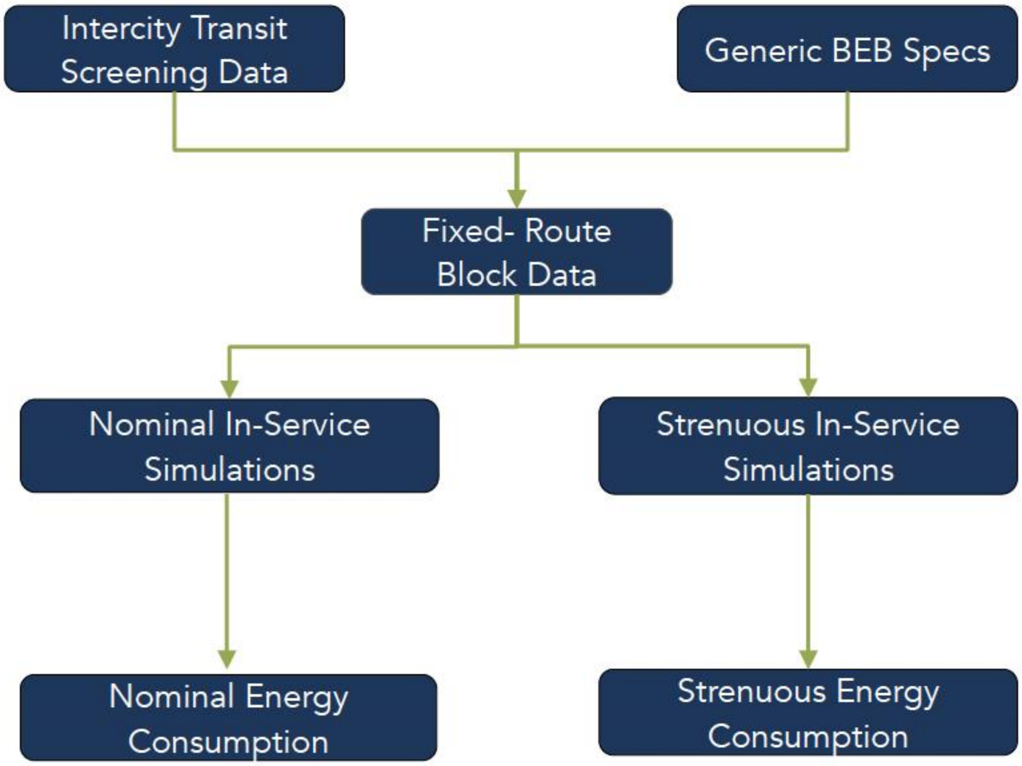

Figure 4: Modeling and Simulation Approach

The nominal energy capacity for each vehicle class used for the analysis was the average capacity of the currently available vehicles on the market that have completed Altoona Testing and are available for purchase using Federal funding. In the case that there was only one vehicle available or tested, then that vehicle was used to provide the baseline assumption. As this is an average, there are currently vehicles with larger nominal energy capacities available in several of the vehicle classes (e.g., 40’ BEB); however, because this analysis does not assume a specific vehicle manufacturer, these average capacities were utilized as the current available on the market. Research suggests that battery density for electric vehicles has improved by an average of 5% each year[3]. For the purposes of this study, considering the extended period of a complete fleet transition (e.g., through 2050 being the goal for Intercity), CTE assumed a more conservative 5% improvement every two years. If the trend continues, it is expected that buses may continue to improve their ability to carry more energy without a weight penalty or reduction in passenger capacity. Over time, BEBs are expected to approach the capability to replace all of an agency's fossil-fuel buses one-for-one. For FCEBs, improvements in hydrogen compression and storage technologies are expected to occur over the course of the transition period. As a result, CTE assumed a 5% improvement in efficiency for FCEBs every other year. Vehicle OEMs are currently developing energy systems with higher storage capacity and energy density. As such, these projections should be considered conservative for the purposes of planning.

Projected battery capacity was based on the assumption that useable battery capacity is 90% of nameplate capacity with 10% degradation, effectively 81% of nominal capacity. At the time of the development of this report, there are multiple BEB manufacturers that are moving towards allowing a larger percentage of the battery (greater than 90%) to be available for use; however, the 81% represents a conservative assumption of available battery capacity at the mid-life of a vehicle.

The block analysis, with the assumption of 5% improvement in battery capacity or improvement in hydrogen storage capacity every other year, is used to determine the timeline for when routes and blocks become achievable for BEBs and FCEBs, respectively, to replace diesel buses one to one. This information is used to then inform ZEB procurements in the Fleet Assessment.

The results from the block analysis are used to determine when/if a full transition to BEBs or FCEBs may be feasible. Results from this analysis are also used to determine the specific energy requirements and develop the estimated costs to operate the ZEBs in the Fuel Assessment.

Results from the block analysis that indicate the average yearly block achievability throughout the transition period for BEBs are included on **Figure 5**. This includes both 35' and 40' BEBs.

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[3] https://arpa-e.energy.gov/technologies/publications/long-range-low-cost-electric-vehicles-enabled-robust-energy-storage

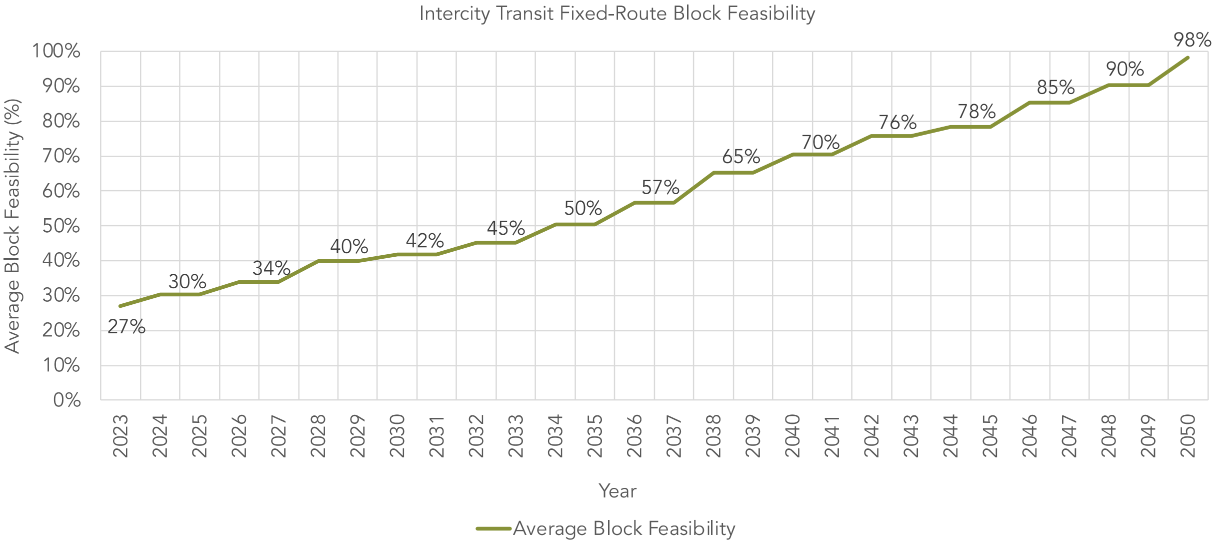

Figure 5*: *Projected Block Achievability (BEBs)

As depicted in **Figure 5**, block feasibility improves over time as improvements to technology enable more of Intercity's existing fixed-route service to be completed using 35' or 40' BEBs. Currently, only 27% of Intercity's blocks are feasible with existing battery-electric technology. By 2035, 50% of Intercity's fixed routes are expected to be feasible and by 2050, 98% of Intercity's routes are projected to be feasible.

The block analysis was also completed modeling FCEB block achievability. FCEBs are currently able to complete 98% of Intercity's blocks and by the end of the transition period in 2050 are able to complete 100%.

While routes and block schedules are unlikely to remain the same over the course of the transition period, this projection assumes the blocks will retain a similar structure to what is in place today. Despite changes over time, this analysis assumes blocks will maintain a similar distribution of distance, relative speeds, and elevation changes by covering similar locations within the city and using similar roads to get to these destinations. This core assumption affects energy use estimates as well as block achievability in each year.

It should be noted that BEB range is negatively impacted by battery degradation over time. A BEB may be placed in service on a given block with beginning-of-life batteries; however, it may not be able to complete the entire block at some point in the future before the batteries are at end-of-life (typically considered 80% of available service energy). Conceptually, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding blocks. Intercity can rotate the fleet to meet the demand assuming there is a steady procurement of BEBs each year to match service requirements. This could also be said for FCEBs, although the impact of degradation is assumed to be less.

4.4 – Fleet Assessment

The goal of the Fleet Assessment is to determine the type and quantity of ZEBs, as well as the schedule and cost to transition the fleet to zero-emission. Results from the Service Assessment are integrated with Intercity's current fleet replacement plan and purchase schedule to produce the projected bus replacement timeline and the associated total capital cost.

Cost Assumptions

CTE created cost assumptions for this analysis for 35' and 40' diesel bus lengths. CTE produced the annual procurement scenario for 2023 through 2050 and annual capital costs for buses. Intercity's procurement cycle is 12 years.

Key assumptions for the bus cost estimate are as follows:

- Inflation rate of 2% applied through 2050, based on historical Producer Price Index (PPI) for transportation equipment and bus bodies.
- Extended battery warranty costs are accounted for in the price of the BEB ($75,000) and in the price for the FCEB ($17,000).
- Bus costs in **Table 7** below are based on maximum price of each bus type from the 2022 Washington State Contract (inflation adjusted by 12% for 2023 pricing), combined with configurable options costs provided by Intercity from a recent bus purchase and battery warranty prices as mentioned in the bullet above.

Conventional wisdom dictates that the costs of BEBs will decrease over time due to higher production volume and competition from new vendors entering the market. While initially this was true, costs appear to have stabilized and begun to increase again in recent years. However, it should also be noted that OEMs have added more battery storage over the same time period. FCEB prices are expected to decrease over time as vehicle orders increase (e.g., California transit agencies have committed to purchasing over 1,300 FCEBs by 2035); however, CTE does not currently have an adequate basis to reduce the costs over time for the purchase of FCEBs.

Table 7 provides cost estimates for new vehicle purchases used in the analysis. The costs for internal combustion engine vehicles were provided by Intercity. The base price used for the 35' and 40' BEBs comes from the 2022 Washington State Contract bus pricing. The base price was adjusted for inflation and configurable items were added to create a 2023 cost estimate for 35' and 40' BEBs. As there are no 35' FCEBs currently on the market, 40' FCEB pricing was assumed.

Table 7: Cost Estimates Used in Fleet Assessment

Vehicle Type	35’	40’
Diesel	$762k	$773k
Battery Electric	$1.45M	$1.58M
Hydrogen Fuel Cell	$1.64M	$1.64M

ZEB Fleet Transition Schedule and Composition

Given the block analysis and Intercity’s fleet replacement schedule and currently planned procurements, a transition timeline was developed. **Figure 6** depicts the annual baseline fleet composition through the transition period.

Figure 6**: **Baseline Fleet Composition

Despite recent increases in energy storage, BEBs are still subject to range limitations and typically cannot be placed into service on every block on a 1:1 replacement basis for diesel. As discussed in the Service Assessment section, BEBs can currently be operated on approximately 27% of Intercity’s blocks today (including 35’ and 40’), improving to approximately 98% by the end of the transition period. If Intercity desires to place BEBs on routes where the estimated vehicle range is less than the block distance, they must (1) modify the block distance and duration; (2) use multiple BEBs to replace a single diesel vehicle; or (3) utilize on-route charging. As there is currently no regulatory driver for full-scale ZEB replacement in Washington, CTE assumes that Intercity would replace the vehicles that could be replaced with BEBs on a 1:1 basis as technology allows. The annual fleet composition through the transition period, assuming 1:1 replacement with depot only charging is depicted in **Figure 7.**

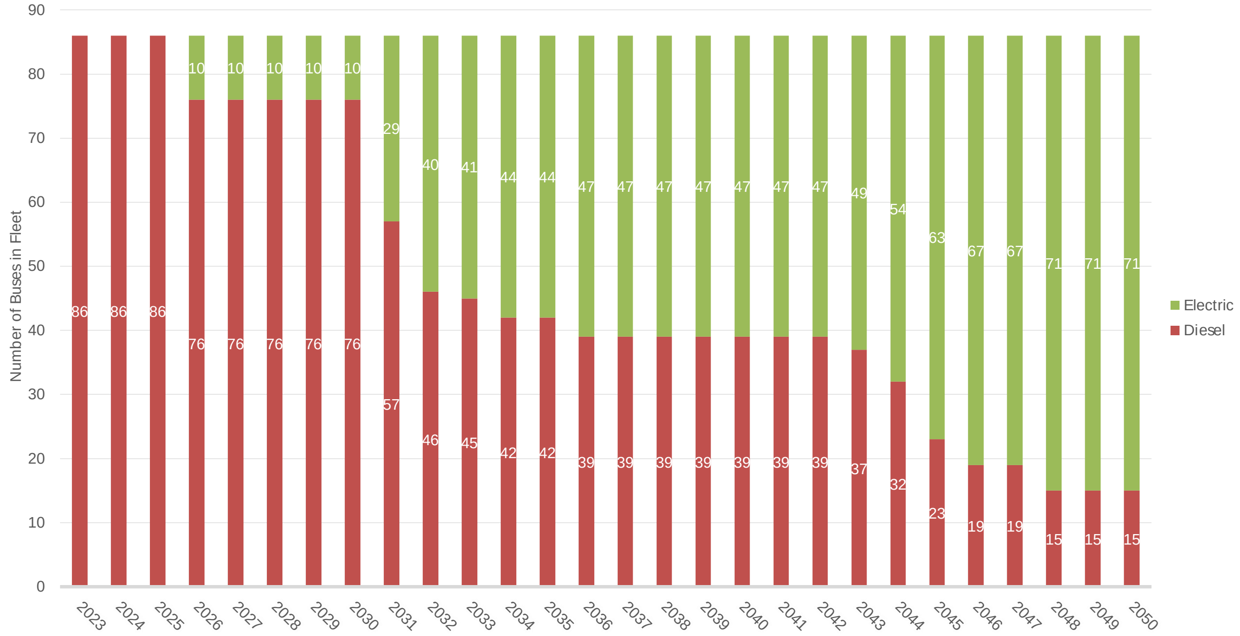

Figure 7**: *BEB Depot Only Fleet Composition***

In the BEB Depot Only scenario, Intercity can reach approximately 84% zero-emission fleet by 2050. In this scenario, all 35’ and 40’ diesel buses are replaced by BEBs based on block feasibility and BEBs are assumed to charge in the bus depot rather than utilizing on-route charging. All 35’ vehicles can be replaced by depot-only BEB alternatives but the feasibility of routes serviced by 40’ vehicles is dependent on BEB nameplate capacity improvements of 5% every other year. For Intercity to reach a 100% ZEB fleet within this timeframe, other technology solutions would need to be considered.

In **Figure 8**, results from the BEB Depot and On-Route Charging scenario are shown. In this scenario, BEBs utilize overnight depot charging and on-route charging. Intercity is able to replace all 35’ and 40’ diesel buses with BEBs, achieving a roughly 85% zero-emission fleet by 2035 and a 100% zero-emission fleet by 2050.

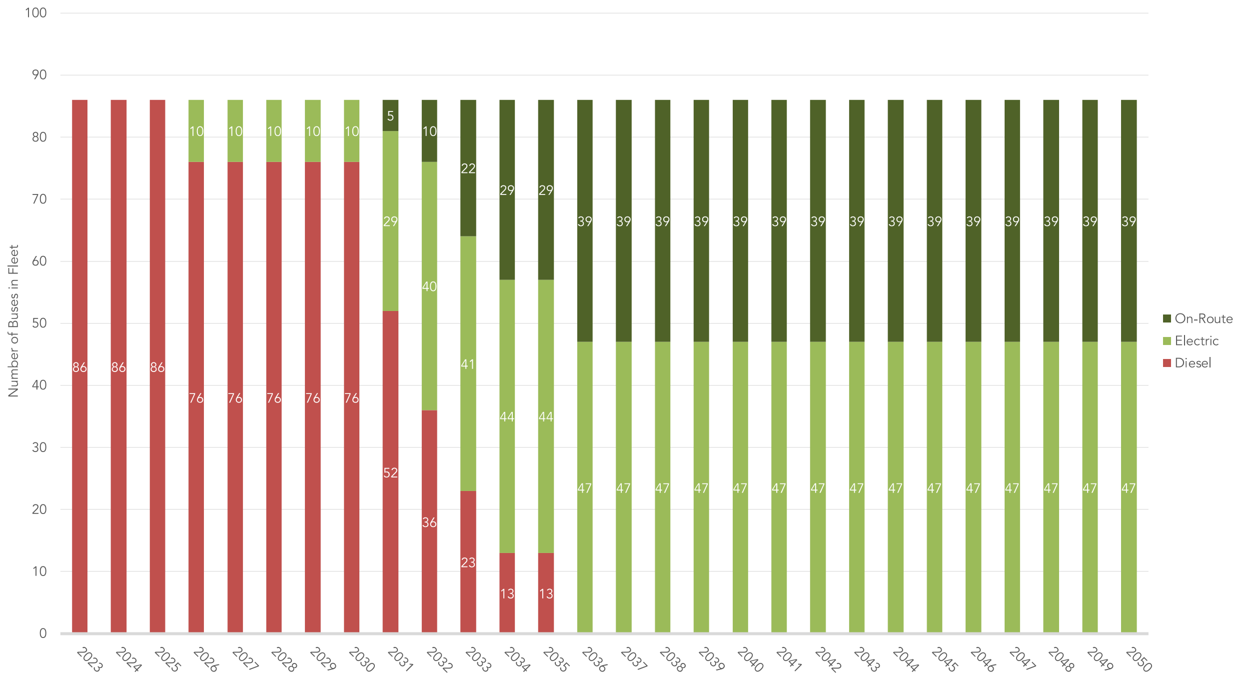

Figure 8: BEB Depot and On-Route Charging

Figure 9 below shows results from the Mixed Fleet (BEB and FCEB) scenario, in which Intercity replaces all diesel vehicles with BEB vehicles that can be charged at the depot and FCEBs.

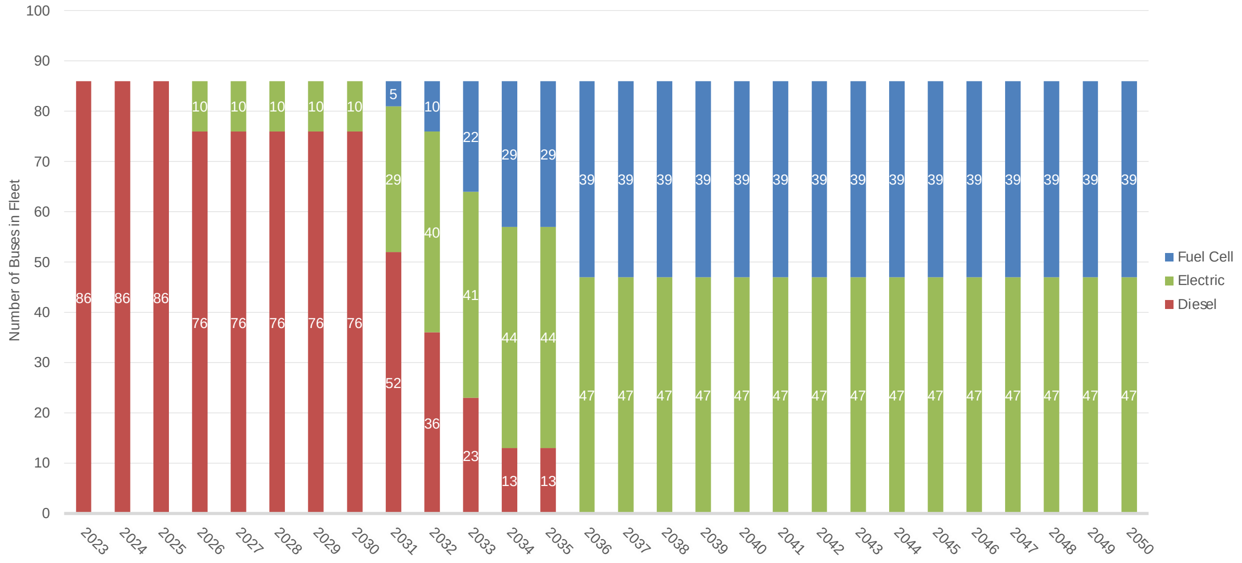

Figure 9: Mixed (BEB and FCEB) Fleet Composition

In the Mixed Fleet scenario, Intercity is able to reach a fleet composed of roughly 85% zero-emission buses by 2035 and 100% zero-emission buses by 2036. In this scenario, a depot-charged BEB is deployed in place of a diesel bus, if the vehicle's block is feasible, and an FCEB is deployed in place of a diesel bus, if the vehicle's block is infeasible with a depot charged BEB. Once a bus is replaced with an FCEB, it stays FCEB in perpetuity.

Figure 10 below shows the final scenario, an FCEB Only Fleet. In this scenario, all 35’ and 40’ diesel buses are replaced with FCEBs based on block feasibility. Using current-day technology (350-mile range), 98% of Intercity’s blocks are feasible. With anticipated improvements to FCEBs, however, all blocks are expected to be feasible by the end of the transition period in 2050.

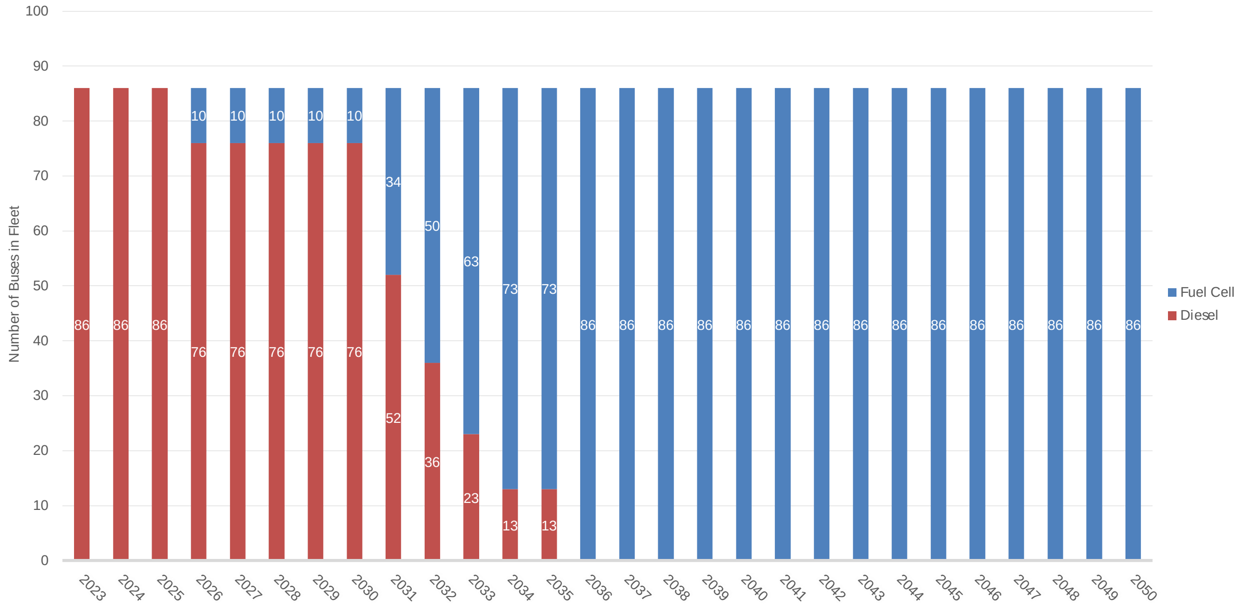

Figure 10: FCEB Only Fleet Composition

BEB Fleet Transition Cost Comparison

The transition and fleet composition schedules were used to develop the total capital cost for vehicle purchases throughout the transition period. Costs for the vehicles were assumed to increase with a 2% rate of inflation, based on historical PPI. The bus costs were based on maximum price of each bus type from the 2022 Washington State Contract (inflated by 12% for 2023 pricing), combined with configurable options costs provided by Intercity from a recent bus purchase and battery warranty prices. Extended battery warranty costs are accounted for in the price of the BEB ($75,000) and in the price for the FCEB ($17,000).

Table 8 below shows the cumulative fleet costs compared to baseline and the percentage of blocks expected to be achievable by 2050.

Table 8: Fleet Evaluation Summary – All ZEB Scenarios (2023-2050)

	Baseline	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet (BEB/FCEB)	FCEB Only
Cumulative Fleet Costs	$270.3M	$408.8M	$468.6M	$477.5M	493.5M
Cost Compared to Baseline	-	+$138.5M	+$198.3M	+$207.2M	+$223.2M
% of Blocks Achievable with ZEBs by 2050	0%	83%	100%	100%	100%

4.5 - Fuel Assessment

CTE conducted a fuel assessment to determine the projected annual cost of fuel during the transition period by fuel type (i.e., diesel, electricity, or hydrogen). A sensitivity analysis for the cost of hydrogen was also completed, to understand and help predict how fluctuations in its price may affect the cost of fuel over time.

The terms “fuel” and “energy” are used interchangeably in this analysis, as ZEB technologies do not always require traditional liquid fuel. For clarity, in the case of BEBs, “fuel” is electricity, and costs include energy, demand and other utility charges. The primary source of energy for a BEB comes from the local electrical grid. Utility companies typically charge separate rates for total electrical energy used and the maximum electrical demand on a monthly basis. As more buses and chargers are added to a system, both the energy used and the demand increase. Rates also vary throughout the year and throughout the day (also called time of day rates); this makes costs highly variable. Costs not only depend on seasonal differences like temperature or local school schedules, but also the time of day that buses are charged.

FCEBs are more similar to diesel vehicles as they are fueled by a gaseous or liquid hydrogen fuel. In addition to the cost of the fuel itself, however, there are additional operational costs associated with the hydrogen fueling station that must be considered. Operation and maintenance costs to maintain fueling infrastructure are built into the Fuel Assessment.

Fuel Assessment Assumptions

For the purpose of this fuel assessment, annual mileage and associated fuel use is constant for all vehicles through the transition period and is based on Intercity’s current fleet averages.

A cost of $4.80 per diesel gallon equivalent, the average 2022 cost paid by Intercity, was used for the analysis. A fluctuating inflation rate was applied through 2050, based on the transportation diesel projection from the 2023 EIA *Annual Energy Outlook*[4]. **Table 9** shows the electricity cost assumptions used for the fuel assessment. Electricity costs were assumed to be driven by PSE’s Schedule 26 for Large Demand General Service (>350 kW). Reactive demand

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[4] https://www.eia.gov/outlooks/aeo/

charges were not taken into consideration and charger maintenance costs in the amount of $3,000 per year were applied per depot and on-route charger.

The 2023 price for hydrogen, $8.61/kg, was estimated using Year 1 and Year 2 costs outlined in the GETBus and PlugPower temporary hydrogen fueling contract dated March 2023 for SamTrans (San Mateo, CA). A fluctuating inflation rate was applied through 2050 using EIA's projection for compressed natural gas (CNG). Since the EIA does not currently produce projections for hydrogen as a transportation fuel, CNG projections were used instead. An additional sensitivity analysis was completed for the Mixed and FCEB Only ZEB scenarios in order to project a reduction in hydrogen costs by 3% year over year beginning in 2026, assuming infrastructure has been built out for regional hydrogen production. **Table 10** and **Table 11** show the fuel efficiency assumptions used and **Table 12** provides the fuel cost escalation applied during the transition period.

Table 9: Electricity Cost Assumptions

Electricity Charges	Oct - Mar	Apr - Sept	Total Charges
Basic Charge (per meter per month)			$109.08
Demand Charges (per kW)	$15.24	$11.16	$13.20*
Energy Charges (per kWh)			$0.080788

***Total demand charges applied to the fuel costs are an average of summer and winter electricity rates, provided the fuel consumption remains consistent throughout the year.*

Table 10: Fuel Consumption Assumption – BEB Charging

Vehicle Type	BEB Fuel Efficiency [kWh/mi]	Charger Rated Power	No. of Buses per Charger	Charger Efficiency	% of On-Route Energy
		Depot Charger			
35'/40'	2.08	150 kW	2	90%	--
		On-Route Charger			
35'/40'	2.08	350 kW	4	90%	80%

Table 11: Fuel Consumption Assumptions - FCEB

Vehicle Type	FCEB [kg/mi]	Hydrogen Safety Factor
35'/40'	0.12	20%

Table 12: Price Inflation Estimates for Transportation Fuel

Fuel Type	2022	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Electricity	100.0%	96.5%	94.4%	100.3%	103.4%	101.4%	101.3%	100.7%	102.4%	103.1%	98.6%	89.6%	100.0%
Hydrogen (based on CNG)	100.0%	95.1%	92.3%	91.2%	91.2%	91.8%	93.7%	92.8%	86.6%	99.9%	86.5%	83.1%	100.0%
Diesel	100.0%	96.5%	107.2%	99.7%	99.6%	101.3%	104.8%	104.2%	104.2%	106.2%	102.0%	105.5%	100.0%

Fuel Type	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Electricity	90.3%	91.5%	90.9%	91.0%	92.2%	90.3%	90.5%	86.1%	85.7%	90.6%	88.7%	85.8%	88.4%	87.0%	83.6%
Hydrogen (based on CNG)	87.5%	88.0%	88.4%	87.5%	95.8%	93.1%	87.0%	94.2%	89.8%	91.7%	93.8%	93.9%	90.1%	91.2%	90.0%
Diesel	111.1%	113.1%	109.1%	106.3%	116.0%	109.2%	101.0%	124.4%	128.1%	109.7%	118.5%	105.9%	95.0%	97.8%	93.6%

Figure 11, below, shows the baseline annual fuel costs based on Intercity's planned replacement schedule. Expenditures during the transition period in the baseline scenario are approximately $109.3 million. The Baseline scenario is for comparative purposes only and assumes that the vehicles follow the planned Intercity replacement schedule throughout the life of the study. The Baseline scenario helps create context for incremental costs incurred or benefits accrued by transitioning the fleet to zero-emission.

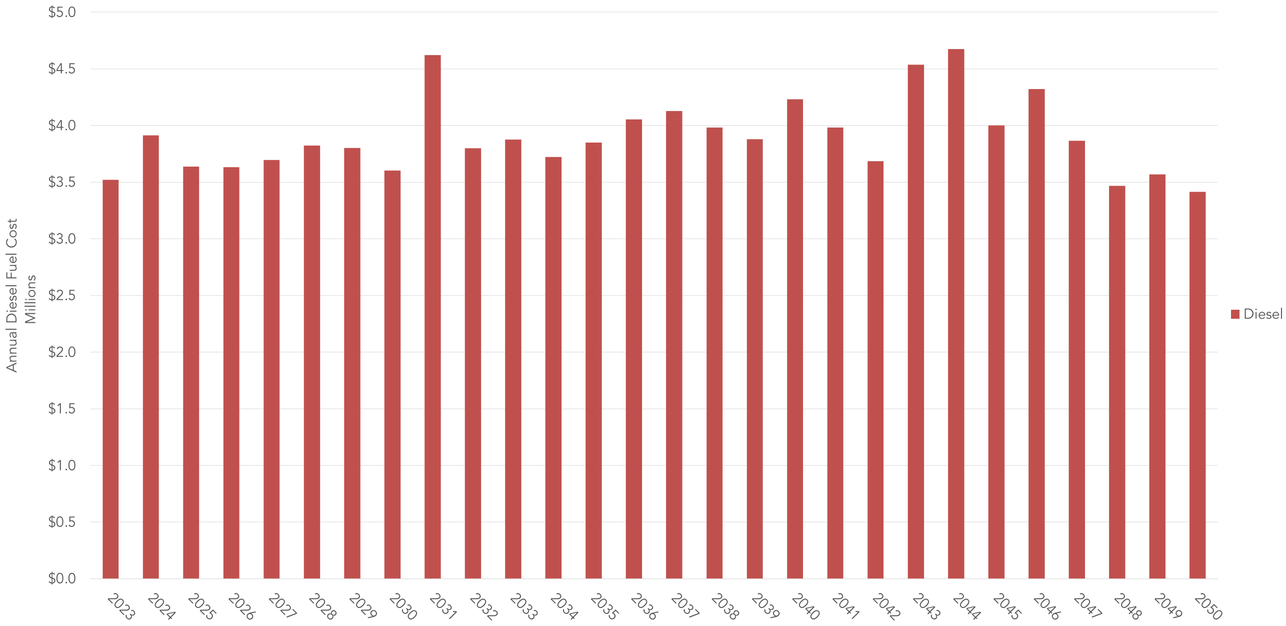

Figure 11: Baseline - Annual Fuel Cost

Annual Fuel Costs

As done in the Fleet Assessment, four scenarios were evaluated as part of the Fuel Assessment. The first scenario, shown in **Figure 12**, provides the annual fuel costs if Intercity purchases only BEBs to replace all 35' and 40' diesel vehicles based on block feasibility and charges BEBs only at the depot. In this scenario, expenditures total approximately $71.1 million from 2023 – 2050.

Figure 12: BEB Depot Only – Annual Fuel Costs

The second scenario, shown in **Figure 13**, depicts the annual fuel costs if all 35’ and 40’ diesel buses were replaced by BEBs utilizing overnight depot-charging and on-route charging. In this scenario, expenditures total approximately $50.1 million from 2023 – 2050.

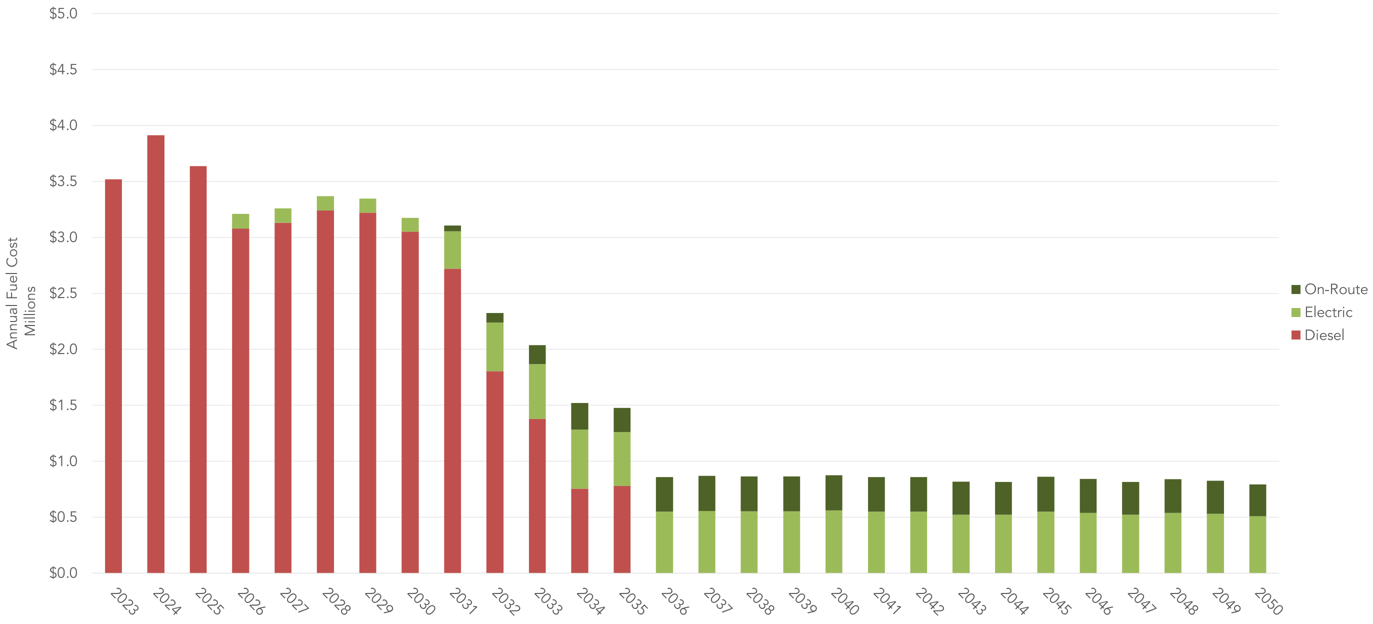

Figure 13: BEB Depot and On-Route Charging – Annual Fuel Cost

The third scenario assessed was the Mixed Fleet scenario in which Intercity transitions to a mixed FCEB and BEB fleet with BEBs utilizing depot charging. As shown in **Figure 14**, total expenditures during the transition period are estimated to be approximately $71.3 million. Inflation for hydrogen is estimated to be similar to that of electricity costs but lower than fossil fuels.

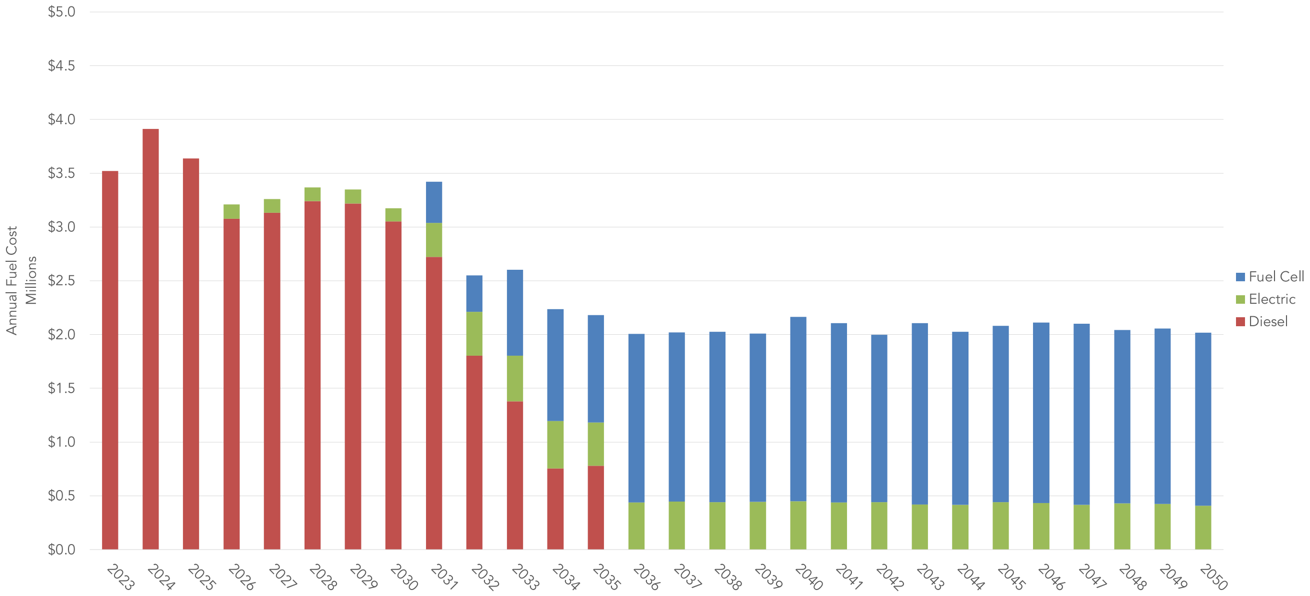

Figure 14*: *Mixed Fleet (BEB/FCEB) – Annual Fuel Cost

If hydrogen pricing decreases by 3% per year beginning in 2026 then the projected cost of hydrogen in 2050 would be $7.75/kg. With the sensitivity analysis (see results in **Figure 15**) fuel cell costs could be as low as $1.94/kg by 2050. The hydrogen sensitivity analysis reduces the overall total cost of fuel throughout the transition period from $71.3 million to $57.2 million ($14.1 million less). It is worth noting that significant investment from the federal government in hydrogen production such as the U.S. Department of Energy's Regional Clean Hydrogen Hubs Program[5] investment of $8B are expected to increase supply and reduce the cost of hydrogen over time.

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[5] https://www.energy.gov/oced/regional-clean-hydrogen-hubs

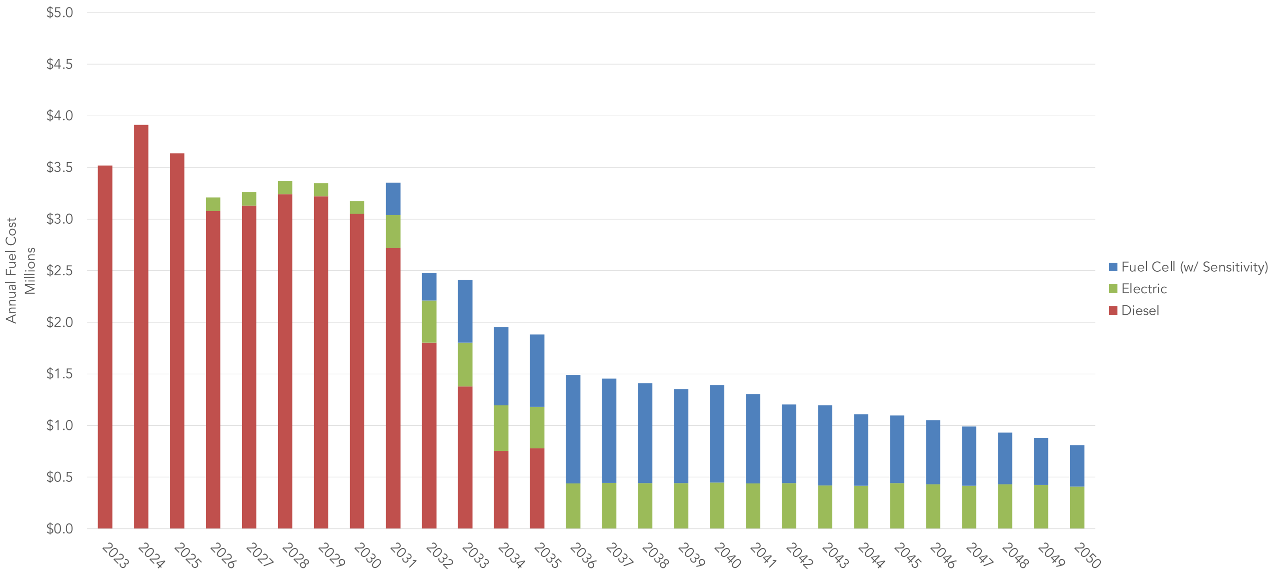


***Figure 15**: Mixed Fleet (BEB/FCEB) with Sensitivity Analysis – Annual Fuel Cost*

The fourth scenario assessed is one in which Intercity replaces all 35’ and 40’ diesel buses with FCEBs based on block feasibility. The projected annual costs are shown in **Figure 16** below. The total cost of hydrogen by the end of the transition period is $102.1 million but with the sensitivity analysis the total cost is projected to be $70.2 million, or roughly $31.9 million less. **Figure 17** shows the FCEB only scenario with the sensitivity analysis applied to the projected annual costs.

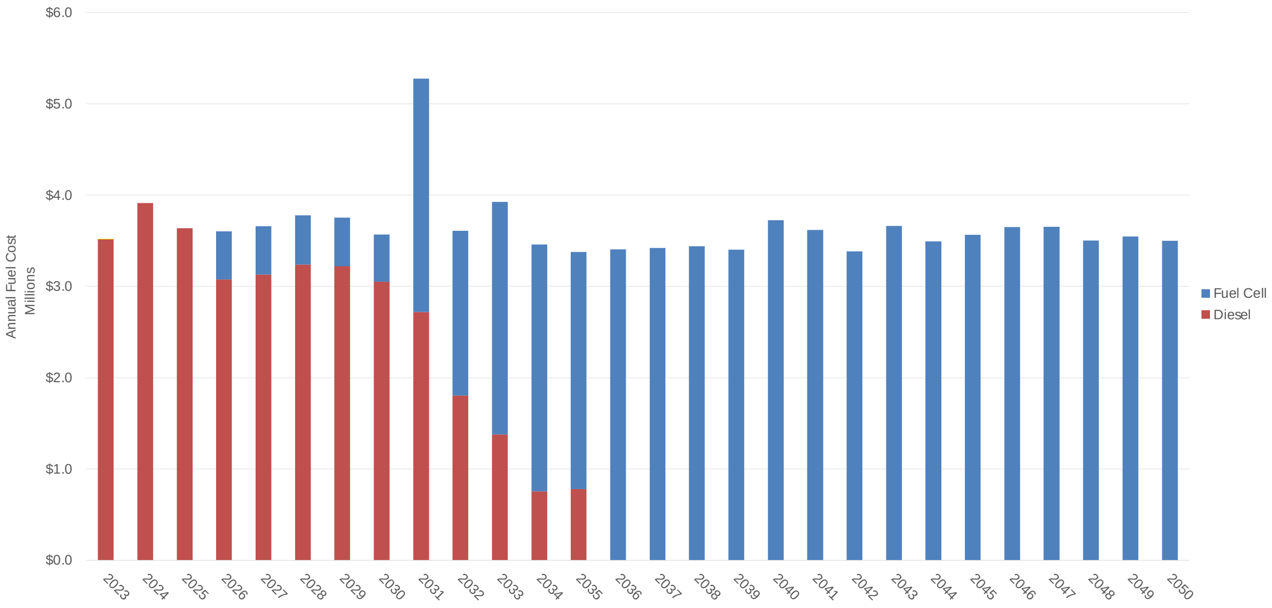


Figure 16: FCEB Only – Annual Fuel Cost

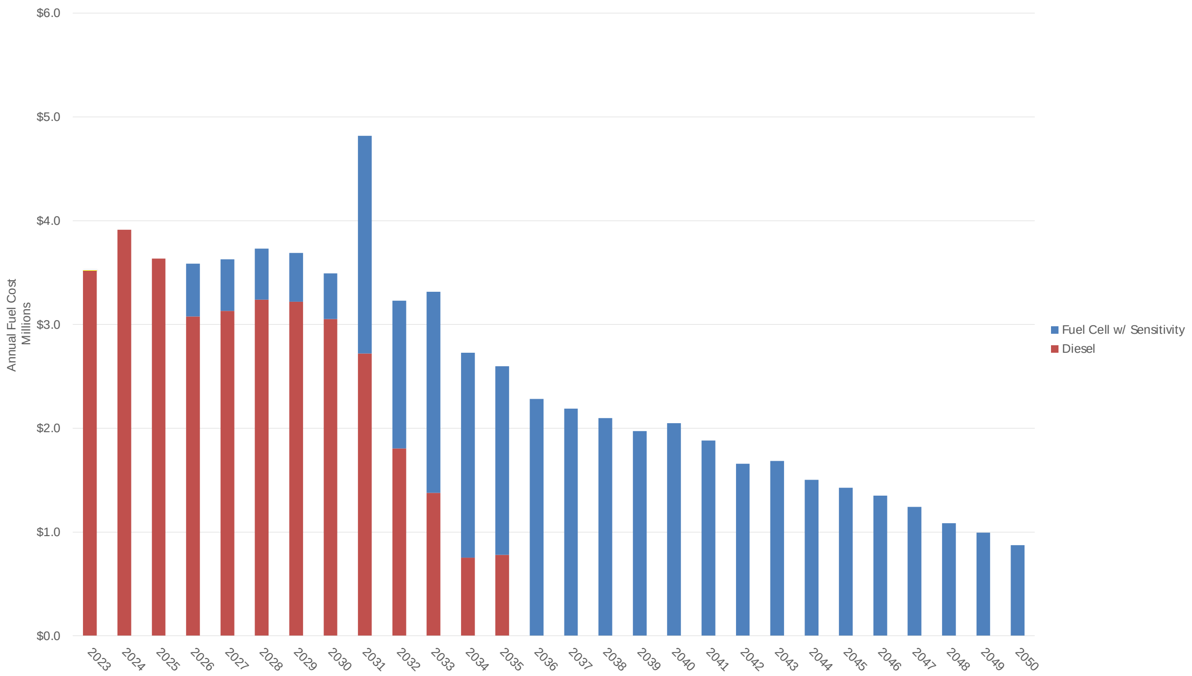


Figure 17: FCEB Only with Sensitivity Analysis – Annual Fuel Cost

Table 13 provides a comparison of the estimated fuel costs for each scenario through 2050 compared to baseline. The percentage of blocks achievable by 2050 for each scenario is also shown in this table.

Table 13: Fuel Evaluation Cost Summary

	Baseline	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet (Depot BEB and FCEB)	Mixed Fleet (w/ Sensitivity)	FCEB Only	FCEB Only (w/ Sensitivity)
Fuel Costs	$109.3M	$71.1M	$50.5M	$71.3M	$57.2M	$102.1M	$70.2M
Cost Compared to Baseline	--	-$38.1M	-$58.7M	-$38M	-$52.1M	-$7.2M	-$39.1M
% of Blocks Achievable with ZEBs by 2050	0%	83%	100%	100%	100%	100%	100%

4.6 - Maintenance Assessment

One of the expected benefits of moving to a ZEB fleet is a reduction in maintenance costs. Conventional wisdom estimates that a transit agency could attain maintenance savings up to 30% by operating BEBs. This is due to the fact that there are fewer fluids to replace (no engine oil or transmission fluid), fewer brake changes due to regenerative braking, and far fewer moving parts than on a diesel bus. However, the savings in traditional maintenance costs may be offset by the cost of battery or fuel-cell replacements over the life of the vehicle. The assumption used in the Maintenance Assessment to account for the average cost of a midlife fuel cell overhaul was $40,000. Extended battery warranty costs are accounted for in the price of the BEB ($75,000) and in the price for the FCEB ($17,000) in the Fleet Assessment portion of the analysis, as these costs are typically paid as upfront capital costs instead of operational costs.

There is limited data available on early deployments and many early deployments are from new manufacturers where production quality issues manifest as maintenance issues. Thus, assumptions used for calculating cost for labor and materials is based on current Intercity maintenance costs. Only the maintenance costs for fleet vehicles were included in the Maintenance Assessment (infrastructure maintenance is not included; those costs are included in the Facilities Assessment summarized in Section 4.7).

Percentages were derived from an analysis performed by the U.S. Department of Energy National Renewable Energy Laboratory (U.S. DOE NREL). There is limited information available regarding maintenance costs for FCEBs due to the limited number of vehicles in operation in the United States. Data from the Orange County Transportation Authority (OCTA), that has operated FCEBs since 2020, was used to estimate expected maintenance costs. An inflation rate of 3% was applied through 2050 based on historical CPI for labor. Maintenance cost assumptions are provided in **Table 14**.

Table 14: Maintenance Cost Assumptions

Type	Labor & Materials Estimate	Source
Diesel	$0.59/mile (35'/40')	Intercity Data
BEB	$0.41/mile (35'/40')	U.S. DOE NREL[1] – 30% decrease in BEB maintenance costs compared to diesel buses
FCEB	$0.44/mile (35'/40')	OCTA – 25% decrease in FCEB maintenance costs compared to diesel buses

[1] *Foothill Transit Battery Electric Bus Demonstration Results: Second Report*, Leslie Eudy and Matthew Jeffers, US DOE NREL,
June 2017

The cumulative estimated costs of maintenance over the transition period and those costs compared to the Baseline scenario are provided in **Table 15.**

Table 15: Maintenance Evaluation Cost Summary

	Baseline	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet	FCEB Only Fleet
Maintenance Costs	$95.7M	$81.5M	$74M	$80M	$88.2M
Cost Compared to Baseline	--	-$14.2M	-$21.7M	-$15.7M	+$7.5M
% of Blocks Achievable with ZEBs by 2050	0%	83%	100%	100%	100%

4.7 - Facilities Assessment

Once bus and fueling requirements are understood for the ZEB transition, the requirements for supporting infrastructure are determined including the charging equipment for BEBs and/or hydrogen fueling equipment for FCEBs. The Facilities Assessment determines the scale of charging and/or hydrogen infrastructure necessary to meet the demands of the projected fleet prepared in the Fleet and Fuel Assessments. The Facilities Assessment includes estimates for the costs of the associated infrastructure.

Charging Equipment Technology Overview

BEB depot charging technology typically combines direct current (DC) charging cabinets with remote charging dispensers equipped with cords or overhead pantographs. Dispensers with cords can be either pedestal mounted or can be mounted in the roof structure of the depot and equipped with a cord retractor system. The charger automatically starts and stops charging the BEB once the charging cord is manually plugged into the bus charging port. The automatic control system (ACS) communicating with the bus determine when to start the charging process and when to stop (at charge completion or manual interruption by the user or charge management software), without any operator interaction required.

The DC charger consists of a charging cabinet that contains an integrated rectifier, and a dispenser. The DC charger takes the utility provided alternating current (AC) power and converts it to DC by using the rectifier located within the charging cabinet. Some vendors supply an integrated dispenser while others separate the dispenser from the charging cabinet. DC charging systems with SAE J1772 compliant charging cords and connectors are compatible with multiple BEBs as long as they are specified with SAE Level J1772 compliant charging plug-in ports. Following this standard will allow initial BEB charging equipment and infrastructure installed to be compatible to multiple BEB manufacturers for future vehicle procurement.

Due to DC power distribution constraints, there is a limit to how far the charging cabinets can be from the dispenser – typically up to 400 feet from the DC charging cabinet to a remote dispenser. This distance includes any vertical drops or rises.

On-route charging, also called opportunity charging, can be accomplished either using conductive or inductive charging methods. A schematic depicting typical on-route charging equipment is provided in **Figure 18.**

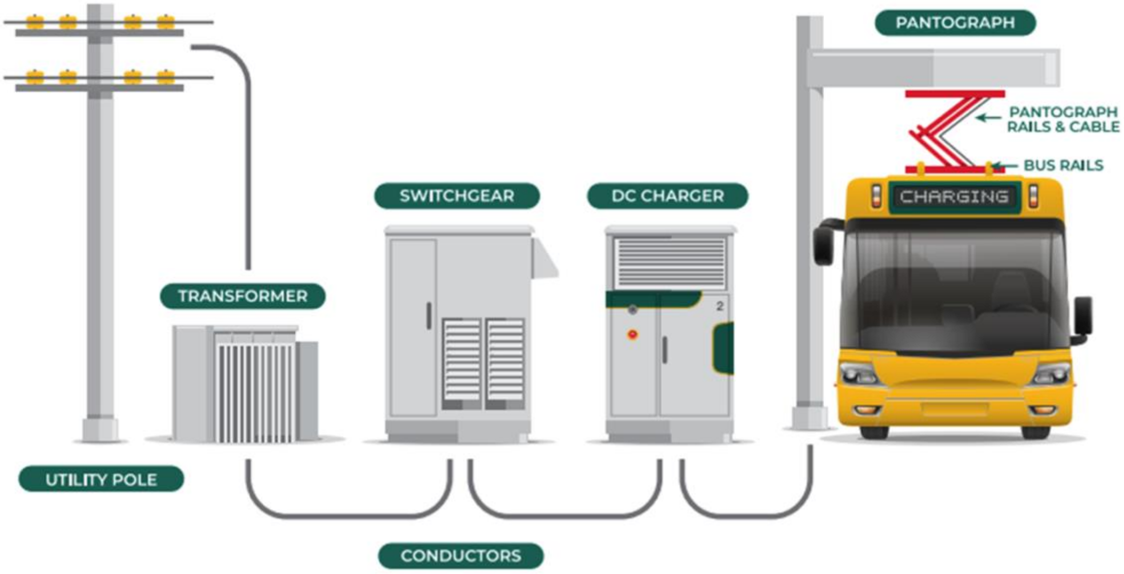


Figure 18 - Typical On-Route Charging Equipment Schematic

Conductive charging equipment includes a DC charging cabinet and a mast that supports an overhead pantograph charger that delivers energy to the bus through conductive rails mounted on the bus roof in accordance with the SAE J3105 charging standard. This high voltage DC power, along with low voltage control and signal power, is then carried through a series of underground conduits to the charging mast, rising up within the vertical mast and across the horizontal arm to the pantograph via high voltage DC cables and low voltage wires respectively.

The mast includes the ACS module for the charging equipment. The ACS module manages the incoming electrical DC and AC power, interlocks and communications with the DC Charging Cabinet and coordinates these systems with the charging Pantograph's systems of WiFi / Radio Frequency Identification (RFID) bus interlocks, charging status indicator, emergency stop (E-Stop), pantograph heater, and pantograph actuators and control systems. A typical charging mast occupies a footprint of approximately 4' x 2' and requires an approximate 3 feet of clearance in front of the mast for service.

The pantograph is the moving armature that raises and lowers from the horizontal arm of the mast and transfers the electrical power to the charging bars located on the bus to charge the on-board batteries. The communications between the bus and the charger are set by the adopted charging standard (SAE J3105). These standards must be matching and compatible for both the bus and pantograph for a successful charging session. The charging process is initiated automatically with the pantograph arm being lowered upon the charging bars on the bus's roof and transferring energy from the pantograph charging bars to the bus charging bars through direct contact.

Relatively level and plumb pavement is necessary at the charging position to allow for successful contact between the pantograph's charging bars and the charging bars on the bus roof. Slope tolerances vary between charger OEMs but pavement cross slopes parallel to the bus of 5 percent and perpendicular to the bus of 3.5 percent are the anticipated maximums. These slopes are inclusive of kneeling buses and the additional angles of cross and parallel slope (road inclination) generated by a kneeling bus will need to be accounted for in the pavement slope design in the charging position. Heated pantographs are recommended for Intercity Transit to keep the articulated arm and charging blades ice free during cold weather.

A key element of a successful on-route charger is the ability for a bus to pull up and stop at the correct position for charging. While there are electronic guides (tones or lights to indicate proximity to charging position) and automated docking systems on the market, a less costly and effective solution is visual stop / position indicators. Painted stripes, unique colored or special pavers patterns and textures are all viable options for a stop / position indicator.

Note that heavy snow and leaves can obstruct ground mounted stop / position indicators. Consider training operators to stop based on orientation to vertical mast or to other vertical alignment indicators.

Inductive charging, also known as wireless charging, utilizes magnetic resonant inductive charging from an inductive ground assembly to deliver energy to an assembly mounted on the bus, which connects to the high voltage system of the vehicle. The vehicle assembly is also connected to the cooling system and the CAN network of the bus. The ground assembly can be installed flush with the ground surface or surface mounted. An inductive charger is modular, with individual charge pads that can deliver between 60 and 75 kWh per pad. For BEB charging, inductive charger manufacturers such as Wave and InductEV typically recommend up to a 300 kW systems. An inductive charging system includes similar equipment to the conductive equipment such as the charging cabinet but the actual delivery of the energy to the vehicle is through the drive-over charging pad, reducing the total footprint required. As of the preparation of this plan, the number of bus manufacturers that support inductive charging is limited (BYD and GILLIG); however, other bus manufacturers have expressed a potential interest in the technology and may include inductive charging in their future product roadmaps. Please note that there is currently no established industry standard for inductive charging over 11 kW.

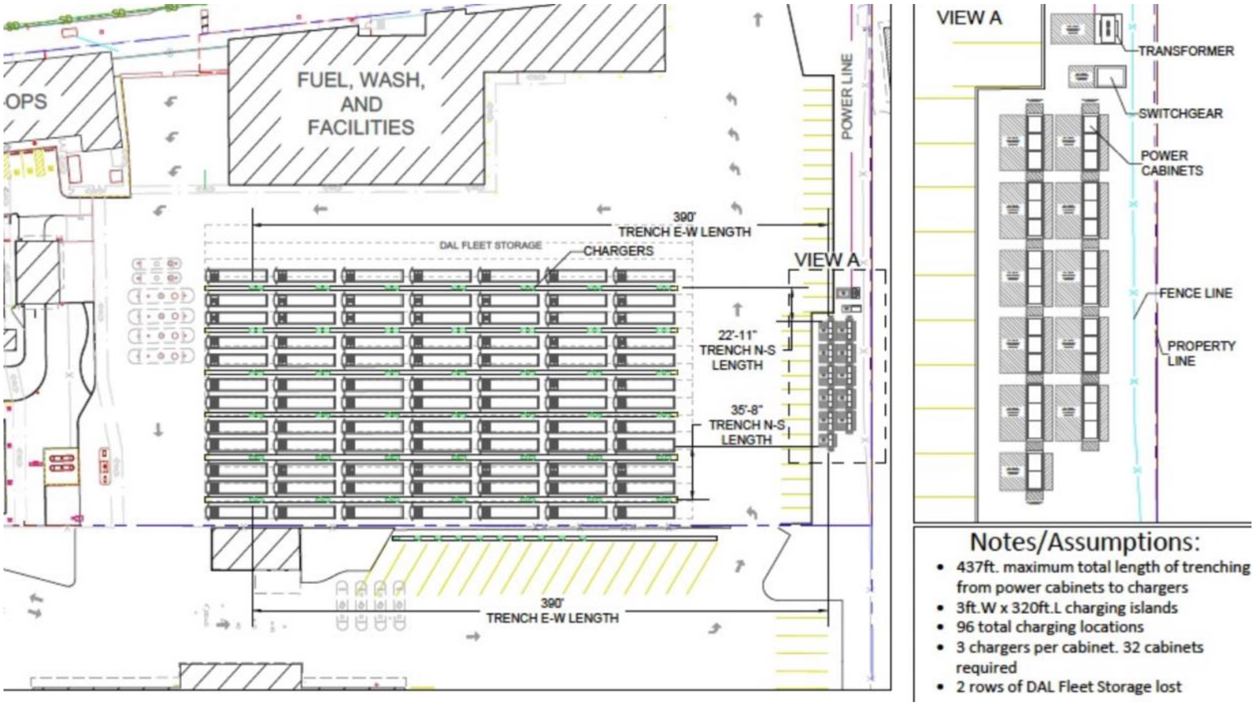
With pilot BEB deployments, charging requirements are met relatively easily with a handful of plug-in pedestal chargers and minimal infrastructure investment. Scaling to a fleetwide BEB deployment requires a substantially different approach to charging and infrastructure upgrades. In addition to installation of the charging stations, installation of new electrical infrastructure including switchgear, new utility service connections, and conduit and conductors are required to support deployment of BEBs. Design work will be required to support BEB deployment including development of detailed electrical and construction drawings required for permitting and construction once specific charging equipment has been selected. Rather than building out the infrastructure all at once, the deployment should occur in phases with each phase sized and scheduled to meet the near-term charging requirements while laying the foundation for future phases.

BEB Depot Charging Only Infrastructure

The BEB Depot Only charging analysis assumes that all charging takes place at Intercity's Pattison Street facility. The cost estimate assumes that by 2050 there will be 71 heavy-duty transit buses (84% of Intercity's fleet) for replacement with BEBs. Following discussions with Intercity staff, the cost estimate was developed assuming pedestal mounted dispensers in the bus parking area located on raised concrete islands to accommodate charging of up to 86 buses by 2050. For cost estimating purposes, it was assumed that each charger would be equipped with three (3) remote dispensers based on the currently available charging window and service schedule. As such a total of 32 chargers would be required to support the bus deployment, which includes approximately 10% spare chargers to mitigate potential issues with malfunctioning equipment and provide redundancy.

Electrical load requirements for the Pattison Street facility were estimated based on the number of chargers at full build-out to accommodate the BEB fleet. An increase of the existing electrical capacity by approximately 6 MW would be required to support full build out for 86 BEBs; however, charge management systems may be able to reduce the capacity needs. Implementation of such a solution requires further in-depth charging schedule optimization and utility approvals. An additional 1.0 MW is also expected to be required to support a fully electric Dial-A-Lift fleet as discussed in **Section 6.6** of this report. As discussed previously, this estimate assumes 10% redundant charging capacity. The cost from PSE to supply this additional 7.0 MW is not included in these costs. PSE was engaged throughout this project to provide information on the approximate electrical capacity increase at the charging location; however, continued coordination is required to manage capacity limitations and expected cost as this is a substantial upgrade and could require additional generation or transmission systems.

Chargers, switchgear and other electrical equipment would be installed as depicted on **Figure 19**. Pedestal mounted dispensers would be installed along the raised islands as depicted in the figure. DC chargers typically can be installed up to approximately 400 feet away from the dispenser locations. Hence, the chargers will be installed on the green space behind the parking on the east side of the lot to reduce the footprint required in the parking area. Installing the chargers in a space away from the parking location also reduces the noise and vibration levels in the parking area where most of the activities take place while providing maintenance workers a safe space to complete charger repair and maintenance.

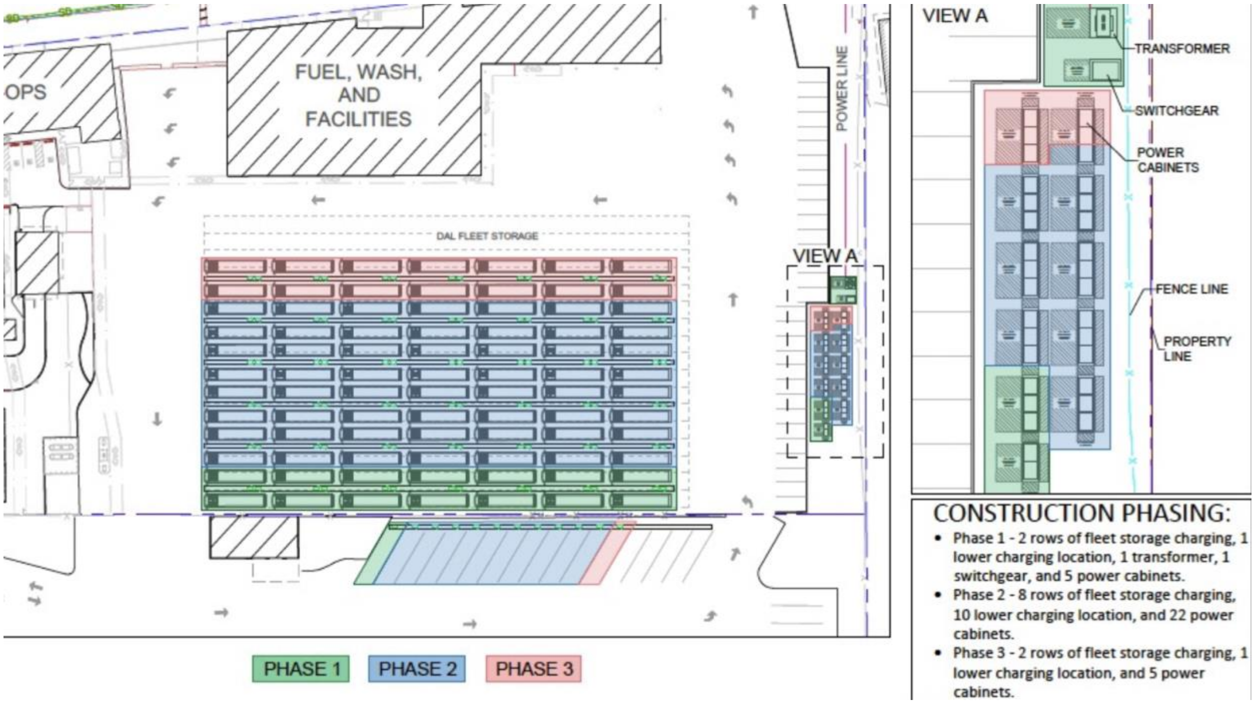


Notes/Assumptions:

- 437ft. maximum total length of trenching from power cabinets to chargers
- 3ft.W x 320ft.L charging islands
- 96 total charging locations
- 3 chargers per cabinet. 32 cabinets required
- 2 rows of DAL Fleet Storage lost

Figure 19: Depot Charging Infrastructure Layout

A phasing plan based on expected BEB operational feasibility is included as **Figure 20.**



CONSTRUCTION PHASING:

- Phase 1 - 2 rows of fleet storage charging, 1 lower charging location, 1 transformer, 1 switchgear, and 5 power cabinets.
- Phase 2 - 8 rows of fleet storage charging, 10 lower charging location, and 22 power cabinets.
- Phase 3 - 2 rows of fleet storage charging, 1 lower charging location, and 5 power cabinets.

Figure 20: Depot Charging Infrastructure Phasing Plan

A rough-order-magnitude (ROM) cost estimate was developed by Hatch to build out charging infrastructure at the depot. All cost estimates for BEB infrastructure should be considered Class IV for a feasibility study, estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates in 2023 dollars are provided in **Appendix A**. Inflation adjusted estimated costs for BEB Depot Only charging infrastructure are depicted in **Figure 21.** Results indicate a total cost of approximately $10.6M to install charging infrastructure at the Pattison Street facility.

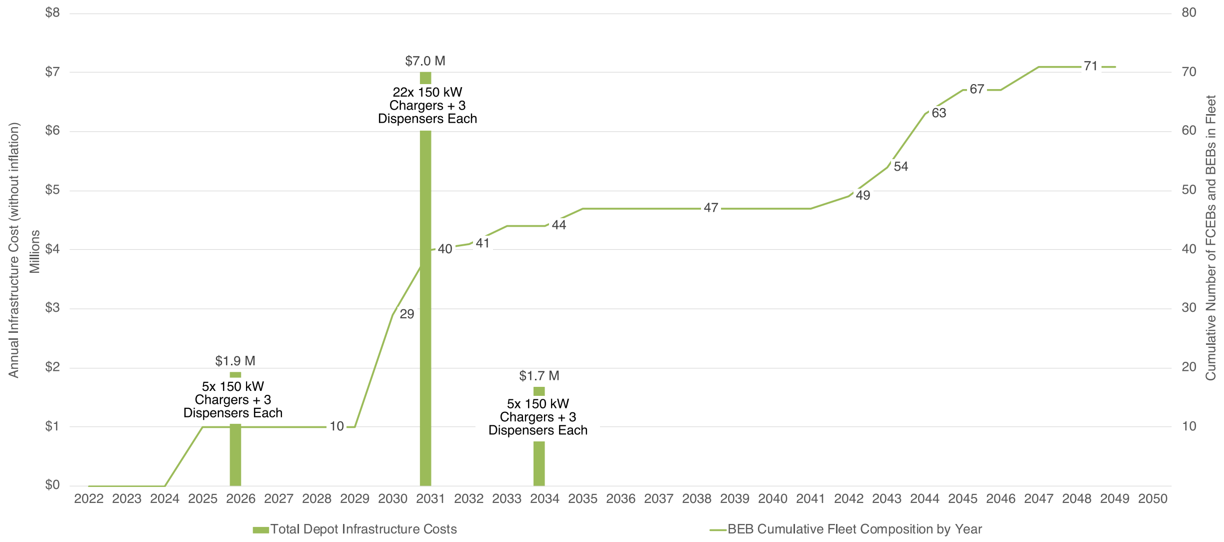


Figure 21: Estimated Infrastructure Costs for BEB Depot Only

On-Route Charging Infrastructure

As discussed in the Service Assessment, on-route charging could be implemented to support Intercity's transition to zero-emission by 2050. On-route charging could be implemented at the Olympia Transit Center (OTC) and Lacey Transit Center (LTC) as early as 2031 to support charging at the depot and extend the range and duration that BEBs can operate on-route. The BEB Depot and On-Route scenario assumes that by 2050, a total of 47 BEBs are charged at the depot only, while 39 BEBs required depot and on-route charging. A more detailed evaluation of on-route charging feasibility, led by Nelson\Nygaard, was completed as part of this assessment to determine the approximate number of chargers required to support this level of on-route charging and determine potential challenges with the strategy. Results from the evaluation, included in **Section 5.1** of this report, indicate that up to eight (8) chargers could be required at the OTC, while only two (2) may be necessary at the LTC based on the current block structure. Based on the electrical demand as well as physical limitations it is likely not feasible to install eight (8) chargers at the OTC. Based on discussions with Intercity, it was determined to assess the cost for on-route charging based on deployment of four (4) chargers at both the OTC and LTC. A more detailed on-route charging evaluation would be required in the future to properly build out a block schedule that would adequately support on-route charging. Additional locations for on-route charging could be considered in the future as well.

Load analysis, based on the installation of four (4) on-route chargers at each of the identified transit centers, was completed to understand the electrical infrastructure and utility sizing requirements. Analysis was previously completed to calculate the peak power that will be drawn by the buses to calculate estimated demand charges; however, the total connected load is driven by the specified size of the charging equipment. This connected load is used to determine the electrical infrastructure design and utility capacity. For the purposes of this analysis, 450-kW overhead conductive chargers were proposed. The load summary is provided in **Table 16.**

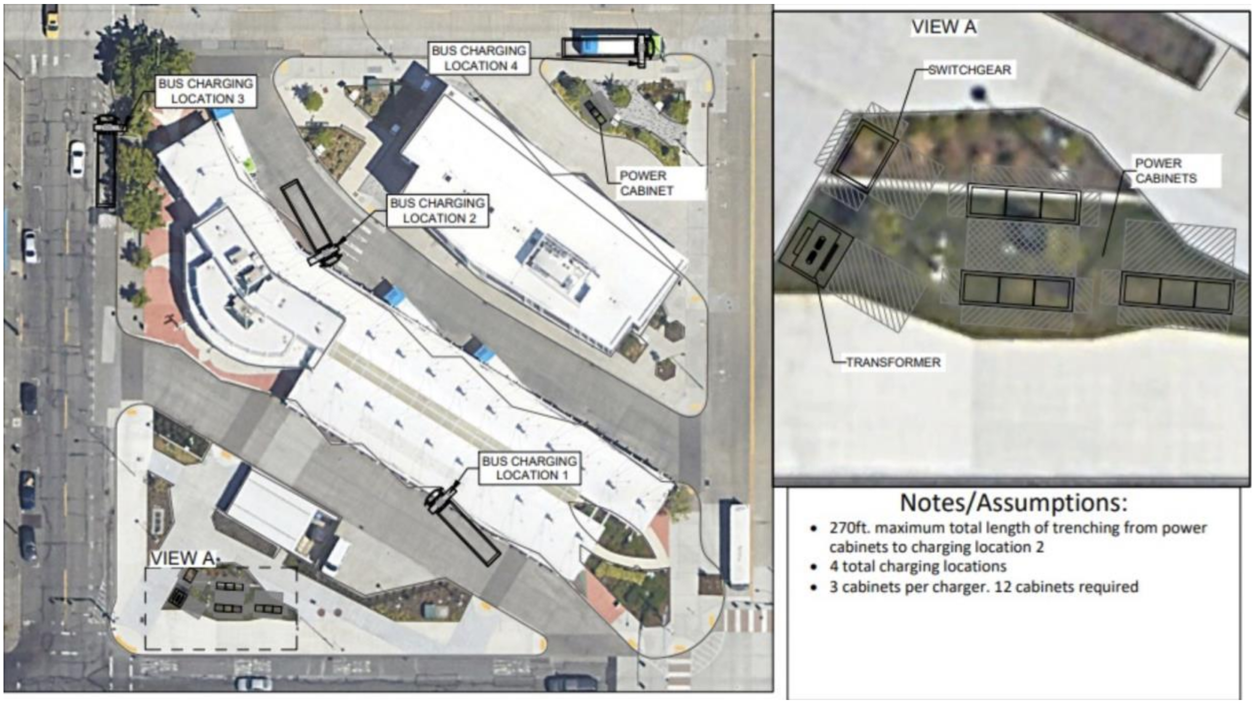
Table 16 - Load Summary for On-Route Charging

Transit Center	# Chargers (450 kW)	Load Summary (kW)
Olympia Transit Center	4	1,800
Lacey Transit Center	4	1,800

At full build-out of four on-route chargers at each location, each transit center is expected to require installation of a minimum 2,000 kVA, 3-phase, 480-volt transformer; however, the electrical utility will ultimately complete the sizing of the transformer. In addition, Intercity will need to design and install 480V switchgear and support infrastructure at each location to distribute the power from the transformer to each charger.

Olympia Transit Center

The OTC, located at 222 State Avenue in downtown Olympia, may be able to support the deployment of up to four (4) 450-kW on-route chargers based on available service capacity and physical space limitations. A conceptual approach for installation of the charging equipment is included in **Figure 22**.

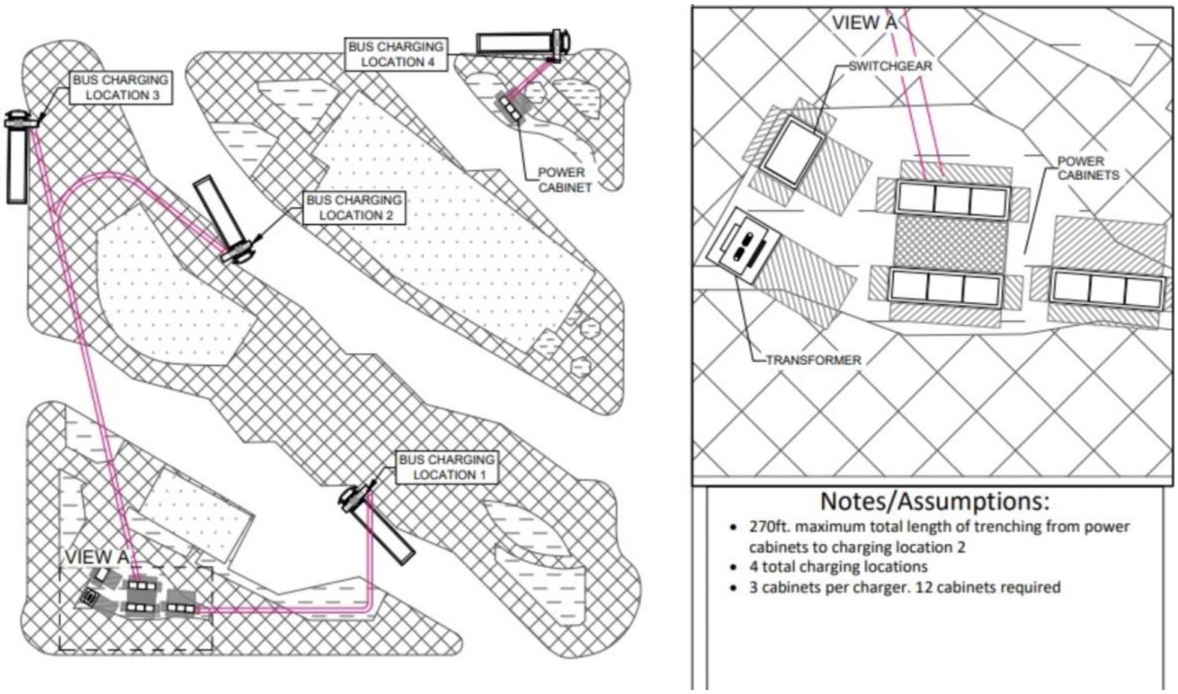


Notes/Assumptions:

- 270ft. maximum total length of trenching from power cabinets to charging location 2
- 4 total charging locations
- 3 cabinets per charger. 12 cabinets required

Figure 22 – Olympia Transit Center Conceptual Charging Layout

A detailed schematic showing the proposed location of the charging infrastructure and the expected trenching required to support installation are included in **Figure 23**.



Notes/Assumptions:

- 270ft. maximum total length of trenching from power cabinets to charging location 2
- 4 total charging locations
- 3 cabinets per charger. 12 cabinets required

Figure 23 – Installation Schematic for On-Route Charging at Olympia Transit Center

Resiliency is an important factor to be considered for on-route chargers because power outages at these locations will have the potential to impact the entire operation. On-site energy storage systems, on-site CNG or diesel generators and mobile generators are all viable alternatives for backup site power. Typically, the frequency and duration of the past outages are used to determine the best resiliency option along with an in-depth cost benefit analysis for each alternative. Unfortunately, information regarding historical power outages at the Olympia Transit Center was not readily available from PSE at the time of this analysis.

However, regardless of the selected technology, there will be additional space requirement at the site. As seen in the layouts, the site is already space constrained which will make it challenging to incorporate these alternatives. A mobile generator, delivered to the site in the event of an outage is likely the most space effective solution for the backup service since the equipment will not take any space at the site when not required. However, the site will still need to have designated space for parking the generator trailers in the event of outages. Provisioning for a connection to a mobile generator to support charging in the event of a power outage is included in the cost estimate.

Lacey Transit Center

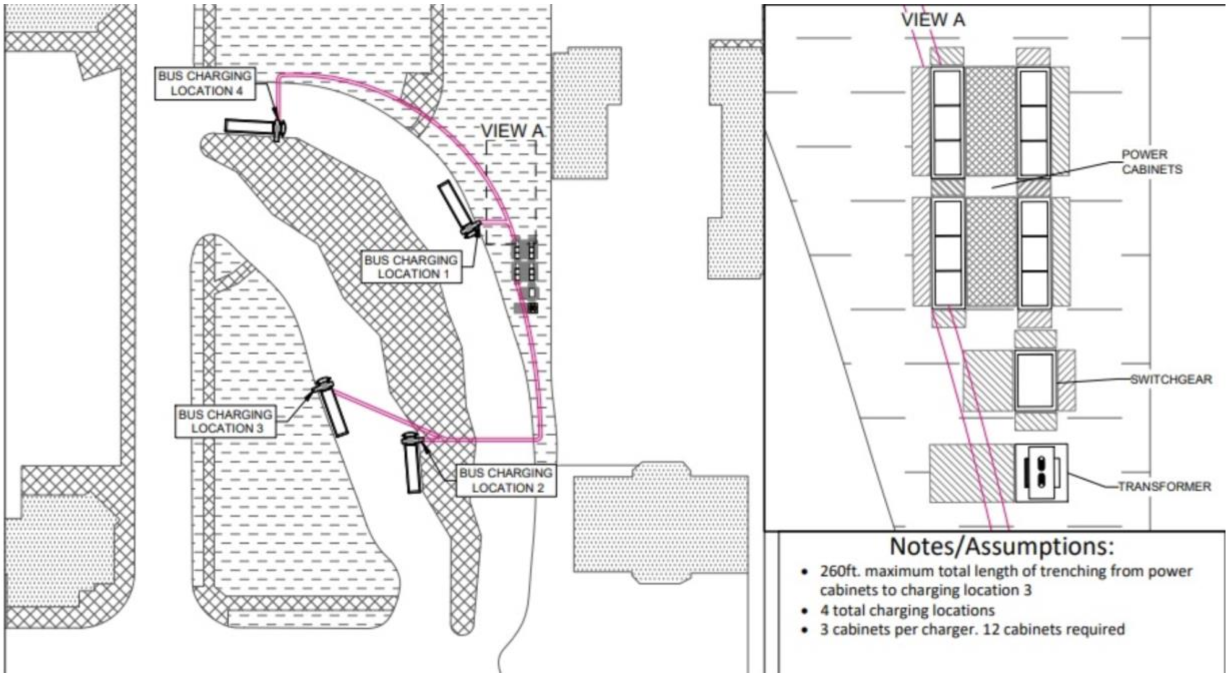
The LTC, located at the corner of 6th Avenue and Golf Club Road in Lacey, is also expected to be able to support the deployment of up to four (4) 450-kW on-route chargers. A conceptual approach for installation of the charging equipment is included in **Figure 24**.

Notes/Assumptions:

- 260ft. maximum total length of trenching from power cabinets to charging location 3
- 4 total charging locations
- 3 cabinets per charger. 12 cabinets required

Figure 24 – Lacey Transit Center Conceptual Charging Layout

A detailed schematic showing the proposed location of the charging infrastructure and the expected trenching required to support installation are included in **Figure 25**.



Notes/Assumptions:

- 260ft. maximum total length of trenching from power cabinets to charging location 3
- 4 total charging locations
- 3 cabinets per charger. 12 cabinets required

Figure 25 – Installation Schematic for On-Route Charging at Lacey Transit Center

Unlike OTC, there is some additional green space to the north of the lot at LTC. Thus, this location might be able to accommodate the selected technology for backup power. As mentioned previously, the frequency and duration of the past outages are typically used to determine the best resiliency option along with an in-depth cost benefit analysis for each alternative. Unfortunately, information regarding historical power outages at the LTC was not readily available from PSE at the time of this analysis. A more in-depth analysis of the outages and a cost-benefit analysis can be conducted to determine if on-site system is suitable for this location and if the available green space can accommodate it. For this study, a provision for a connection to a mobile generator is included in the cost estimate.

A ROM cost estimate was developed to build out charging infrastructure at the two transit centers identified for potential on-route charging. These cost estimates for BEB infrastructure should be considered Class IV intended for a feasibility study with an accuracy range of -30% to +50%. Inflation. An inflation rate of 3% year over year was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates for on-route charging infrastructure in 2023 dollars are provided in **Appendix A**. Inflation adjusted estimated costs for BEB Depot and On-Route BEB charging infrastructure are depicted in **Figure 26.** Results indicate a total cost of approximate $10.6M to install charging infrastructure at the Pattison Street facility and approximately $11M to install charging infrastructure at the Olympia Transit Center and Lacey Transit Center, for a total infrastructure cost of approximately $21.6M.

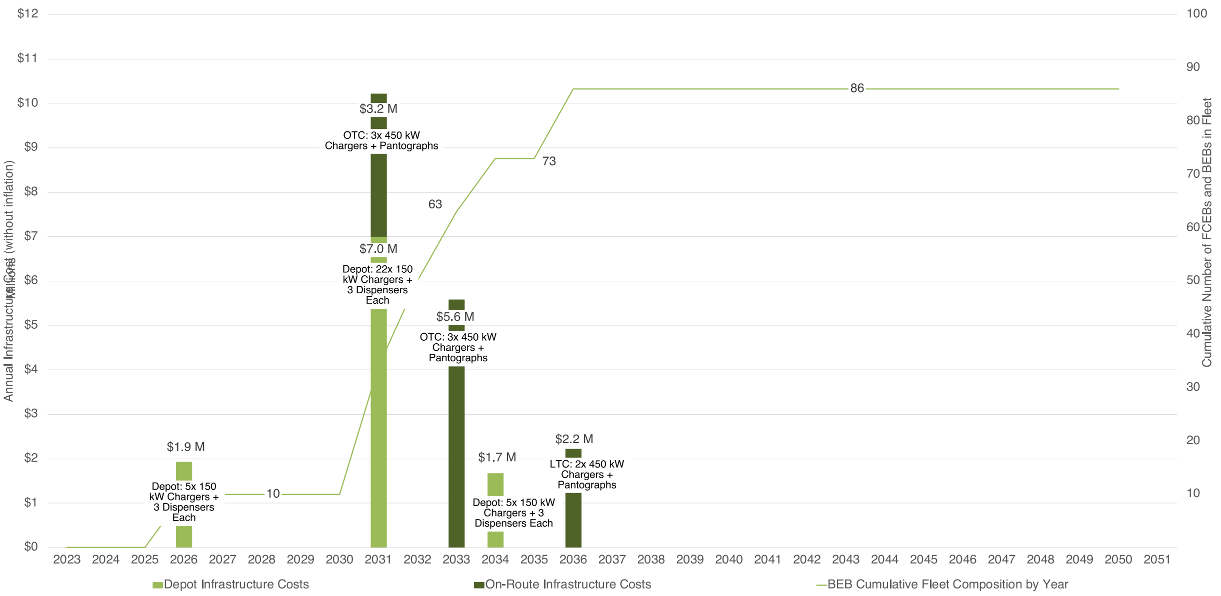


Figure 26: Depot and On-Route BEB Scenario – Infrastructure Assessment

FCEB Infrastructure

A primary advantage of FCEBs is that fueling operations with hydrogen are similar to diesel or CNG fueling operations. As with electric, rather than building out the infrastructure all at once, projects are sized and scheduled to meet the near-term fueling requirements. There are three primary ways that hydrogen can be sourced as depicted in **Figure 27**.

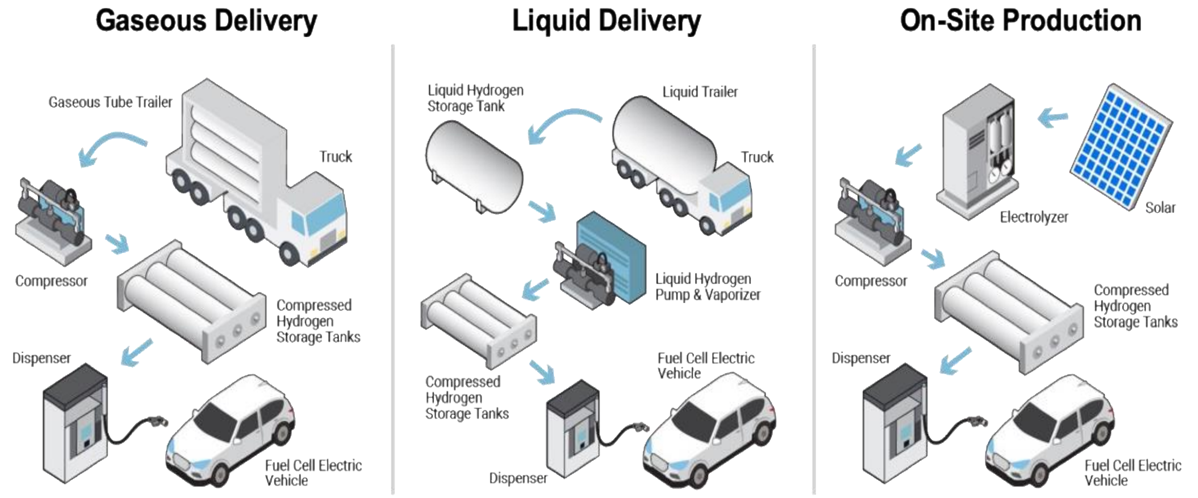


Figure 5. Summary of hydrogen fueling station delivery options (Image source: California Fuel Cell Partnership)

Figure 27: Hydrogen Delivery

Hydrogen can be delivered to the depot either in gas or liquid phases. Although gaseous hydrogen is more readily available today, it is not generally available in quantities that would support a large-scale deployment of buses. Liquid hydrogen is less common; however, there is a major industry-wide effort under way to develop a liquid hydrogen supply chain for transportation sector use. Liquid hydrogen is more energy dense compared to gaseous hydrogen, therefore more energy can be stored on-site to support operations. In addition, it is also more efficient to transport compared to gaseous hydrogen. Photos provided in **Figure 28** depict liquid hydrogen storage and fueling infrastructure at the Orange County Transportation Authority (top) and AC Transit (bottom).

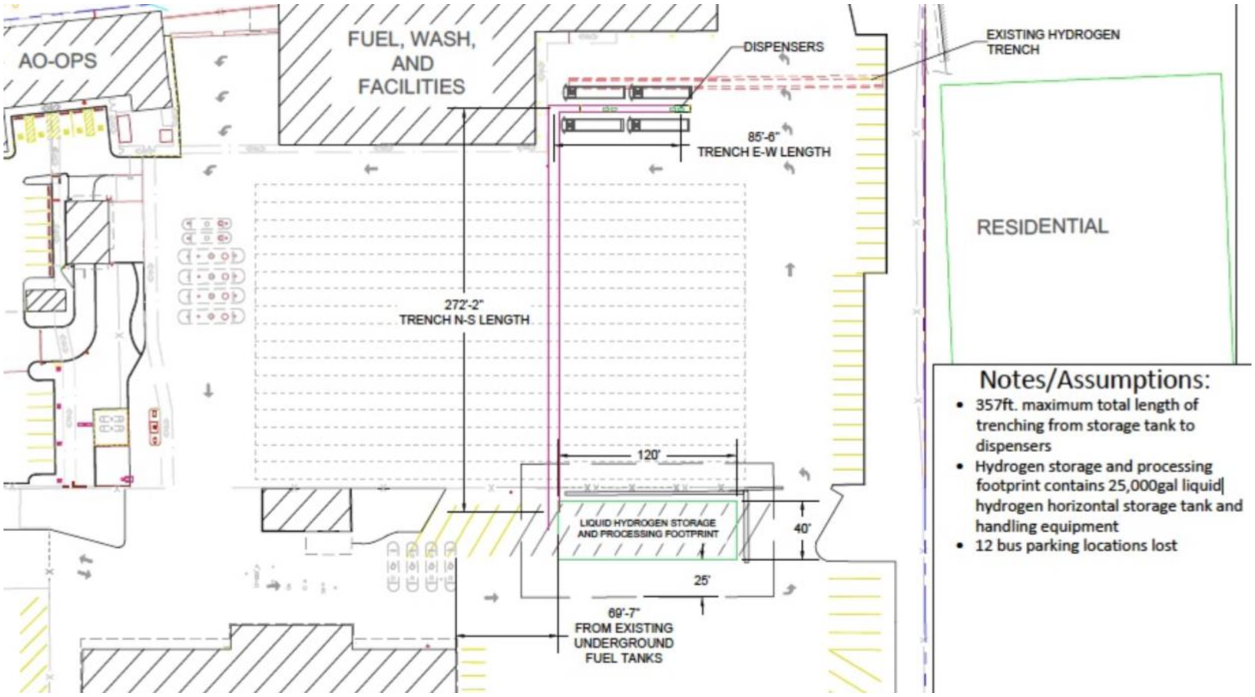
Figure 28: Hydrogen Storage and Dispensing Examples

A third option is the on-site production of hydrogen through steam methane reformation (SMR) or electrolysis. SMR, utilizing methane, water, and heat, is the cheapest and most common method for hydrogen production in the United States today; however, significant quantities of carbon dioxide are produced as a byproduct. Electrolysis utilizes water and electricity to produce hydrogen with the only biproduct being oxygen gas. This is the preferred alternative for hydrogen production, particularly if it is produced using renewable energy sources. This is often referred to as green hydrogen and is low-carbon intense. The United States government has made significant investment in building out hydrogen production infrastructure with $8 billion in funding for the Regional Hydrogen Hub program as well as providing tax incentives for producers/suppliers of green hydrogen.

For Intercity's application, it was assumed that the hydrogen will be delivered and stored at the depot rather than produced on-site due to the space constraints and cost. Intercity would also have the associated dispensers and fueling infrastructure on site in addition to the storage. Infrastructure costs were estimated based on similar projects that are either completed to date or currently scoped.

A mobile fueling station (fueler), provided by a third-party hydrogen supplier, could be used to support the deployment of the first approximately ten (10) FCEBs as part of an initial pilot program considered by Intercity. A mobile fueler consists of the equipment to store, compress, chill, and dispense hydrogen fuel to the buses. The fuelers are typically zero-emission and may not require utility hook ups. Liquid hydrogen can be delivered by truck to the fueler. A cost estimate for this option was not included in this evaluation.

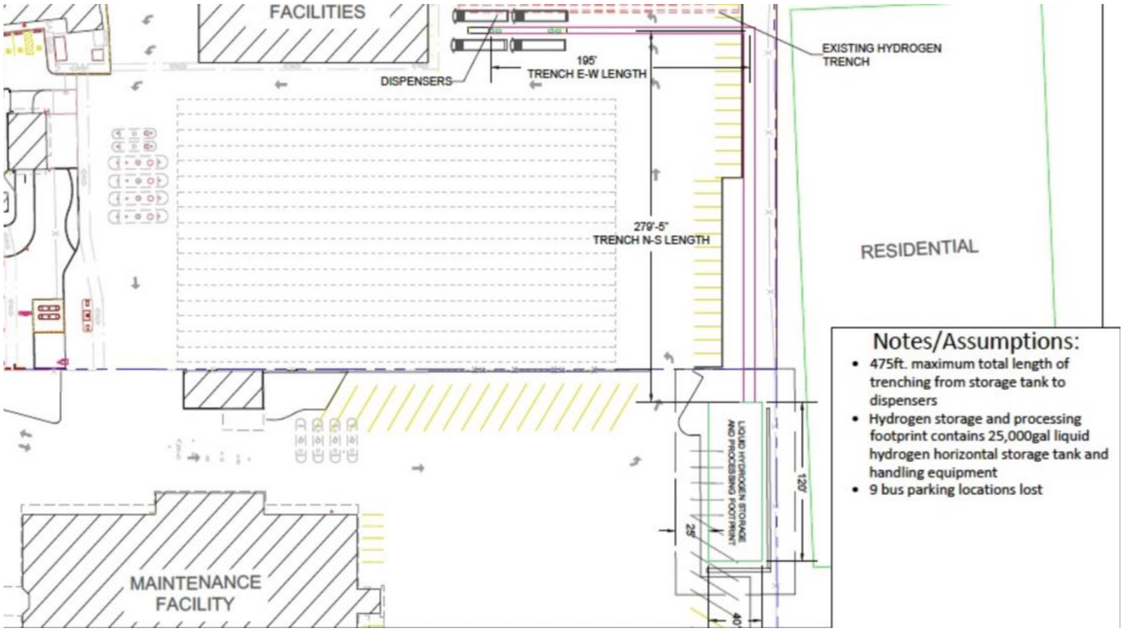
In order to support a growing FCEB fleet beyond ten (10) vehicles, permanent hydrogen fueling infrastructure would be required which would include a 25,000-gallon liquid hydrogen tank, two vaporizers, two pumps, and one assembly of high-pressure gaseous hydrogen storage vessels. This equipment is based on an assumed fueling time of 12 to 18 minutes per bus, a 36 kg hydrogen storage capacity of the bus, and up to three (3) days of hydrogen storage. Conceptual layouts for three different options for location of the storage and dispensing equipment are included in **Figure 29** through **Figure 31**. Final determination of the hydrogen storage equipment and fueling infrastructure would be developed as part of a competitive procurement process to select the infrastructure vendor.



Notes/Assumptions:

- 357ft. maximum total length of trenching from storage tank to dispensers
- Hydrogen storage and processing footprint contains 25,000gal liquid| hydrogen horizontal storage tank and handling equipment
- 12 bus parking locations lost

Figure 29: Hydrogen Fueling Infrastructure Layout – Option 1



Notes/Assumptions:

- 475ft. maximum total length of trenching from storage tank to dispensers
- Hydrogen storage and processing footprint contains 25,000gal liquid hydrogen horizontal storage tank and handling equipment
- 9 bus parking locations lost

Figure 30: Hydrogen Fueling Infrastructure Layout – Option 2

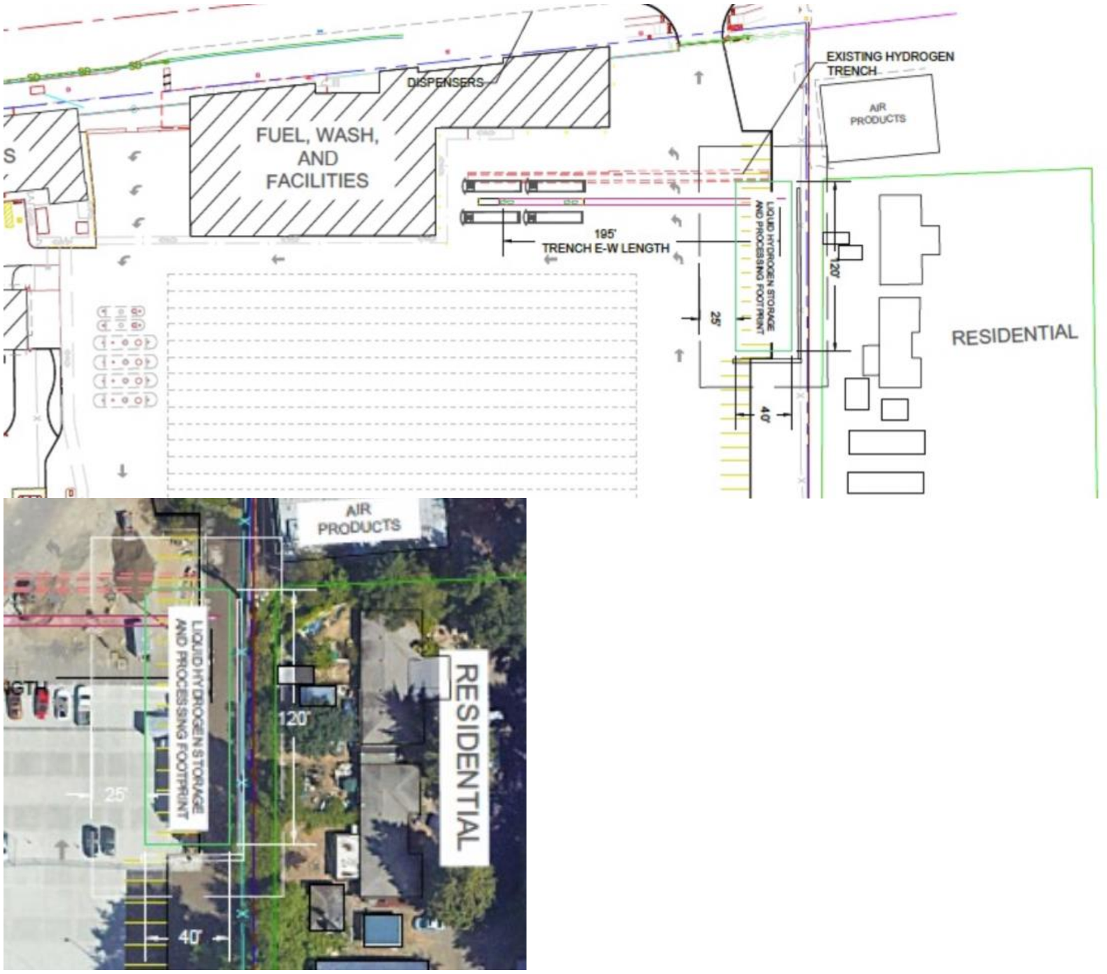


Figure 31: Hydrogen Fueling Infrastructure Layout – Option 3

In addition to the hydrogen fueling infrastructure, upgrades to the maintenance building would be required to support conducting maintenance activities on the fueling systems for hydrogen FCEBs. Typically, these include improvements to ventilation, addressing electrical hazards, and adding hydrogen gas detection. It is expected that the necessary improvements to the maintenance building will be completed as part of a current capital improvement project scheduled for the facility.

A ROM cost estimate was developed to build out hydrogen fueling infrastructure at the Pattison Street facility. Please note that the costs do not include estimates for development of an initial pilot that could include use of a mobile fueler for the deployment of FCEBs. The cost estimates for FCEB infrastructure should be considered Class IV for a feasibility study estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates in 2023 dollars for hydrogen fueling infrastructure are provided in **Appendix A**. Inflation adjusted estimated costs for hydrogen fueling infrastructure to support a transition to FCEB operations are provided in **Figure 32.** Results indicate a total cost of approximately $11.7 million, completed over two years.

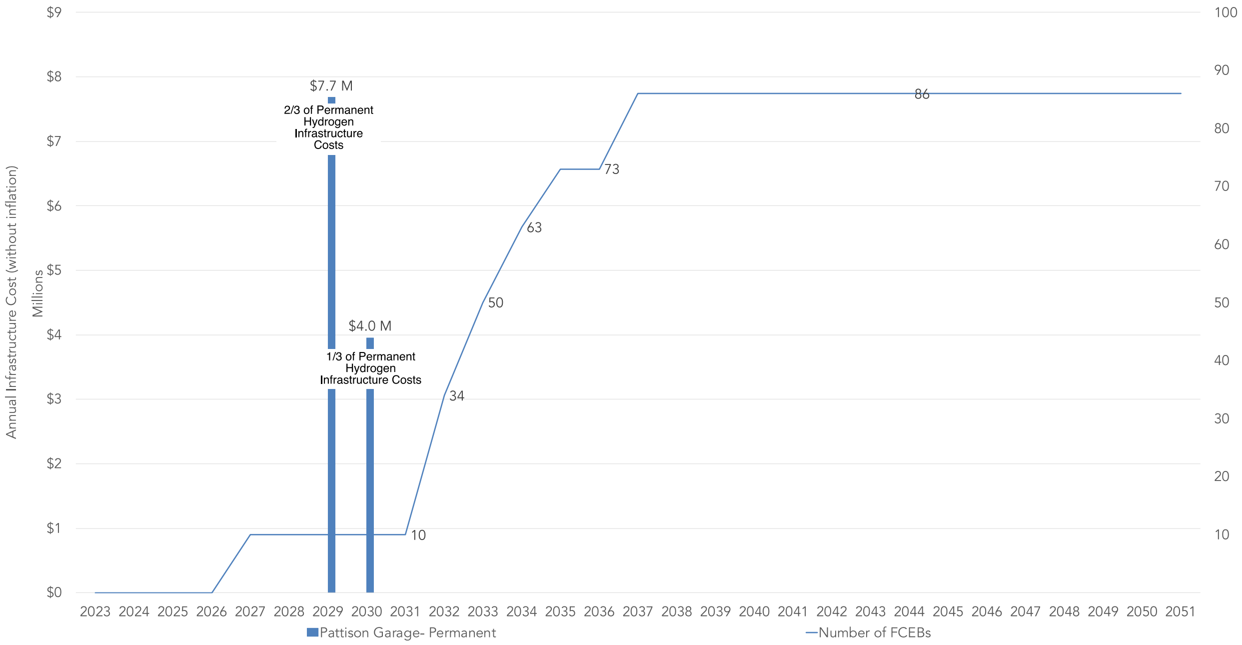


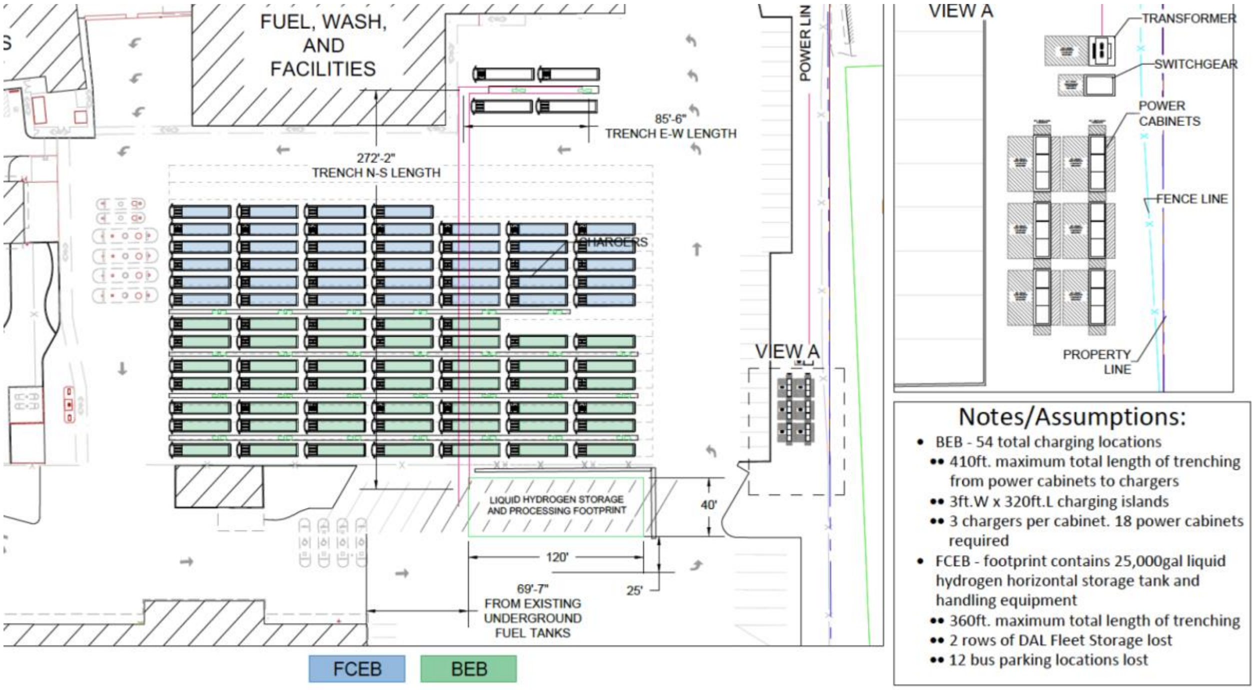
Figure 32: FCEB Only Scenario – Infrastructure Assessment

Mixed Fleet – BEB and FCEB Infrastructure

In a mixed fleet scenario, BEB charging infrastructure is required to support 39 BEBs while hydrogen fueling infrastructure is required to support the remaining 47 FCEBS that would compose the Intercity fleet in 2050 in this scenario.

The BEB infrastructure in this scenario is a scaled down version of the BEB Infrastructure previously detailed in the BEB Depot Only scenario – as less buses are transitioned to BEB. This scenario would include sufficient charging capacity to charge 39 BEBs (three buses per charger) with plug-in dispensers installed on raised concrete islands in the parking area.

FCEB infrastructure associated with a mixed fleet would be similar to the equipment described in the FCEB Only scenario, including installation of at least two (2) dispensers at the current fueling rack. A conceptual layout to include both charging and hydrogen fueling to support transit bus deployment are included on **Figure 33**.



Notes/Assumptions:

- BEB - 54 total charging locations
  - 410ft. maximum total length of trenching from power cabinets to chargers
  - 3ft.W x 320ft.L charging islands
  - 3 chargers per cabinet. 18 power cabinets required
- FCEB - footprint contains 25,000gal liquid hydrogen horizontal storage tank and handling equipment
  - 360ft. maximum total length of trenching
  - 2 rows of DAL Fleet Storage lost
  - 12 bus parking locations lost

Figure 33: Depot BEB and FCEB Infrastructure Layout

A ROM cost estimate was developed to build out both the charging and hydrogen fueling infrastructure at the Pattison Street facility to support a mixed fleet of transit buses. The cost estimate should be considered Class IV for a feasibility study estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates for the Mixed Fleet scenario in 2023 dollars, to include both charging and hydrogen fueling infrastructure, are provided in **Appendix A**. Inflation adjusted estimated costs for the charging infrastructure are approximately $6M while the hydrogen fueling infrastructure is estimated at approximately $11.7M for a total infrastructure cost of approximately $17.7M as provided in **Figure 34.**

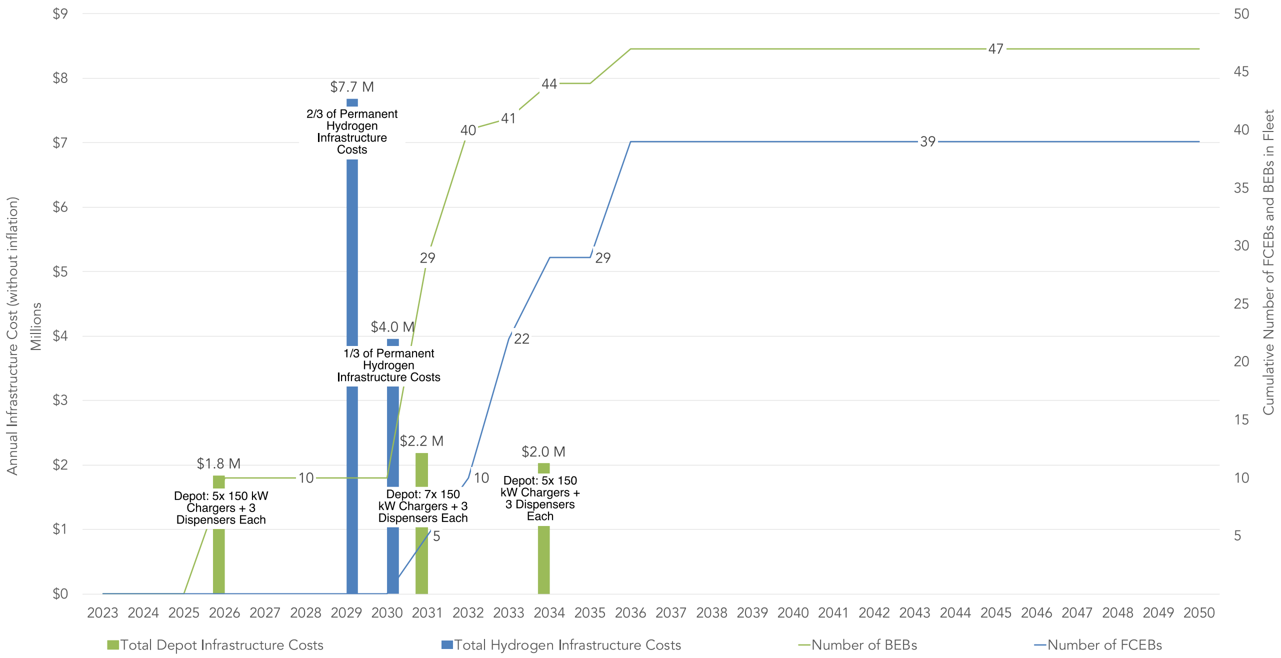


Figure 34: Depot BEB and FCEB Scenario – Infrastructure Assessment

Infrastructure upgrade costs for the different transition scenarios, including a comparison to Baseline, are provided in **Table 17**. Please note that there are no capital costs associated with the Baseline as all of the infrastructure associated with baseline fueling is already in place. On-going maintenance costs for fueling infrastructure are included in the fuel cost evaluation as a component of the fuel cost.

Table 17: Infrastructure Cost Evaluation (ROM Estimates, -30% to +50% Range)

Category	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet	FCEB Only Fleet
Infrastructure	$10.6M	$21.6M	$17.7M	$11.6M
% of Blocks Achievable with ZEBs by 2050	83%	100%	100%	100%

4.8 - Total Cost of Ownership

The Total Cost of Ownership compiles the results from the Service, Fleet, Fuel, Maintenance, and Facilities assessments to provide estimated costs for the fixed route fleet throughout the transition period. It includes selected capital and operating costs of each transition scenario over the transition timeline. There may be other costs incurred (i.e., incremental operator and maintenance training); however, these four assessment categories are the key cost drivers in ZEB transition decision-making.

It is important to note that cost reductions are not considered for economies of scale related to ZEB technology growth because there is no historical context with which to estimate. Future changes to Intercity's service level, depot locations, route alignments, block scheduling, etc. are unknown. The provided costs are an estimate, informed by detailed analysis using assumptions explained throughout this study. The estimated Total Cost of Ownership for Intercity's fixed-route ZEB transition as detailed in this analysis are provided in **Table 18** and **Figure 35**.

Table 18: Total Cost of Ownership for ZEB Transition (2023-2050)

Category	Baseline	BEB Depot Charging Only	BEB Depot and On-Route Charging	Mixed Fleet	FCEB Only Fleet
Fleet	$270.3M	$408.8M	$468.6M	$477.5M	$493.5M
Fuel	$109.3M	$71.2M	$50.5M	$71.3M	$102M
Maintenance	$95.7M	$81.5M	$74M	$78M	$88.2M
Infrastructure	$-	$10.6M	$21.6M	$17.7M	$11.6M
Total	**$475.3M**	**$572M**	**$614.8M**	**$646.5M**	**$695.4M**
Compared to Baseline	$-	+$96.7M	+$139.5M	+$171.2M	+$220.1M
% of Blocks Achievable with ZEBs by 2050	0%	83%	100%	100%	100%

Results from the total cost of ownership analysis indicates that additional costs, expected to be between $96.7 million to $220.1 million more than Baseline, will be required to support a transition to ZEBs, whether BEBs, FCEBs, or a Mixed Fleet are selected.

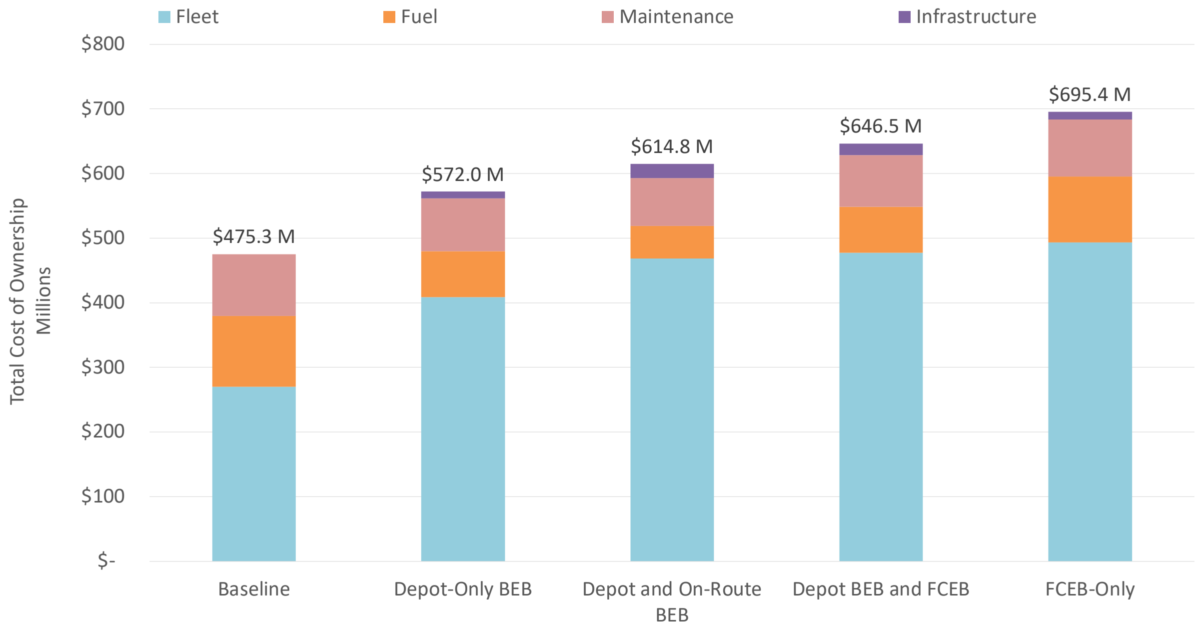


Figure 35: Total Cost of Ownership for ZEB Transition (2023-2050)

Section 5 - Risks, Challenges, and Operational Considerations for Fixed Route

5.1 Scheduling Impacts

Background and Purpose

The purpose of this analysis was to better understand the implications of electrification on scheduling for Intercity's fixed-route transit service. This analysis was part of Intercity's broader initiative to plan for a full zero-emissions fleet across its lines of business by 2050.

This analysis was based on Intercity's 2023 route network and schedule, and assesses the implications of on-route and depot charging on scheduling and operations. This analysis should not be considered comprehensive. By the time on-route charged buses become part of Intercity's fixed route operations sometime in the early part of the next decade, the precise service makeup is almost certain to have changed from the actual conditions present in today's system. This assessment was intended to gauge the implications of on-route charging at a conceptual level and to point out areas that require further analysis and planning before final decisions are reached or further design efforts are launched.

Assumptions and Methodology

For the 2023 assessment, the feasibility analysis for charging at the depot was used as a baseline, which consisted of identifying the vehicle blocks that could be served by one bus on a single battery charge within a service day. Then, for the remaining blocks, an evaluation of the vehicle's block length and on-route charger location was performed to understand the electrification feasibility and the block scheduling impacts if the vehicle was charged on-route.

The performance of the electric batteries installed in a bus is a critical determinant of the electrification feasibility. The nameplate or nominal battery capacity (the capacity stated by the manufacturer) cannot be considered as the actual energy available for the bus operation. **Figure 36** shows the constraints that reduce the nameplate capacity to the actual on-board battery capacity used in this analysis. Other best practices for BEB operations that were considered in this analysis include the following:

- **Maximum allowable charge:** To maximize the performance and increase the longevity of a battery, manufacturers recommend charging the battery below its 100% capacity. Most battery charging management systems automatically limit the charge of a battery to a certain threshold. For this analysis, we assumed that the maximum allowable capacity of the bus battery is 90%, i.e., 10% of the battery energy capacity cannot be considered available.
- **Battery life degradation:** Batteries have a finite number of cycles that can be recharged, and under the current technology, the battery's energy capacity diminishes with every cycle. Hence, to accurately estimate the feasibility of on-route charging, this analysis assumes that there will be a 10% decrease in the usable capacity (or 9% of the nameplate capacity) due to midlife battery degradation.

- **Minimum state of charge and energy reserve:** To protect the long-term useful life of the battery, manufacturers also recommend maintaining a minimum energy level in the battery, i.e., to avoid draining the energy in the battery to zero. Additionally, it is a best practice to reserve some energy in the battery in case unexpected conditions arise that force the bus to use more energy, for example, unexpected route detours. This analysis assumes that the battery must maintain 20% of energy for a minimum state of charge and reserve.

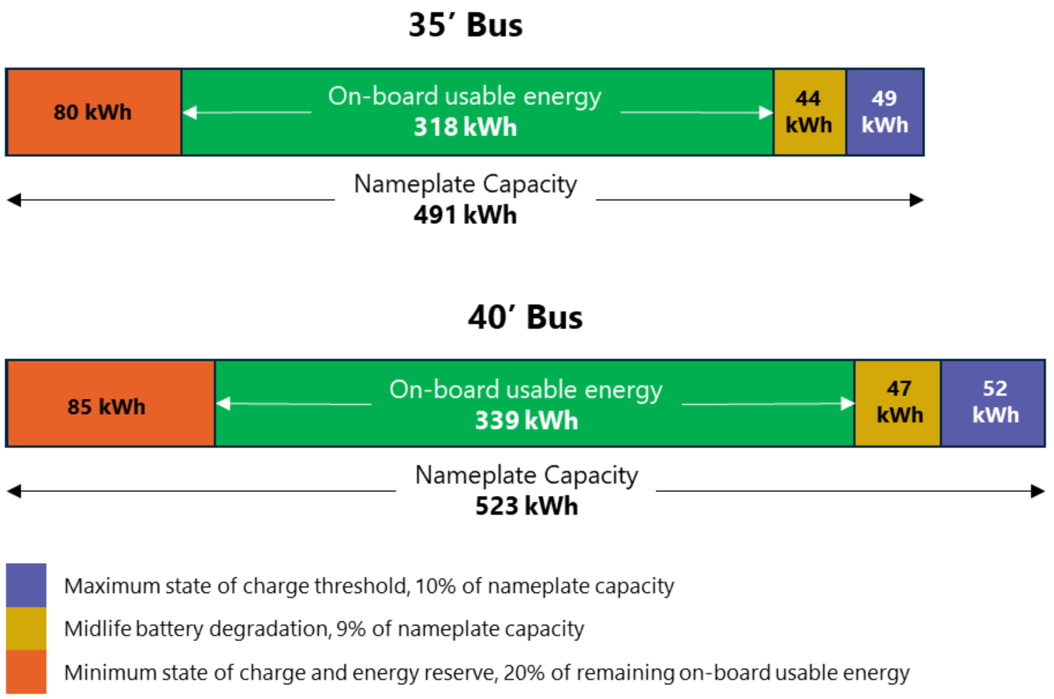


Figure 36: Typical Battery Capacity on a BEB

Using this battery on-board capacity and the strenuous energy consumption for each route, the blocks were estimated that could be electrified using on-route charging as depicted in **Figure 37**. Additional assumptions for this assessment are as follows:

- Scheduling for all infeasible blocks was attempted on-route
- On-route chargers would be located at the Olympia Transit Center and Lacey Transit Center with the following capacity:
  - 300 kW on-route charger (overhead SAE J3105-1 pantograph)
  - 5% of transmission loss from max power
  - Use of full layover time for charging at max power

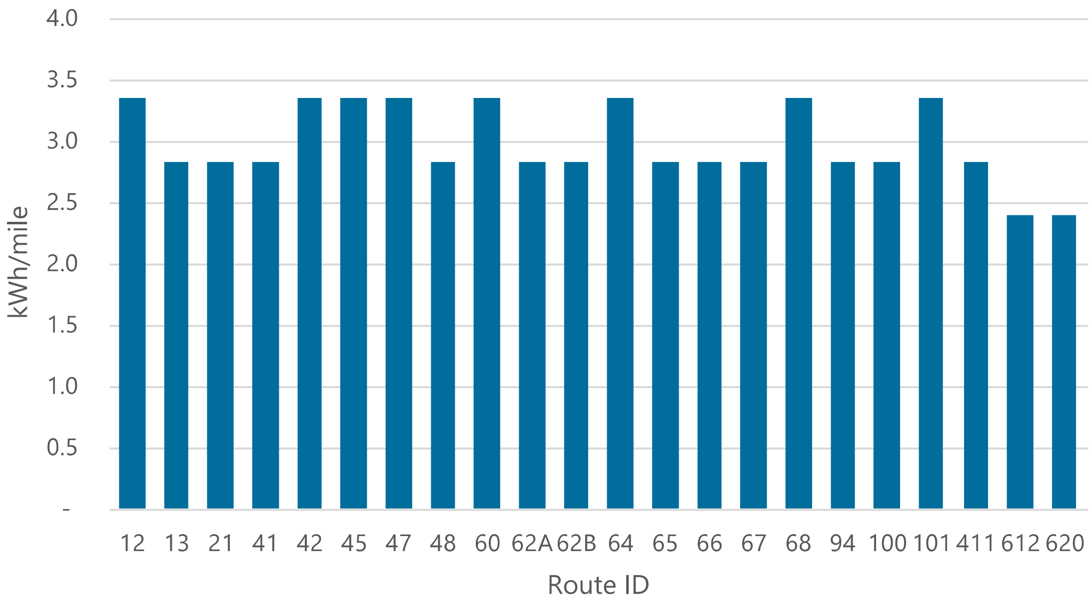


Figure 37: Assumed Strenuous BEB Energy Consumption by Route

To account for the evolution of battery technology, the on-route charging and scheduling impact was also evaluated, assuming the 2036 expected battery capacity as calculated based on a 5% improvement in capacity every other year. The 2036 assessment follows the same assumptions as in 2023, but incorporating the battery capacity outlined in **Figure 38**.

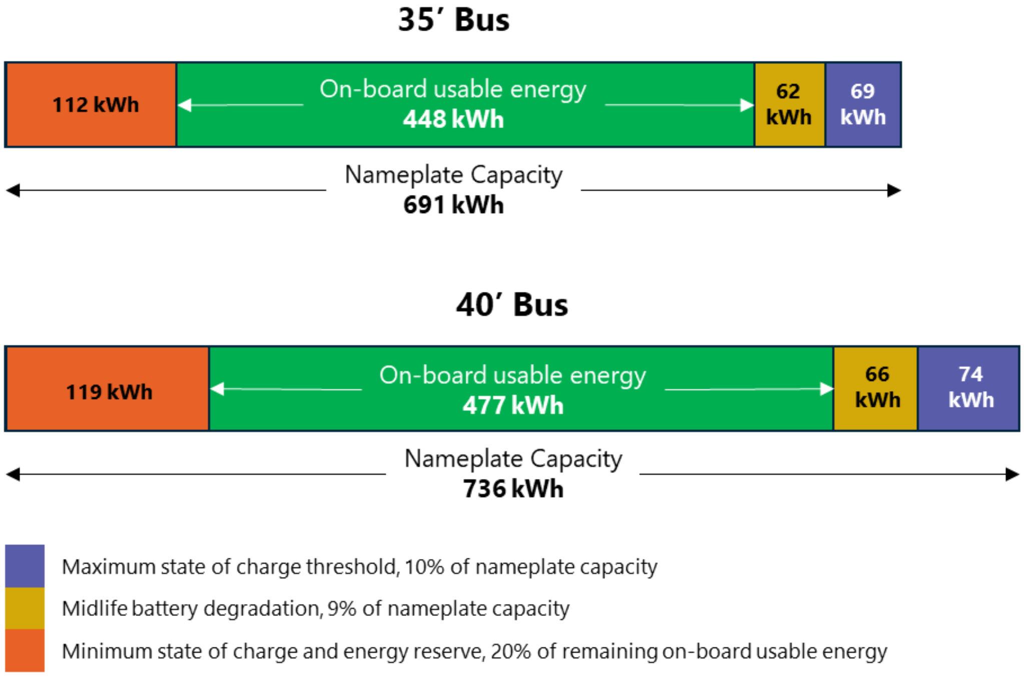


Figure 38: Expected Battery Capacity on a BEB in 2036

Results

Under the 2023 model, 69% of blocks could be electrified, either with charging at the depot or while laying over at the end of the line at the Olympia and Lacey Transit Centers as detailed in **Table 19**.

Table 19: On-Route Modeling Results (2023)

	Number of Blocks	Percent of Blocks
All Blocks	76	100%
Depot Charging	27	36%
On-Route Feasible	25	33%
On-Route Infeasible	24	32%

Under 2023 conditions, the model identified nine routes with infeasible blocks for on-route charging: Routes 12, 45, 612, 62A, 62B, 64, 65, 68, and 94. Of the infeasible blocks, five blocks would additionally need to charge on-route for less than 15 minutes, eight blocks would need additional charging time of between 15 and 30 minutes, and eleven blocks would need more than 30 minutes of on-route charging time added to the block to maintain the desired state of charge.

Olympia Transit Center Demand

Figure 39 shows the results of the model for on-route charging at the OTC. Because several blocks converge at OTC, the number of chargers in use varies significantly. For some 5-minute intervals between 7 AM and 4 PM, zero or one charger would be in use, but for many five-minute intervals, either seven or eight chargers would be in use simultaneously. The maximum simultaneous demand for chargers is eight, and there are 31 instances throughout the day of a five-minute periods where there is demand for seven chargers. At peak demand, the model estimates a power draw of 2,700 kW.

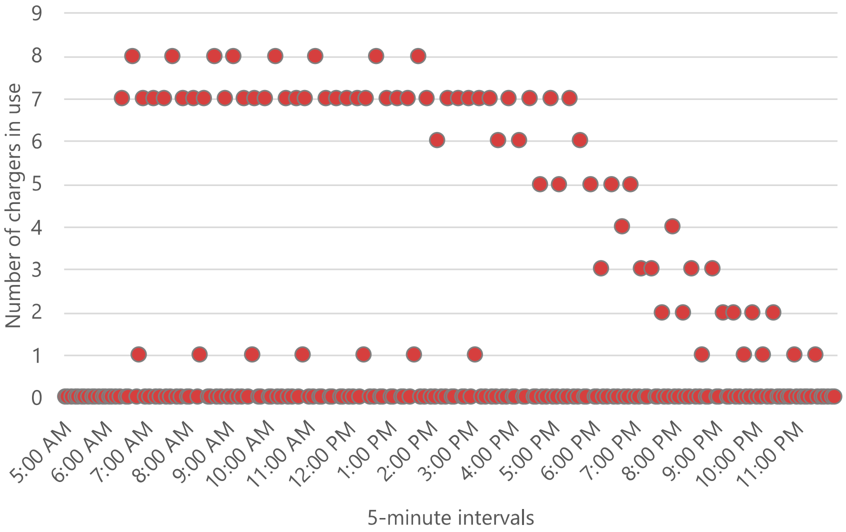


Figure 39: Olympia Transit Center Charging Demand, 2023 Model

Lacey Transit Center Demand

Figure 40 represents on-route charging at the LTC. The LTC experiences significantly less demand than OTC, with a maximum of only two chargers needed simultaneously, and only for three 15-minute intervals between 1 PM and 4 PM. Peak demand at LTC would require about 600kW of power.

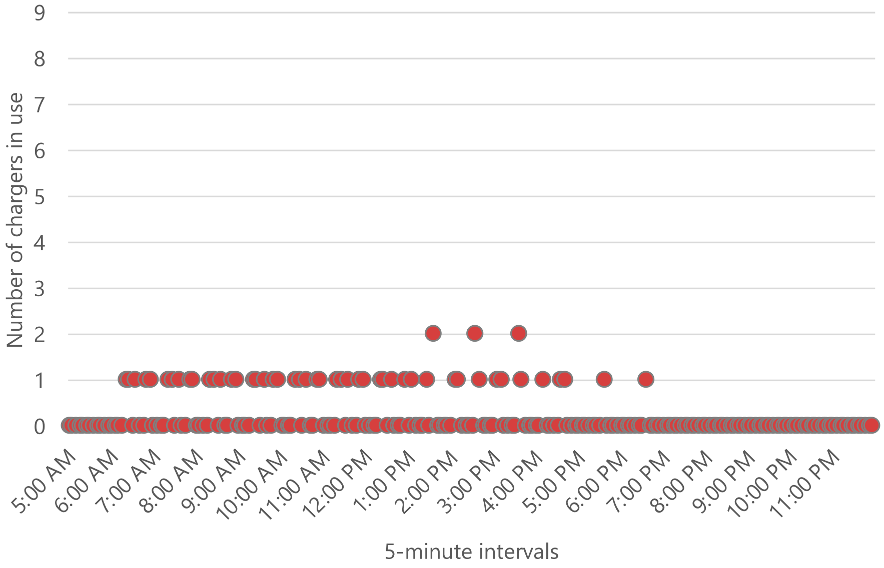


Figure 40: Lacey Transit Center Charging Demand, 2023 Model

Under the 2036 model, there is a significant increase in the number of blocks that can be electrified with the combination of depot and on-route charging, with 85% of blocks able to charge at the depot or on-route at the Olympia and Lacey Transit Centers as depicted in **Table 20.**

Table 20: On-Route Modeling Results (2036)

	Number of Blocks	Percent of Blocks	Percent Change from 2023
All Blocks	76	100%	--
Depot Charging	46	61%	+70%
On-Route Feasible	18	24%	-28%
On-Route Infeasible	12	16%	-50%

Under 2036 conditions, the model identified six routes with infeasible blocks for on-route charging: Routes 12, 45, 612, 62B, 65, 68, and 94. Additionally, only two blocks would need more than 15 additional minutes of on-route charging at their layover to become feasible as depicted in **Table 21**.

Table 21: On-Route Modeling Results (2036)

Infeasible Block	Route	Min State of Charge at end of Block (kWh) – 2036	Additional Required kWh	Additional Required Time (min)
9401	94	-77.0	196.21	41
9902	612	41.2	78.06	16
6803	65, 68	47.5	71.73	15
9405	94	63.3	55.89	12
6801	65, 68	69.7	49.50	10
6802	65, 68	69.7	49.50	10
6806	68	69.7	49.50	10
6808	68	69.7	49.50	10
1203	12	84.5	34.75	7
1202	12, 62B	86.4	32.86	7
6807	65	108.8	10.39	2
6804	68	117.6	1.65	0.3

Olympia Transit Center Demand

The 2036 model still requires significant charging capacity at the OTC. With larger batteries and more blocks operating on-route charging, the use of chargers extends further into the day with some even in use until midnight. The peak demand period extends into the evening for an additional hour, spanning from 7 AM and 7 PM as depicted in **Figure 41**. The maximum simultaneous demand for chargers is eight, with 14 instances throughout the day. There are 34 instances throughout the day when seven chargers would be simultaneously in use. At peak demand, the model estimates a power draw of 2,700 kW.

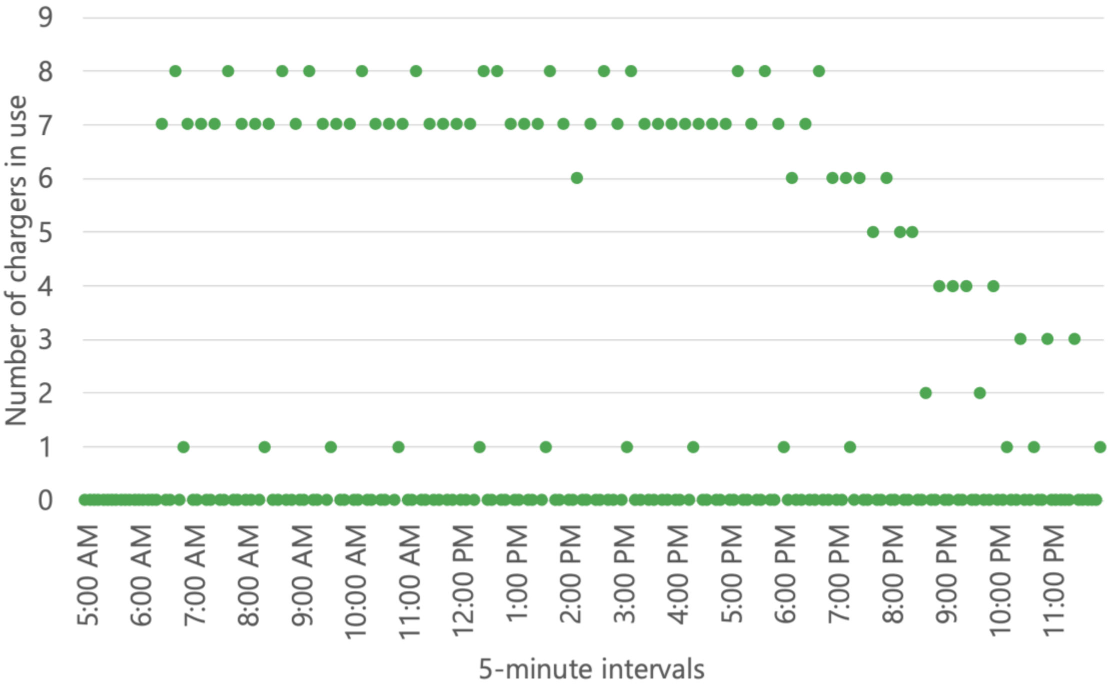


Figure 41: Olympia Transit Center Charging Demand, 2036 Model

Lacey Transit Center demand

Charging demand at the LTC will increase slightly in the 2036 model but will remain significantly lower than OTC. There is still a maximum of only two chargers used simultaneously throughout the day for five 15-min intervals between 1 PM and 6 PM as depicted in **Figure 42**. Peak demand at LTC would continue to require about 600kW of power.

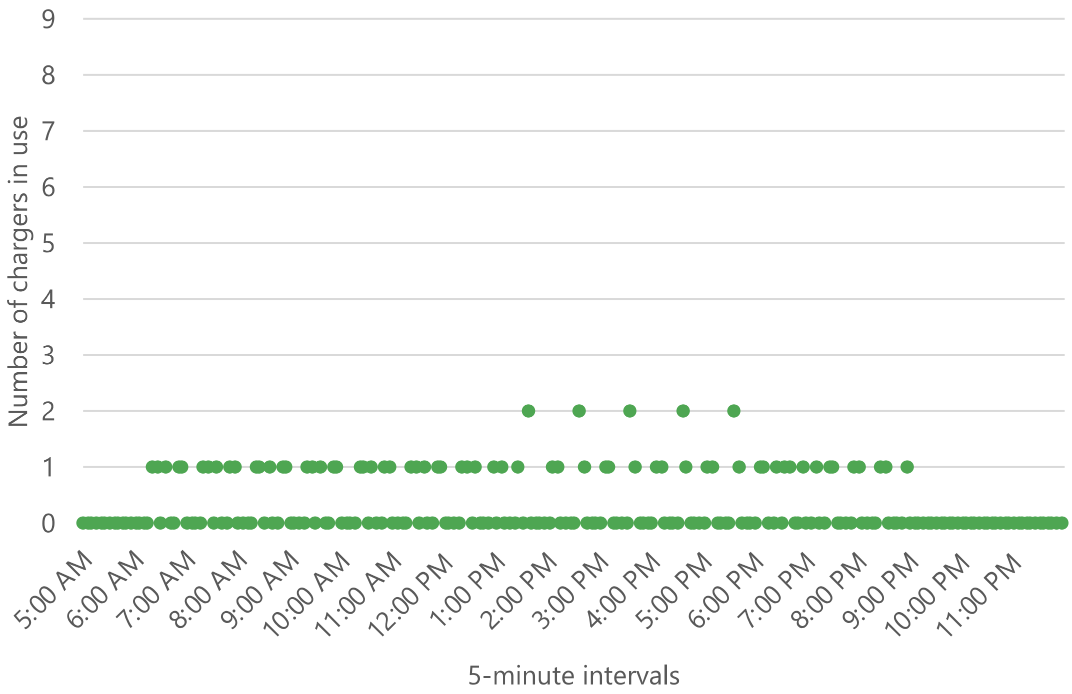


Figure 42: Lacey Transit Center Charging Demand, 2036 Model

Recommendations and Next Steps

The model relies on Intercity's current fixed-route schedule and will need to be reassessed in the event of future service changes that significantly change vehicle routing, vehicle blocking, practices in layover, practices in operator reliefs, service area, service frequencies, or service span.

The 2036 model is also based on anticipated technological improvements in battery capacity. However, it should also be noted that the last decade has resulted in significant advances in battery chemistry that improve charging times and charging capacity. These factors are expected to continue to evolve and improve. Taken together, these factors may draw a more optimistic picture of on-route charging in 2036 compared to today. It would be beneficial for Intercity to reevaluate this model in the interim period between 2023 and 2036 to evaluate if the conclusions are still accurate and adjust as necessary.

Evaluation in 2036 was selected for a future scenario, as Intercity is expected to first purchase depot charged buses to replace existing diesel buses. Only by 2036 does it become necessary, assuming a constant fleet size and the existing block construction, to begin adding replacement buses with on-route charging capability to improve the number of feasible blocks. That is not a mandate or an absolute, but does provide a reasonable assumption about how Intercity may phase in on-route charged BEBs.

The model shows that there will be consistent high demand for on-route charging at the OTC in both the 2023 and 2036 scenarios. To accommodate infeasible blocks or better distribute charging demand across the system, it is recommended to investigate the feasibility of alternative layover locations to better distribute demand across the transit system and service area. Nelson\Nygaard identified potential locations during this evaluation. These locations are not solely owned by Intercity, but may be feasible with negotiation and agreement between stakeholders. These locations are the Amtrak Station, Capital Mall, the Tacoma Dome Station, and the Yelm Walmart.

Further, the projections assume that the layover times reflected in the current schedules are 100% available for charging. This assumption requires careful evaluation as there are two factors that could decrease this availability and reduce the block feasibility:

1. Some amount of time may be necessary to connect the bus with the charging infrastructure. Even if overhead pantograph charging systems are deployed, the physical connection/disconnection and then the digital connection/disconnection still require some time to occur. During these times, power is not flowing into the bus.
2. There are two primary purposes for layovers, sometimes called recovery time. One purpose is to allow the human operating the vehicle to take a rest break. The other reason is to make up for the fact that fixed route operations are not precise. They operate within a range, and recovery time provides a buffer so that operations remain reliable. For depot charging scenarios, this will have an impact on charging time and block feasibility. The actual variability of Intercity’s operations, which is different than on-time performance where the standard for on-time allows as much as five minutes of variability, needs to be evaluated to test the sensitivity of assumptions about how much charging time is routinely available as opposed to what is scheduled.

Many transit agencies experienced with on-route charging report that the charging requirements often exceed the amount of layover/recovery time allocated and that to achieve full charge, schedules must be adjusted to allow enough time to take on enough power for the bus to remain in service. This factor, along with the others listed above, will require more investigation and analysis if Intercity decides to pursue a strategy that extensively depends on on-route charging.

Section 6 – Dial-a-Lift Fleet Analysis

6.1 –Scenarios and Assumptions

The Dial-A-Lift service is a door-to-door transportation service compliant with the Americans with Disabilities Act. As part of this analysis, a market assessment of currently available zero emission vehicle technology was completed. Requests for information were submitted to a wide range of zero emission cutaway vehicle manufacturers. Electric cutaways are an emerging market in the U.S. in the early stages of development and use, and have primarily been deployed by municipalities, airports, and transit agencies in California. Many electric vehicles in this class are 'repowered' meaning they are built on an OEM or factory truck chassis, such as those manufactured by Ford or Chevrolet. These vehicles are rebuilt with third-party electric drivetrains and have specialized passenger bodies installed. The process of rebuilding or 'repowering' an OEM chassis with an electric drivetrain involves removing the internal combustion engine and related parts and replacing them with an electric motor and drivetrain. There has not been widespread use of these vehicles in the transit industry to date and data is limited on cost and performance so CTE used data collected from the cutaway market assessment completed for Intercity to develop some of the assumptions used for the Dial-A-Lift service assessment.

Transition Scenarios

The approach for this assessment is based on the development and analysis of the four transition scenarios in addition to the baseline scenario, used as a point of comparison:

- **Baseline**: Intercity's current Dial-A-Lift service is composed of both gas and propane cutaways. Intercity is planning to transition its current fleet to fully propane over the next few procurements. It is assumed that there are no changes to Intercity's current procurement schedule during the transition timeline (2023 – 2050).
- **Overnight Charging Only**: Replace all gas, propane, and diesel vehicles with battery-electric cutaways charged only at the bus depot overnight.
- **Overnight and Midday Charged**: Replace all gas, propane, and diesel vehicles with battery-electric cutaways charged overnight at the depot and also midday where possible.
- **Overnight Charged and Fuel Cell Electric Fleet**: Replace all gas, propane, and diesel vehicles with battery-electric cutaways charged overnight at the depot and fuel cell-electric cutaways.
- **Fuel Cell Only Fleet**: Replace all gas, propane, and diesel vehicles with fuel cell-electric cutaways.

The baseline fleet composition is shown in **Figure 43** below. This scenario shows Intercity's current cutaway procurement strategy where after 2023, diesel transit cutaways are replaced with propane transit cutaways. After 2027, the seven gas transit cutaways are replaced with propane transit cutaways, reaching a 100% propane fueled fleet composed of 54 cutaways by 2027.

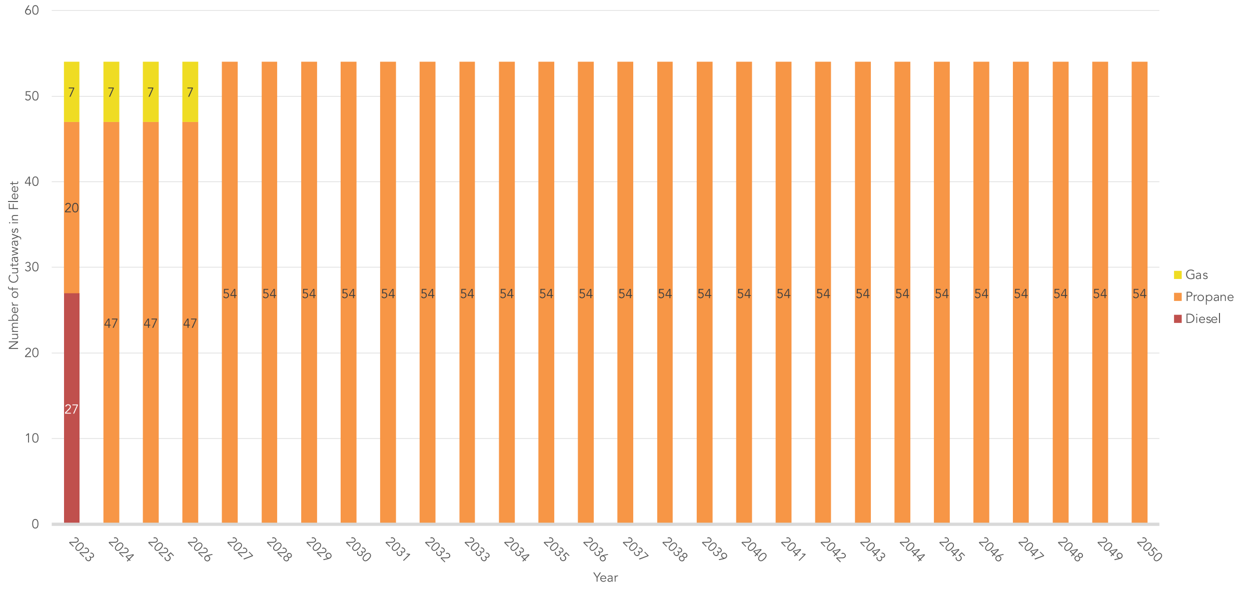


Figure 43: Baseline Fleet Composition – Dial-a-Lift

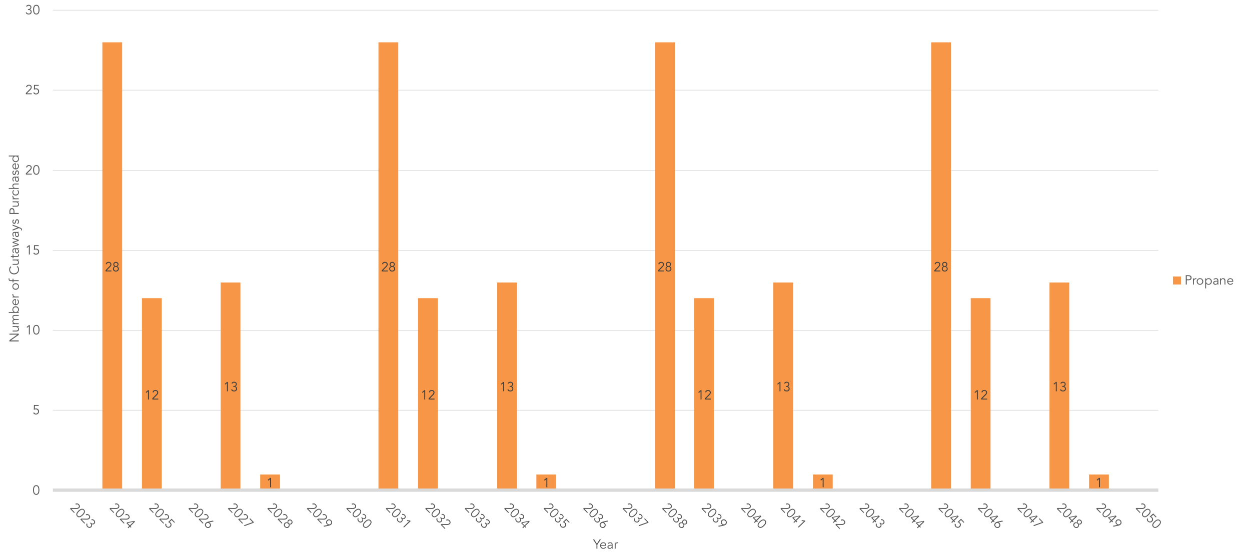


Figure 44: Baseline Procurement Schedule – Dial-a-Lift

Assumptions

As was done for the fixed route service, a number of assumptions were developed based on discussions between CTE and Intercity during the Planning & Initiation stage of this project. Those assumptions are listed below:

- Transition to a 100% ZEB fleet by 2050 with zero-emission procurements beginning in 2032 at the point at which feasibility of all the demand response service reaches over 50%.

- 7-year lifespan assumed for cutaways (battery warranty does not apply for the lifespan as there is no need for midlife replacement).
- Electric cutaway battery capacities are based on the average of the OEM reported battery capacities (92 kWh average) for cutaways currently available in the market.
- A 5% improvement in battery capacity for cutaways every two years.
- 10% of battery capacity is assumed to be unusable and 90% degraded battery; effectively 81% of nominal capacity.
- Efficiencies for electric cutaways from CTE data sources (other project analyses).
- The fuel conversion factor, the efficiency used for hydrogen, is 17 kWh/kg.

6.2 - Dial-A-Lift Service Assessment

Similar to the Service Assessment conducted on Intercity's fixed route service, a screening model developed by CTE was used to assess the Dial-A-Lift fleet. The analysis was based on Intercity's busiest pre-Covid month for Dial-A-Lift service which was October 2019. A total of 47 Dial-A-Lift vehicles were considered in the assessment with the average operations between 71 and 167 miles of service per day. It was assumed that each of the 47 vehicles would perform one block of service each day. Other assessments used to complete the Service Assessment of the Dial-A-Lift fleet are summarized below:

- A 5% improvement in battery nameplate capacities every other year was assumed, based on technological improvements, therefore leading to an average nameplate battery capacity estimate of 182 kWh through 2050.
- Provided that operator midday/lunch breaks and locations are defined by when and where trips are scheduled during the service day, daily service mileage capabilities based on opportunities to midday charge the vehicles at the depot were not considered.

Using these assumptions, with current battery-electric cutaway technology only 6% of Intercity's blocks are feasible. By 2050, 96% of Intercity's blocks are expected to be feasible using battery-electric cutaways considering future improvements to technology. It was also estimated that 100% of Intercity's blocks could be feasible using hydrogen fuel cell cutaways; however, the current hydrogen fuel cell cutaways have generally only been deployed on demonstration projects.

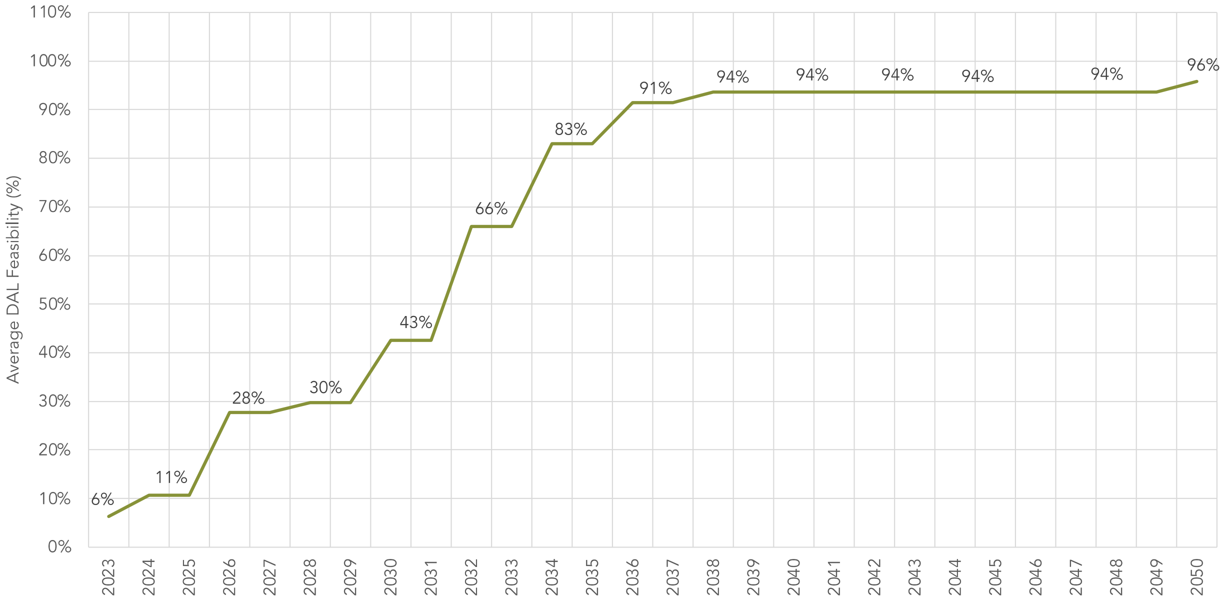


Figure 45: Average Dial-A-Lift Block Feasibility – Battery Electric Cutaways

Analysis indicated that 31 of the shortest Dial-A-Lift service mileages (71 – 103 mi) will be feasible by 2032, accounting for a service feasibility of 66%. Thirteen of the mid-range Dial-A-Lift service mileages (103 - 135 mi) will be feasible by 2038, increasing feasibility to 94% and by 2050, only one of three of the long-range Dial-A-Lift trips (135 - 167 mi) will be feasible, resulting in 96% overall service feasibility by 2050. Daily service mileages above 152 mi remain infeasible based on current projections in battery capacity improvements. The number of vehicles that reach the shortest, mid-range, and longest average vehicle service mileages are shown in the figure below, **Figure 46**.

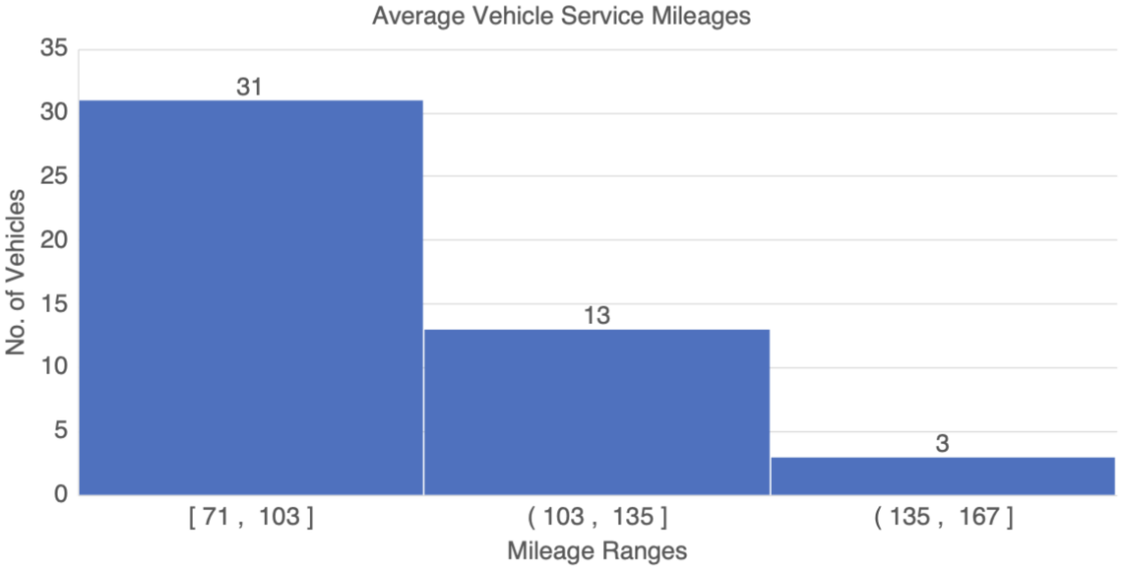


Figure 46: Average Vehicle Service Mileages for Dial-A-Lift

As described above, Dial-A-Lift data from October 2019 was used for analysis. The figure below shows the daily average vehicle mileages in October 2019.

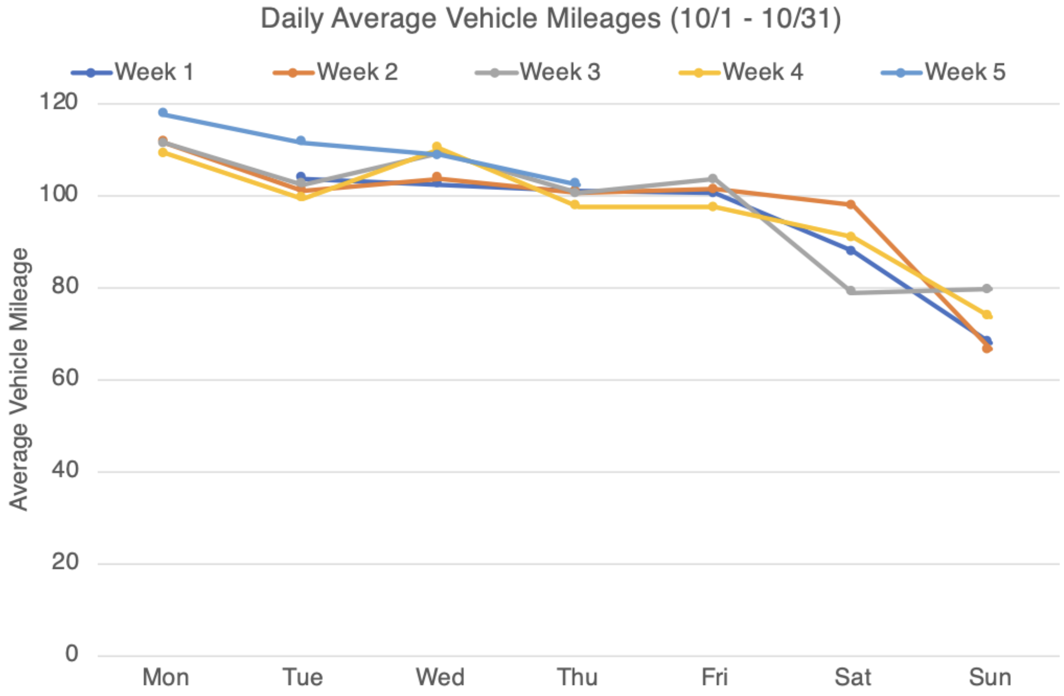


Figure 47: Daily Average Vehicle Mileages for Dial-A-Lift (October 2019)

Sunday service mileages range between 60 and 80 miles of service; these ranges are currently feasible using existing zero emission technology in 2023. Thursday through Saturday service mileages range between 80 and 100 miles of service; these ranges are expected to be feasible using zero emission by 2032 based on anticipated improvements to zero emission technology. Monday through Wednesday trips range between 100 and 120 miles of service and tend to be the busiest days of service; these ranges are expected to be feasible by 2050. In addition, 96% of Dial-A-Lift service is expected to be feasible by 2050 with battery-electric technology.

Intercity could consider specifically assigning battery-electric transit vans to shorter service mileages, without major changes to scheduling, in stages based on daily average vehicle service mileages:

- 71 – 103 mi expected to be feasible by 2032
- 103 – 135 mi expected to be feasible by 2038
- Dial-A-Lift service mileages under 152 mi expected to be feasible by 2050

Operationally, Intercity may group similar trips together, versus maintaining service mileage limitations for the battery-electric Dial-A-Lift fleet. Assigning Dial-A-Lift trips based on battery-electric range limitations limits flexibility of service during the day (e.g., last-minute requests or modifications of service in real-time). There may be an opportunity to run a larger portion of weekend service with battery-electric vehicles.

6.3 - Dial-A-Lift Fleet Assessment

The goal of the Fleet Assessment is to determine the type and quantity of ZEBs, as well as the schedule and cost to transition the fleet to zero-emission. Results from the Service Assessment are integrated with Intercity's current fleet replacement plan and purchase schedule to produce the projected bus replacement timeline for the DAL fleet and the associated total capital cost.

Cost Assumptions

CTE created cost assumptions for this cutaway analysis. CTE produced the annual procurement scenario for 2023 through 2050 and annual capital costs for cutaways. Intercity's procurement cycle is 7 years for these vehicles.

Key assumptions for the bus cost estimate are as follows:

- Inflation rate of 2% applied through 2050, based on historical Producer Price Index (PPI) for transportation equipment and bus bodies.
- Extended battery warranty costs are not included as there is no need for midlife replacement on these 7-year vehicles.

Table 22 provides cost estimates for new vehicle purchases used in the analysis. The costs for internal combustion engine vehicles were provided by Intercity based on most recent purchases by the agency. The base price used for the battery electric cutaway is based on the pricing of a GreenPower EV Star+ (up to 25 passenger seats) from the CA state contract, inflated by 12% for 2023 pricing. The base price used for the fuel cell electric cutaway is based on the demonstration vehicle pricing of a Fenton Mobility Ford e-Transit upfitted by US Hybrid/Ideanomics (up to 9 passenger seats).

Table 22: Cost Estimates Used in Fleet Assessment for DAL

Vehicle Type	Cutaway
Propane	263.5k
Battery Electric	$283.9k
Hydrogen Fuel Cell	$450k

ZEB Fleet Transition Schedule and Composition

Given the block analysis and Intercity's fleet replacement schedule and currently planned procurements, a transition timeline was developed. **Figure 48** depicts the annual baseline fleet composition through the transition period.

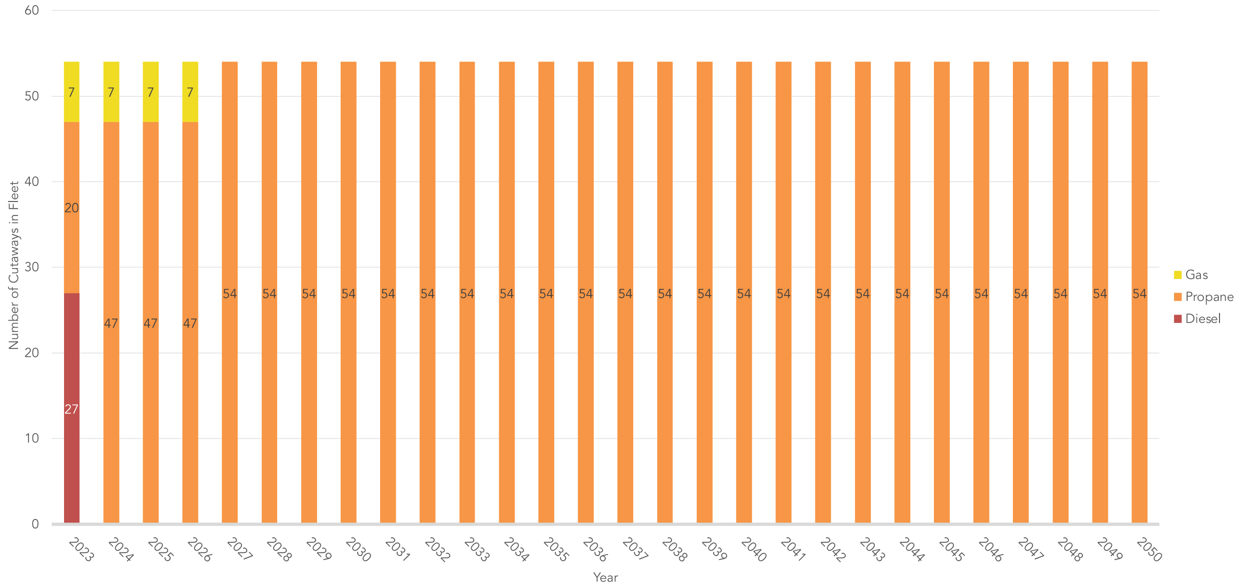


Figure 48: Baseline Fleet Composition – Dial-a-Lift

The annual fleet composition through the transition period, assuming 1:1 replacement with overnight depot only charging is depicted in **Figure 49.**

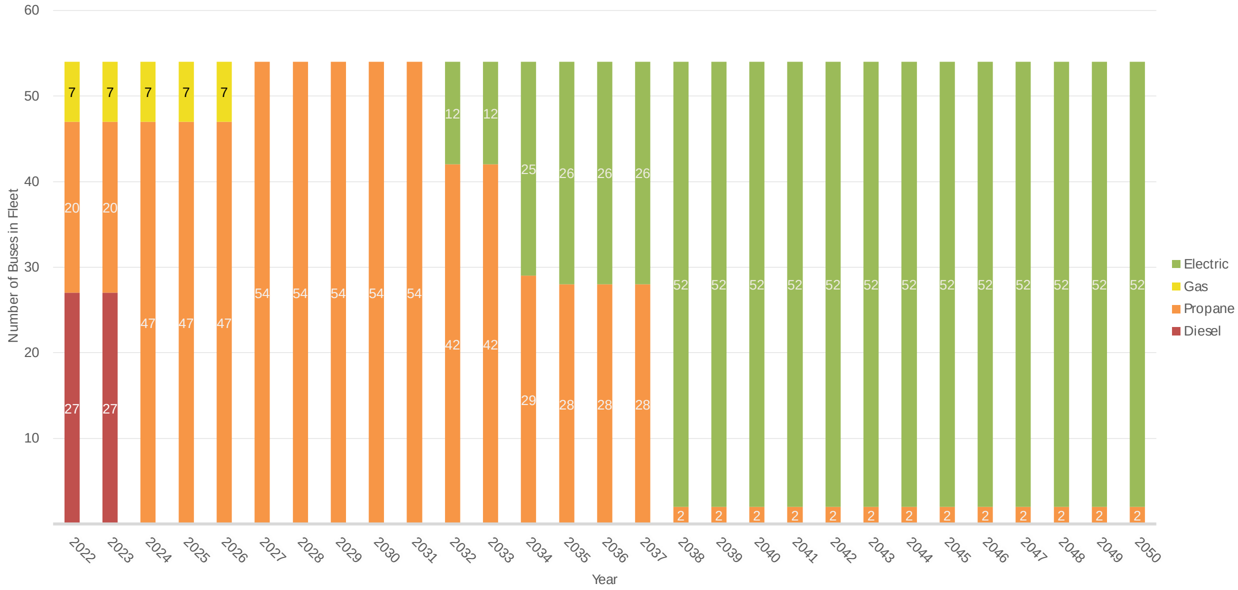


Figure 49: *BEB Overnight Depot Only Fleet Composition – Dial-a-Lift*

In the BEB Depot Only scenario, Intercity can reach approximately 96% zero-emission fleet by 2050. For Intercity to reach a 100% ZEB fleet within this timeframe, other technology solutions would need to be considered.

In **Figure 50**, results from the BEB Overnight and Midday Charging scenario are shown. In this scenario, BEBs utilize overnight depot charging and a midday depot charging session. Intercity is able to replace all Dial-a-Lift vehicles with electric cutaways, achieving a 100% zero-emission fleet by 2038.

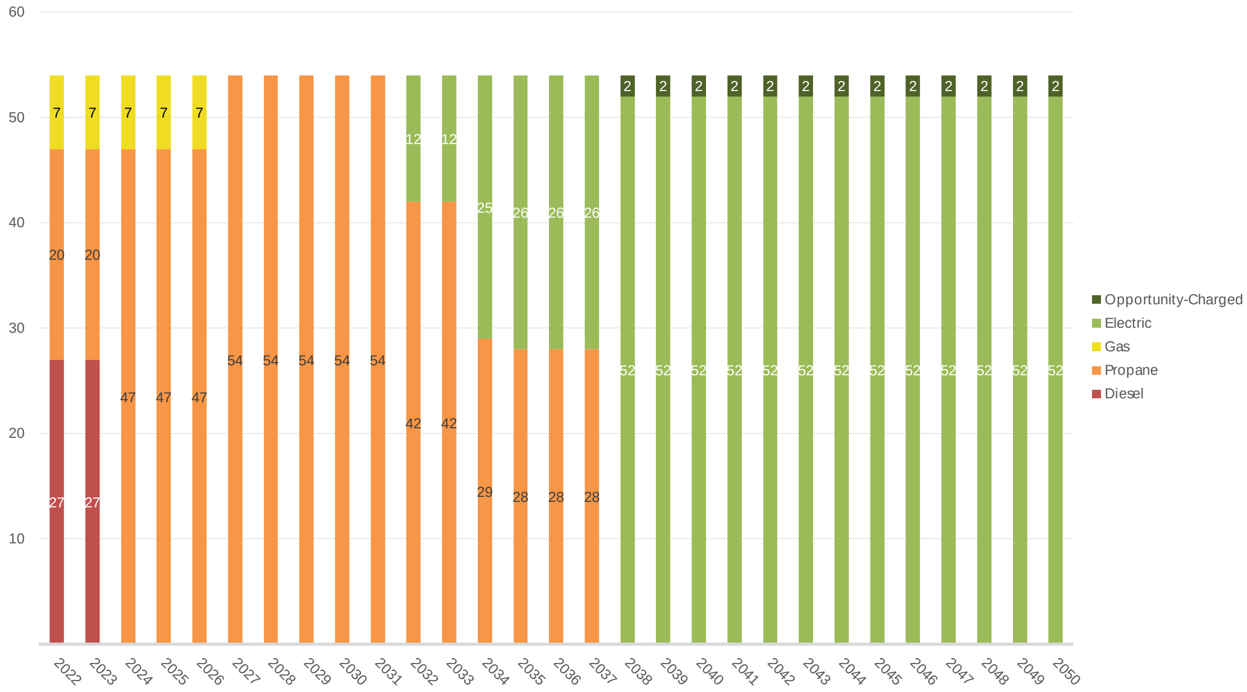


Figure 50: BEB Overnight Depot and Midday Charging – Dial-a-Lift

Figure 51 below shows results from the Mixed Fleet (BEB and FCEB) scenario, in which Intercity replaces all conventionally fueled vehicles with overnight charged BEB vehicles and FCEBs.

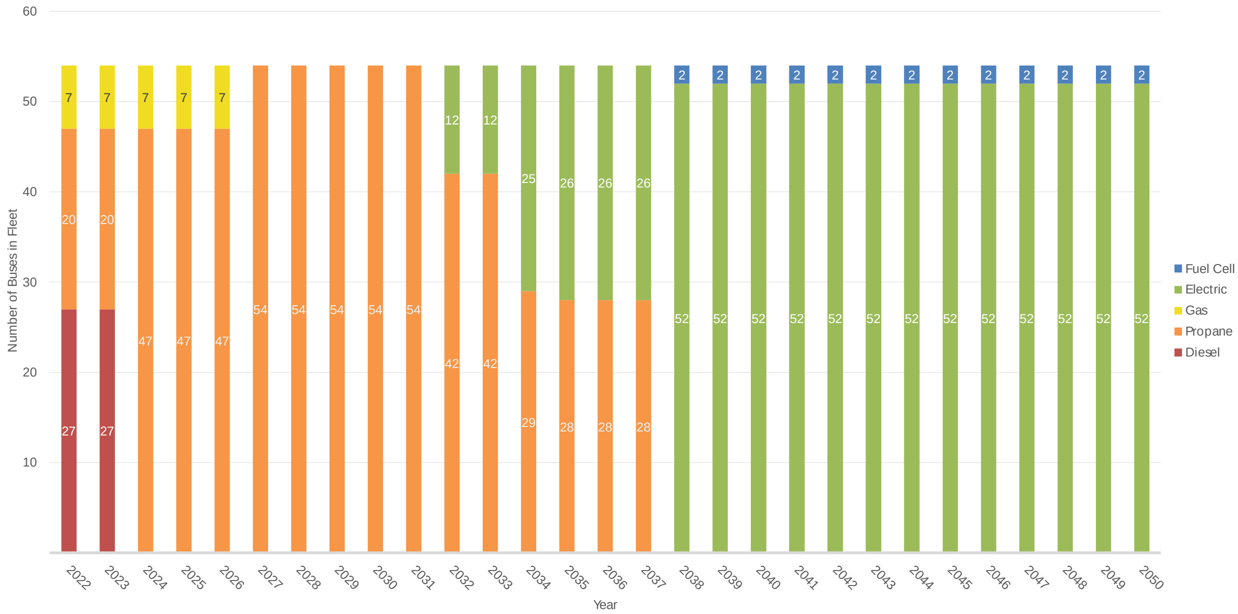


Figure 51: Mixed (BEB and FCEB) Fleet Composition – Dial-a-Lift

In the Mixed Fleet scenario, Intercity is able to reach a 100% ZEB fleet by 2038.

Figure 52 below shows the final scenario, an FCEB Only Fleet. In this scenario, all buses are replaced with FCEBs based on block feasibility, reaching a 100% ZEB fleet ay 2038.

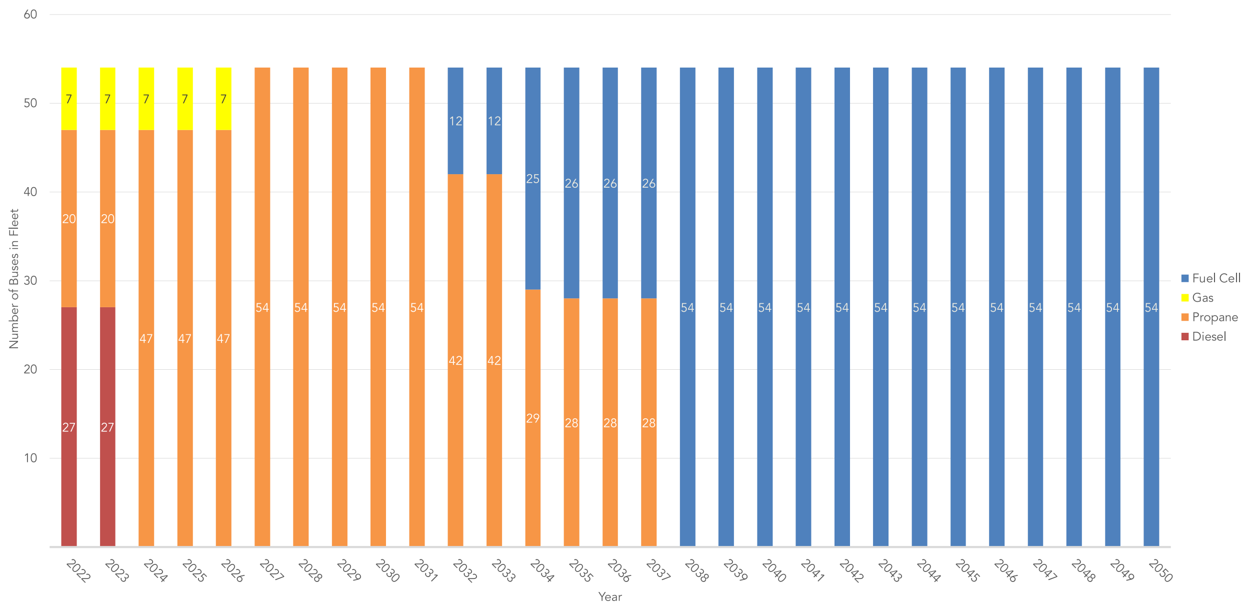


Figure 52: FCEB Only Fleet Composition – Dial-a-Lift

BEB Fleet Transition Cost Comparison

The transition and fleet composition schedules were used to develop the total capital cost for vehicle purchases throughout the transition period. Costs for the vehicles were assumed to increase with a 2% rate of inflation, based on historical PPI. **Table 23** below shows the cumulative fleet costs compared to baseline and the percentage of blocks expected to be achievable by 2050.

Table 23: Fleet Evaluation Summary – All ZEB Scenarios (2023-2050)

	Baseline	BEB Overnight Depot Charging Only	BEB Overnight Depot and Midday Charging	Mixed Fleet (BEB/FCEB)	FCEB Only
Cumulative Fleet Costs	$75.3M	$79.2M	$79.3M	$80.3M	$111.7M
Cost Compared to Baseline	-	+$3.9M	+$4.0M	+$5.0M	+$36.4M
% of Blocks Achievable with ZEBs by 2050	0%	96%	100%	100%	100%

6.4 - Dial-A-Lift Fuel Assessment

CTE conducted a fuel assessment to determine the projected annual cost of fuel for Dial-A-Lift service during the transition period by fuel type (i.e., propane, gas, diesel, electricity, or hydrogen).

Fuel Assessment Assumptions

Assumptions were developed for both fuel consumption and fuel costs. Electricity cost assumptions shown in **Table 24** were the same used in the Fuel Assessment completed for Intercity's fixed-route service. Electricity costs are assumed to be driven by PSE Schedule 26 for Large Demand General Service (>350 kW). Charger maintenance costs in the amount of $500 per Level 2 depot charger were applied to the electricity costs. **Table 25** shows the fuel cost assumptions used for propane, gas, and diesel. A fluctuating inflation rate was applied to these values through 2050, based on the EIA's projection for diesel, propane, gasoline, and electricity (transportation fuel).

Fuel consumption per vehicle type was determined by vehicle fuel efficiencies derived from Intercity's annual fleet mileage and fuel consumption data (2019 - 2022) and these figures are shown in **Table 26** below. **Table 27** provides the assumptions used for electricity consumed at the depot.

For hydrogen, a safety factor of 20% was applied to fuel costs. This figure takes into account hydrogen-related losses through venting and transportation. The cost of hydrogen was based on the 2023 price for hydrogen: $8.61/kg. This figure was derived from the average Year 1 and Year 2 costs outlined in the GETBus + PlugPower temporary hydrogen fueling contract, dated March 2023. A fluctuating inflation rate was applied through 2050, based on the EIA's projection for compressed natural gas (transportation) fuel.

Table 24: Electricity Cost Assumptions

Electricity Charges	Oct - Mar	Apr - Sept	Total Charges
Basic Charge (per meter per month)			$109.08
Demand Charges (per kW)	$15.24	$11.16	$13.20*
Energy Charges (per kWh)			$0.080788

***Total demand charges applied to the fuel costs are an average of summer and winter electricity rates, provided the fuel consumption remains consistent throughout the year.*

Table 25: Fuel Cost Assumptions – Dial-A-Lift

Fuel Type	Cost	Source
Propane	$1.70/gal	Intercity's annual fleet fuel consumption data and fuel costs; 2019 – 2022
Gas	$4.56/GGE	Intercity's annual fleet fuel consumption data and fuel costs; 2019 – 2022
Diesel	$4.80/DGE	Intercity's annual fleet fuel consumption data and fuel costs; 2019 – 2022

Table 26: Fuel Consumption Assumptions – Dial-A-Lift

Vehicle Type	Vehicle Fuel Efficiency	Source
Propane	5.76 mpg	Intercity annual fleet mileage and fuel consumption data; 2019 – 2022
Gas	5.15 MPGGE	Intercity annual fleet mileage and fuel consumption data; 2019 – 2022
Diesel	7.44 MPDGE	Intercity annual fleet mileage and fuel consumption data; 2019 – 2022
Battery-Electric	0.85 kWh/mi	Intercity annual fleet mileage and fuel consumption data from 2019 – 2022; based on the average strenuous efficiency for Dial-A-Lift low and high-speed services
Fuel Cell Electric	0.05 kg/mi	Intercity annual fleet mileage and fuel consumption data from 2019 – 2022; based on a 17 kWh/kg conversion from battery-electric kWh/mi

Table 27: Fuel Consumption Assumptions – Depot Electricity

Category	Assumption
Depot Charger Rated Power	20 kW
Dispensers per Charger	2
Charger Utilization	100%
Vehicle Utilization	80% (based on a spare ratio of 20%)
Charger Efficiency	90%

Overnight Depot Charging Only

As was completed for the Fleet Assessment, four scenarios were evaluated as part of the Fuel Assessment. **Figure 53** depicts projected annual fuel consumption for battery electric cutaways charged overnight at the depot. Units of consumption are expressed in diesel gallon equivalent (DGE). In this first scenario, a 96% ZEB fleet is reached by the end of the transition period, 2050. **Figure 54** shows the projected annual fuel costs in this scenario.

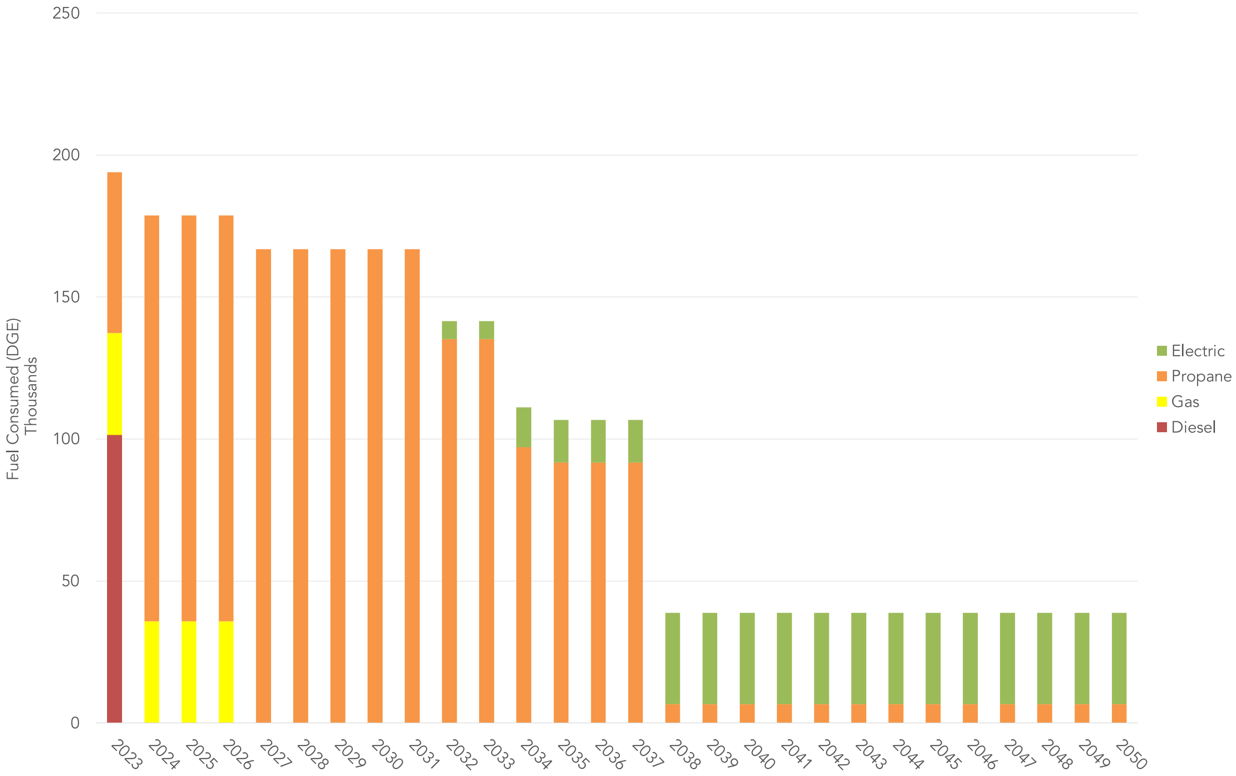


Figure 53: Overnight Depot Charging Only – Annual Fuel Consumption (DGE) – Dial-a-Lift

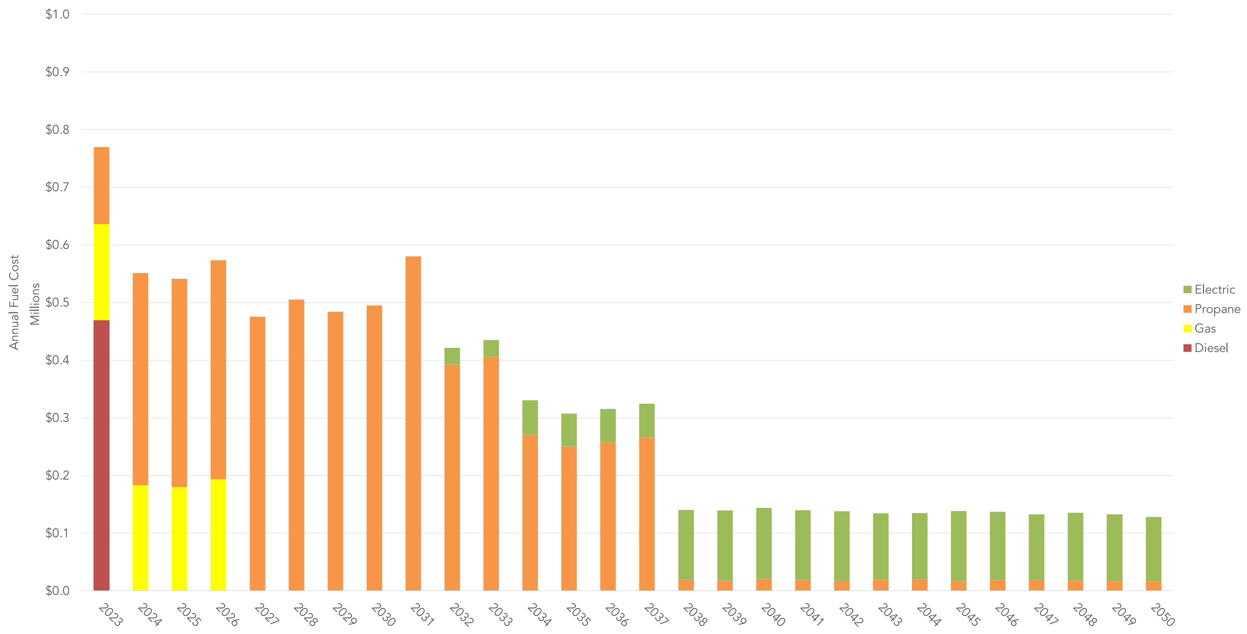


Figure 54: Overnight Depot Charging Only – Annual Fuel Cost - Dial-a-Lift

Overnight and Midday Charged

The second scenario assessed in the Fleet Assessment was the Overnight and Midday Charged scenario in which Intercity transitions to a 100% zero emission fleet by 2050 through replacing all gas, propane, and diesel vehicles with battery electric cutaways charged overnight and midday. **Figure 55** depicts the estimated annual fuel consumption and **Figure 56** shows the estimated annual fuel cost through the end of the transition period.

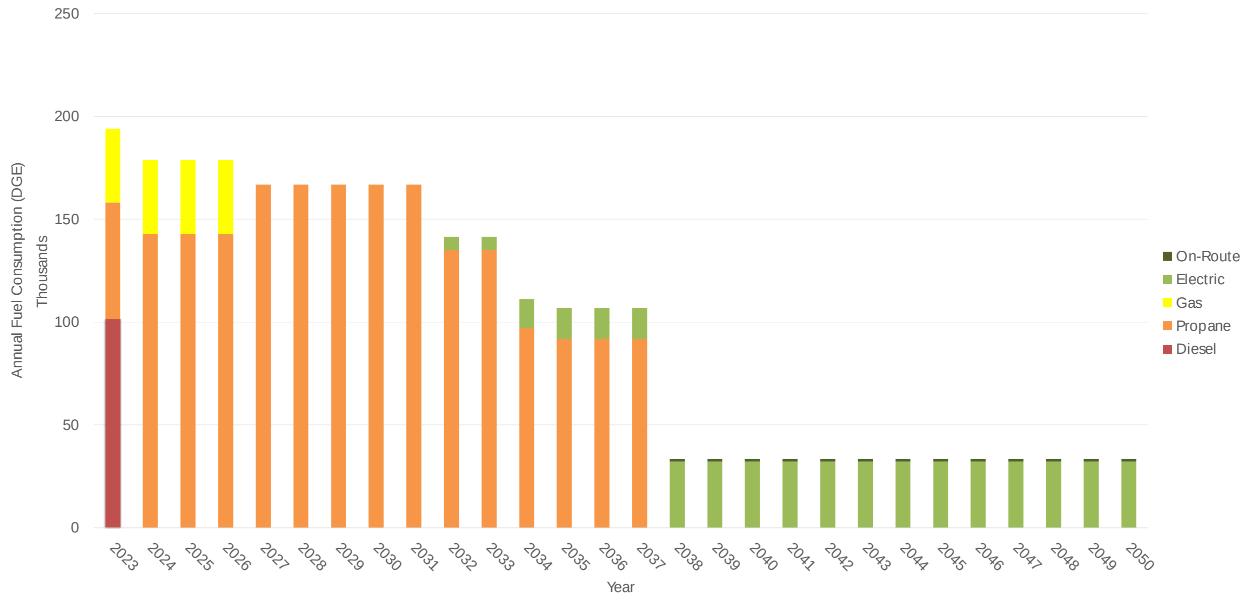


Figure 55: Overnight and Midday Charged – Annual Fuel Consumption (DGE) - Dial-a-Lift

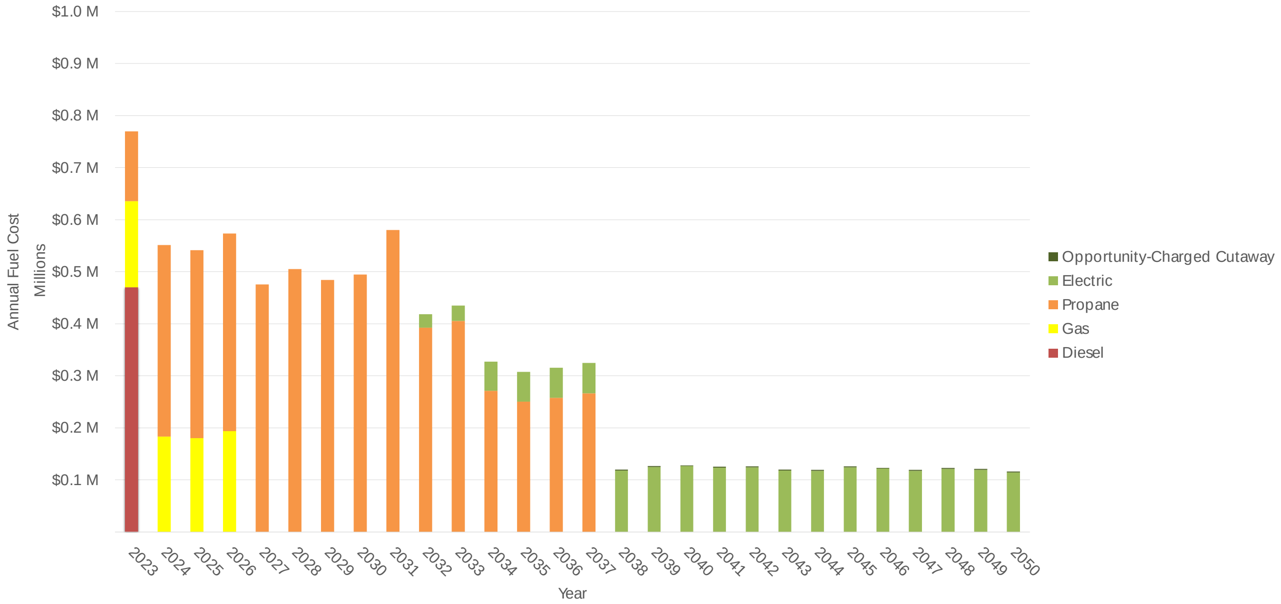


Figure 56: Overnight and Midday Charged – Annual Fuel Cost (DGE) – Dial-a-Lift

Mixed Fleet

The third scenario evaluated in the Fleet Assessment was the Mixed Fleet in which Intercity transitions to a 100% zero emission fleet by 2050 through replacing all gas, propane, and diesel vehicles with overnight charged battery-electric cutaways and fuel cell electric cutaways. **Figure 57** depicts the estimated annual fuel consumption and **Figure 58** shows the estimated annual fuel cost through the end of the transition period.

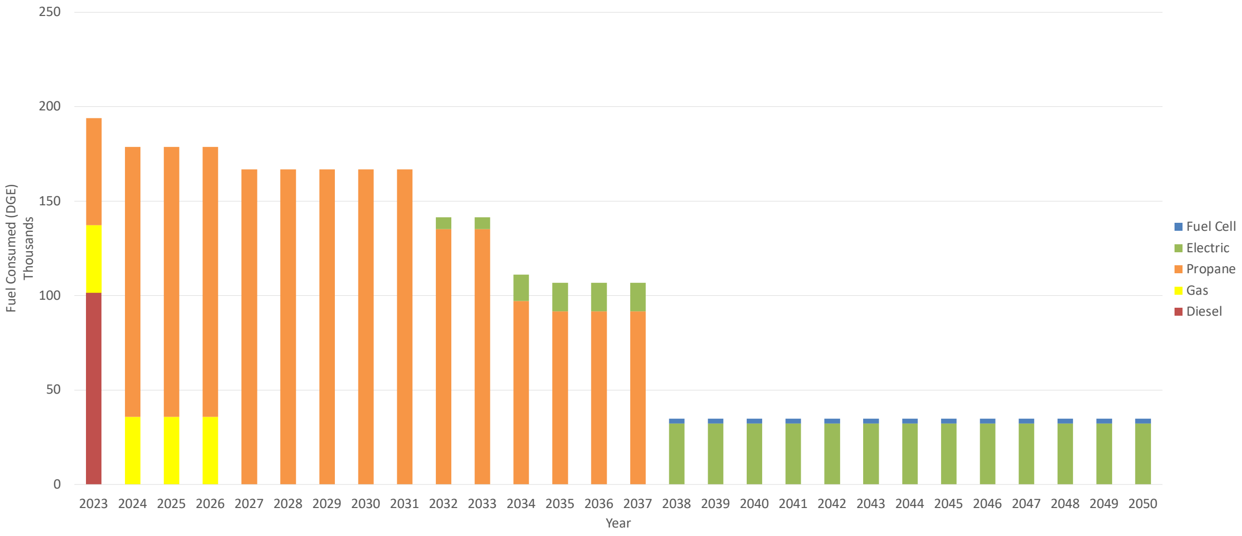


Figure 57: Mixed Fleet – Annual Fuel Consumption (DGE) – Dial-a-Lift

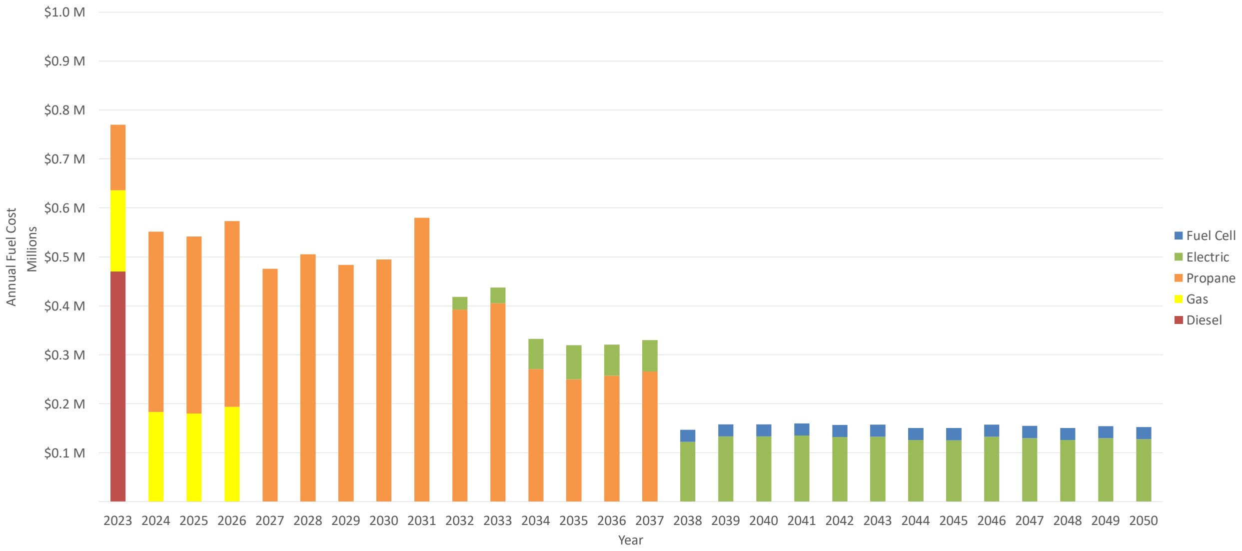


Figure 58: Mixed Fleet – Annual Fuel Cost (DGE) – Dial-a-Lift

Fuel Cell Only Fleet

The fourth scenario assessed was the Fuel Cell Only Fleet scenario in which Intercity transitions to a 100% zero emission fleet by 2050 through replacing all gas, propane, and diesel vehicles with fuel cell electric cutaways. **Figure 59** depicts the estimated annual fuel consumption and **Figure 60** shows the estimated annual fuel cost through the end of the transition period.

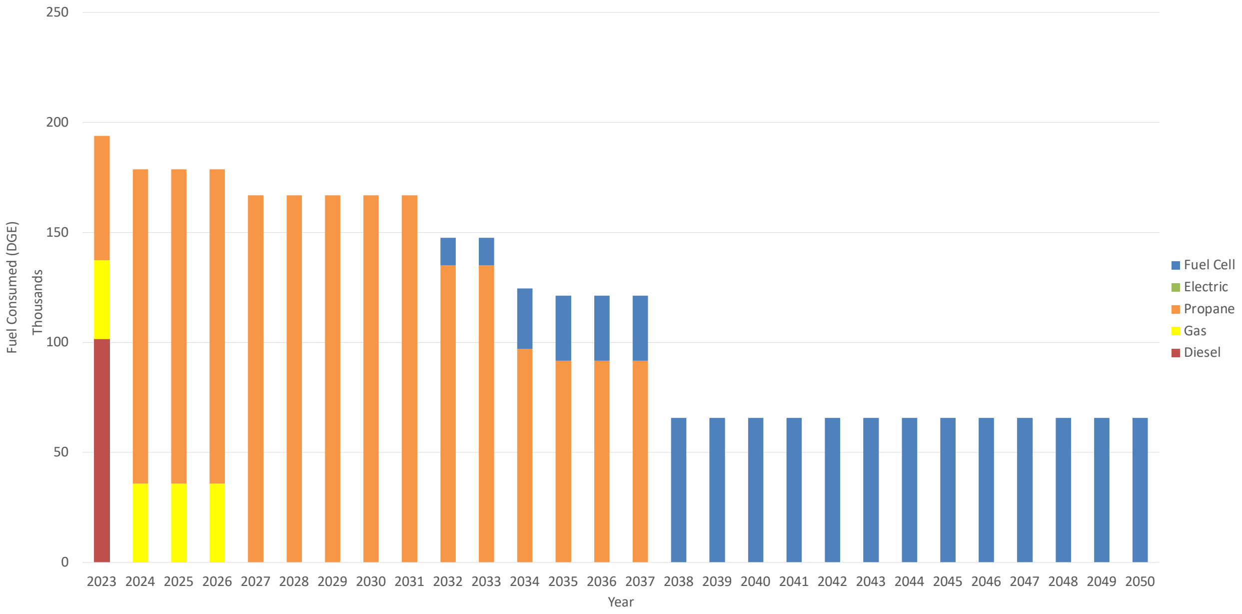


Figure 59: Fuel Cell Electric Fleet – Annual Fuel Consumption (DGE) – Dial-a-Lift

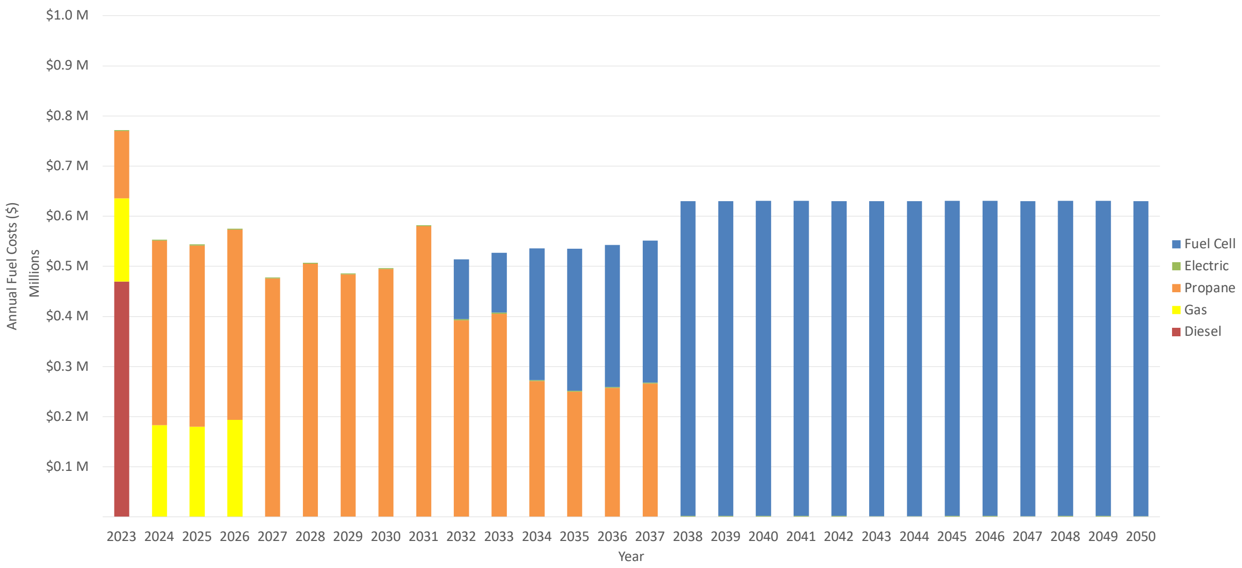


***Figure 60**: Fuel Cell Electric Fleet – Annual Fuel Cost (DGE) – Dial-a-Lift*

Table 28 below provides a comparison of the estimated fuel costs for each scenario through 2050 compared to the baseline. The percentage of blocks achievable by 2050 for each scenario is also shown in this table. The Fuel Cell Only scenario has the highest associated estimated fuel costs whereas the Overnight and Midday Charged electric fleet scenario has the lowest estimated fuel costs compared to the baseline.

Table 28: Fuel Evaluation Cost Summary – Dial-A-Lift

	Baseline	Overnight Charging Only	Overnight and Midday Charged	Mixed Fleet	Fuel Cell Only Fleet
Fuel Costs	$13.9M	$8.9M	$8.7M	$9.1M	$16.3M
Cost Compared to Baseline	--	-$5.0M	-$5.2	-$4.8M	+$2.4M
% of Blocks Achievable with ZEBs by 2050	0%	96%	100%	100%	100%

6.5 - Dial-A-Lift Maintenance Assessment

A Maintenance Assessment to determine the estimated annual maintenance costs for each of the four scenarios was completed. Maintenance cost assumptions used for this assessment are provided in **Table 29**.

Table 29: Maintenance Cost Assumptions

Type	Labor & Materials Estimate	Source
Propane	\$0.60/mile	Intercity Data, August 2023
Gas	\$0.39/mile	Intercity Data, August 2023
Diesel	\$0.65/mile	Intercity Data, August 2023
BEB	\$0.46/mile	U.S. DOE NREL[1] – 30% decrease in BEB maintenance costs compared to diesel buses
FCEB	\$0.49/mile	OCTA – 25% decrease in FCEB maintenance costs compared to diesel buses

[1] *Foothill Transit Battery Electric Bus Demonstration Results: Second Report*, Leslie Eudy and Matthew Jeffers, US DOE NREL,
June 2017

Overnight Depot Charging Only

Figure 61 shows the estimated annual maintenance cost for the Overnight Charging Only scenario in which battery-electric vehicles procured beginning in 2032 are charged only overnight at the depot.

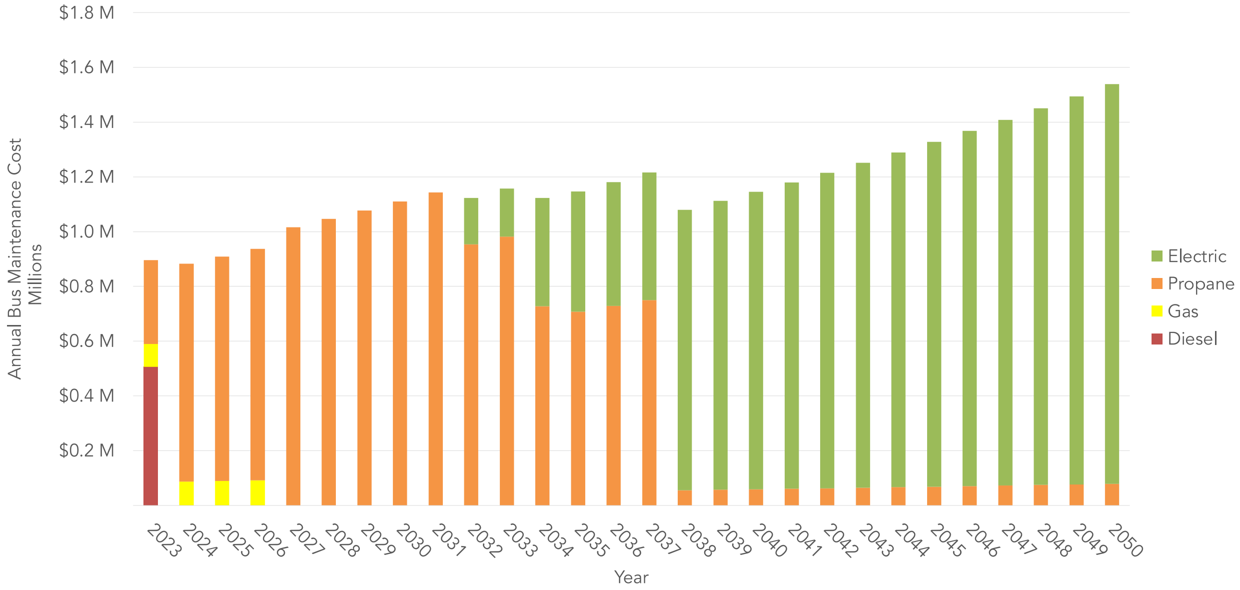


Figure 61: Overnight Charging Only – Annual Maintenance Cost – Dial-a-Lift

Overnight and Midday Charged

Figure 62 shows the estimated annual maintenance cost for the Overnight and Midday Charged scenario in which battery-electric vehicles procured beginning in 2032 are charged overnight at the depot and beginning in 2038 midday charged as well.

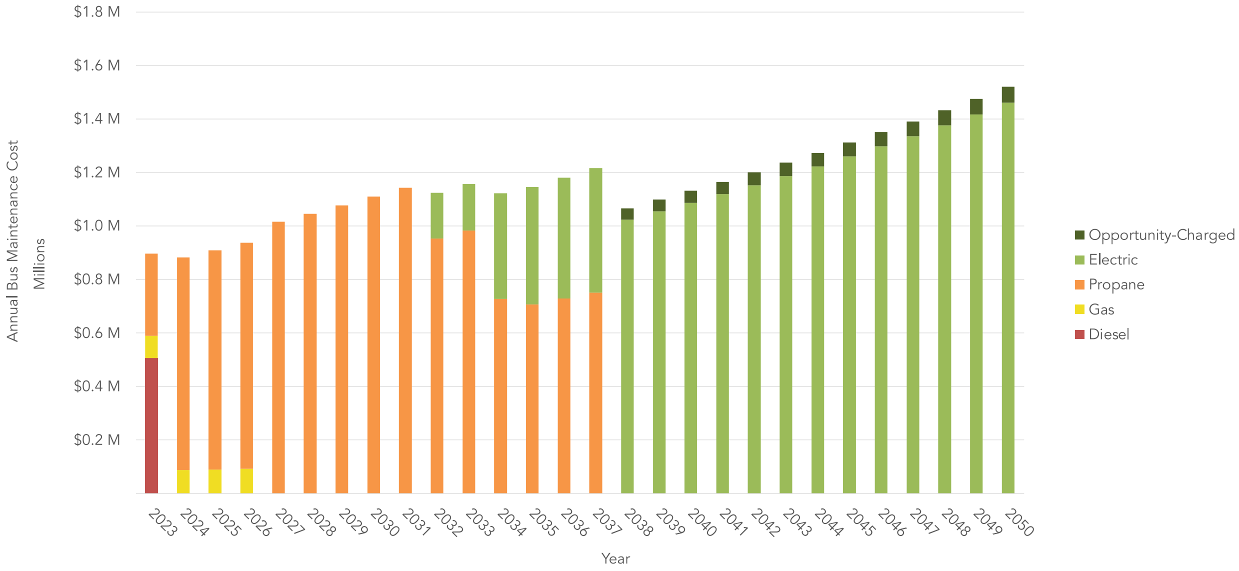


Figure 62: Overnight and Midday Charged – Annual Maintenance Cost – Dial-a-Lift

Mixed Fleet

Figure 63 shows the estimated annual maintenance cost for the Overnight Charged and Fuel Cell Electric Fleet scenario in which overnight depot charged battery-electric vehicles are procured beginning in 2032 and fuel cell cutaways are purchased beginning in 2038.

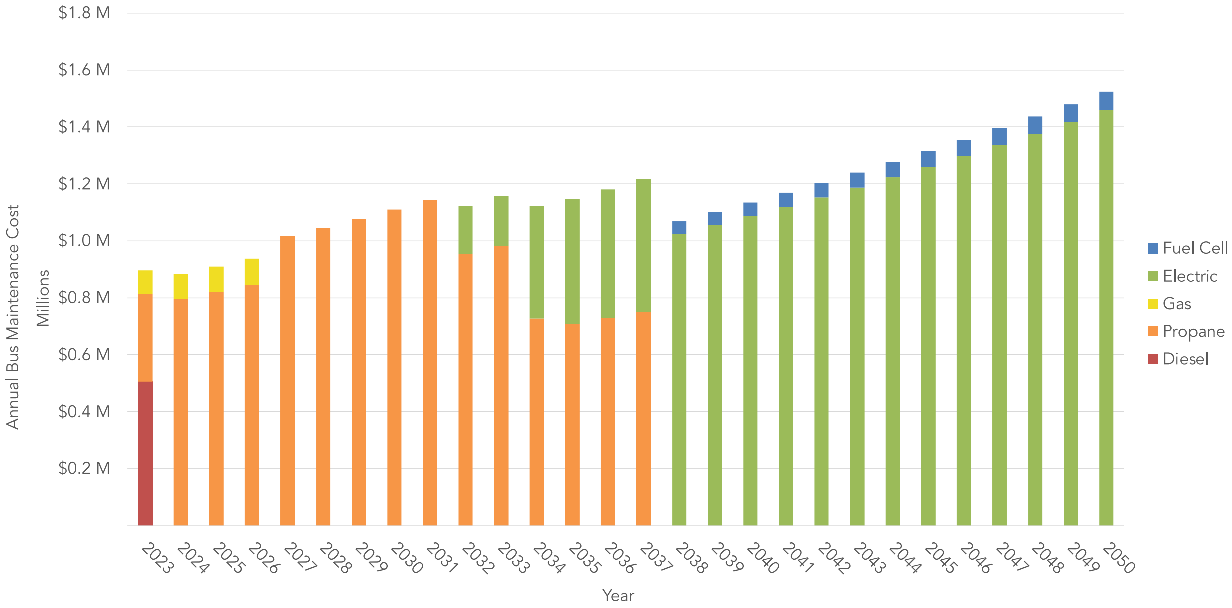


Figure 63: Overnight Charged and Fuel Cell Electric Fleet – Annual Maintenance Cost – Dial-a-Lift

Fuel Cell Only Fleet

Figure 64 shows the estimated annual maintenance cost for the Fuel Cell Only scenario in which fuel cell vehicles are procured beginning in 2032.

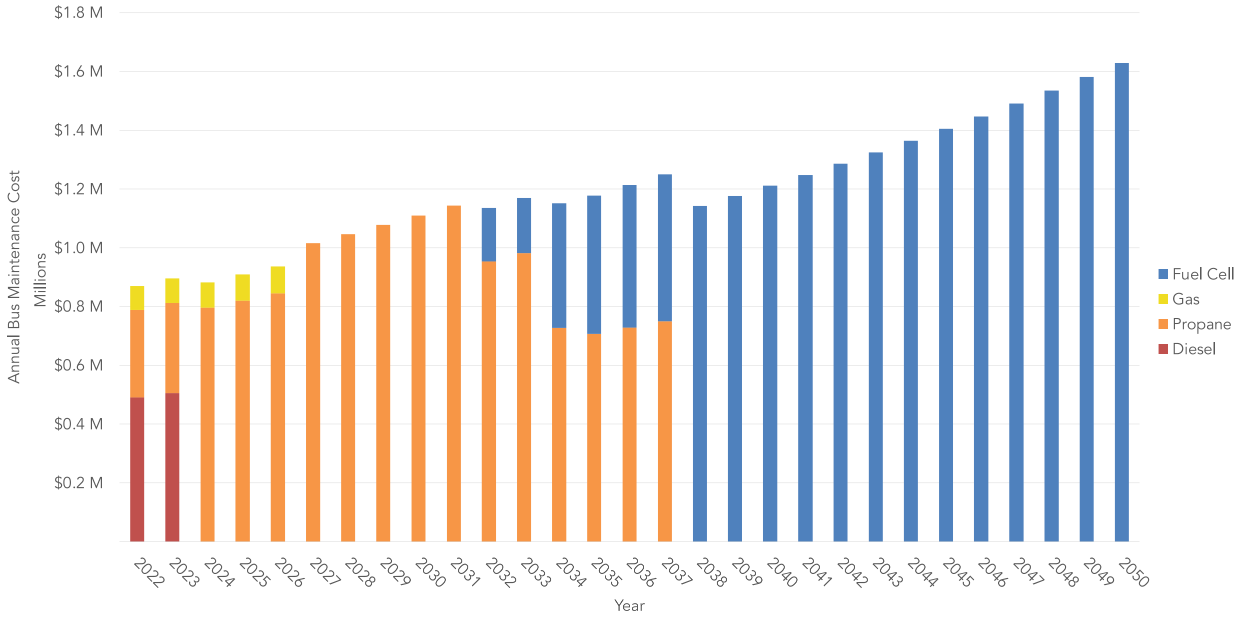


Figure 64: Fuel Cell Only Fleet – Annual Maintenance Cost – Dial-a-Lift

Table 30 below provides a comparison of the estimated maintenance costs for each scenario through 2050 compared to the baseline. The percentage of blocks achievable by 2050 for each scenario is also shown in this table.

Table 30: Maintenance Evaluation Cost Summary – Dial-A-Lift

	Baseline	Overnight Charging Only	Overnight and Midday Charged	Overnight and Fuel Cell Electric Fleet	Fuel Cell Only Fleet
Fuel Costs	$38.6M	$32.8M	$32.6M	$32.7M	$34.0M
Cost Compared to Baseline	--	-$5.8M	-$6.0M	-$5.9M	$4.6M
% of Blocks Achievable with ZEBs by 2050	0%	96%	100%	100%	100%

6.6 - Dial-A-Lift Facilities Assessment

As with the fixed-route service, once fueling requirements are understood for the zero-emission transition, the requirements for supporting infrastructure are determined including the charging equipment for the battery-electric and fuel cell cutaways and vans.

Charging Infrastructure

Charging infrastructure for the Dial-A-Lift vehicles requires similar infrastructure to the fixed route service including transformers, switchgear, conduit and conductors; however, typically the vehicles do not require high speed chargers. For this analysis, level 2 chargers equipped with one dispenser each with a maximum charge rate of 20 kW were utilized.

Overnight Depot Charging Only

The Overnight Depot Only charging analysis for Dial-A-Lift assumes that all charging of the vehicles takes place at Intercity Transit's Pattison Street facility. The cost estimate assumes that by 2050, 96% of Intercity's fleet will be feasible for replacement with battery electric cutaways, although the facility charging infrastructure is built out to support the full fleet cutaways, with 10% spare charging positions. A total of 58 level 2 chargers (20 kW) with one (1) dispenser each would be required to support the service.

Electrical load requirements for the Pattison Street facility were estimated based on the number of chargers at full build-out to accommodate the battery electric cutaway fleet. Increasing the existing electrical capacity by approximately 1 MW would be required to support full build out. As discussed previously, this estimate assumes 10% redundant charging capacity. The cost from PSE to supply this additional capacity is not included in these costs. Continued coordination with PSE is required to manage capacity limitations and expected cost as this is a substantial upgrade and could require additional generation or transmission systems.

Following discussions with Intercity staff, it was assumed that the Dial-A-Lift vehicles would be parked and charged at the location of the parking canopy as depicted in **Figure 65**.

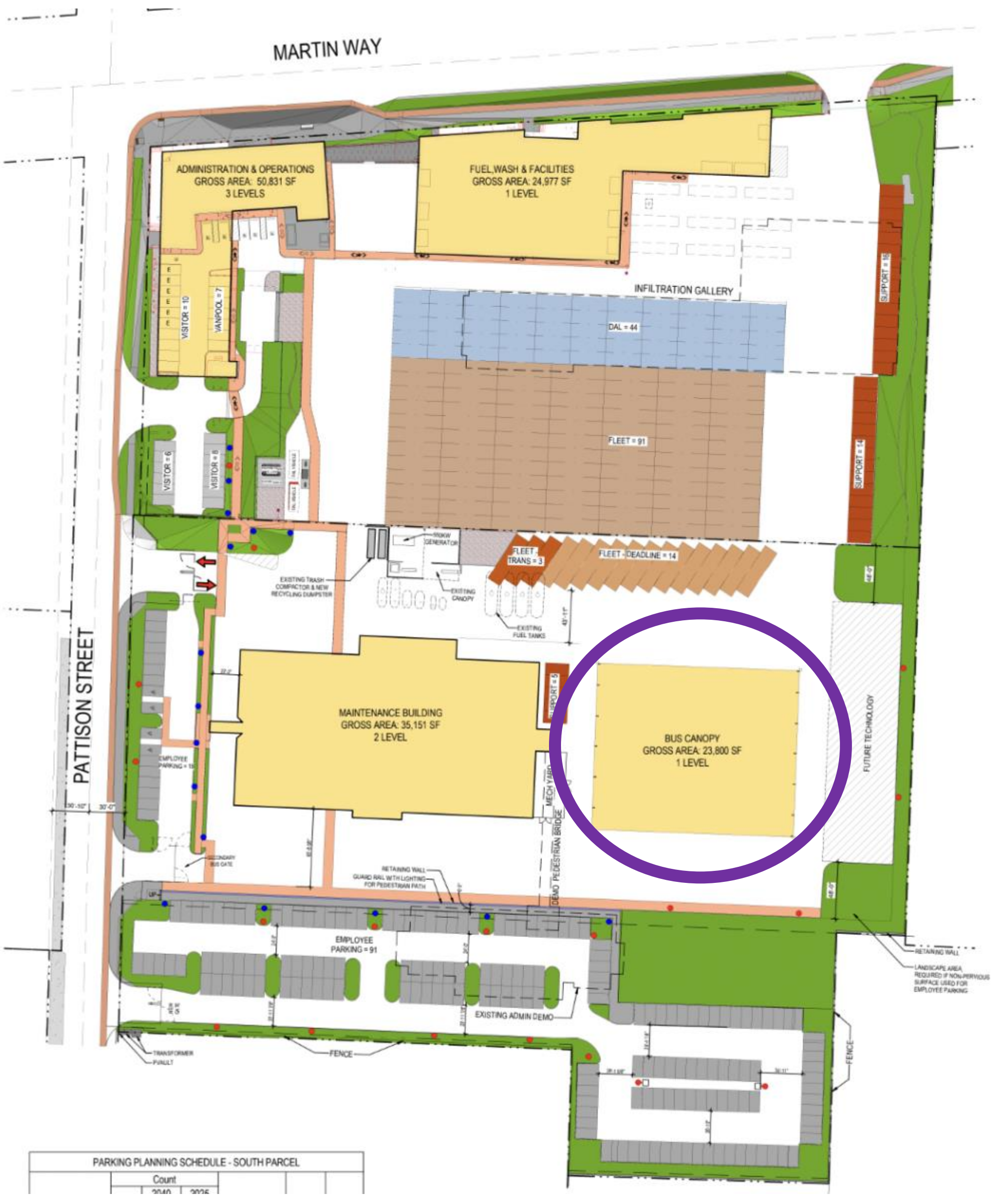
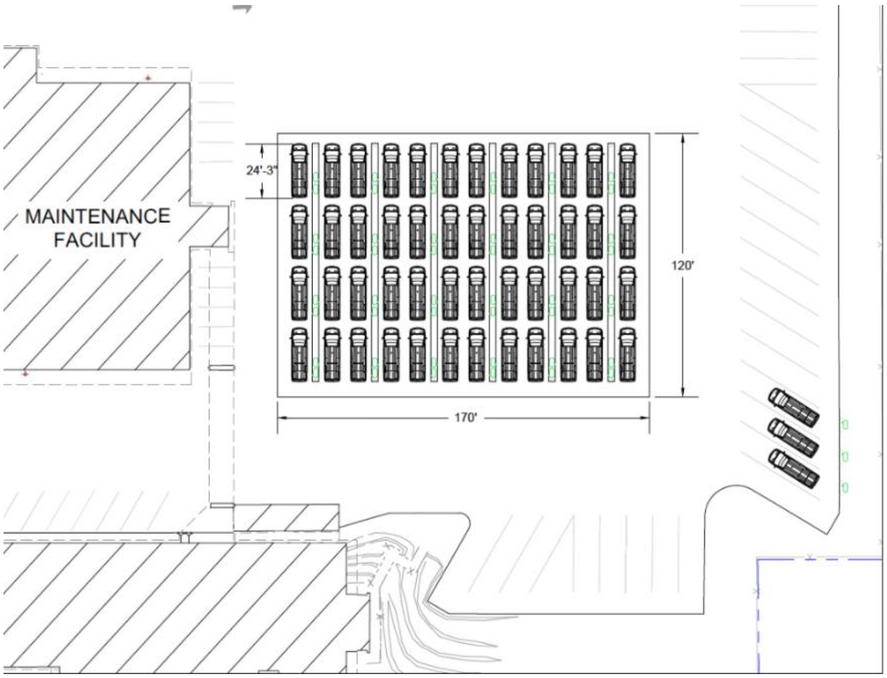


Figure 65: Dial-A-Lift Parking Location

Switchgear and other electrical equipment would be installed in the same charging area as proposed for the fixed route fleet charging infrastructure. 58 Level 2 chargers with one (1) dispenser each would be installed in the parking area as depicted in **Figure 66**.



Notes/Assumptions:

- 51 DAL Fleet Charging locations
  - 48 locations in Main Area
  - 3 in Overflow Area
- Level 2 chargers
- Main Area is 20,400 sq.ft.

Figure 66: Dial-A-Lift Charging Layout

A rough-order-magnitude (ROM) cost estimate was developed by Hatch to build out charging infrastructure for the Dial-A-Lift services at the depot. All cost estimates for infrastructure should be considered Class IV for a feasibility study, estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates are provided in **Appendix A**. Estimated costs for BEB Depot Only charging infrastructure are depicted in **Figure 67.** Results indicate a total cost of approximately $2.5M to install charging infrastructure to support the Dial-A-Lift service at the Pattison Street facility.

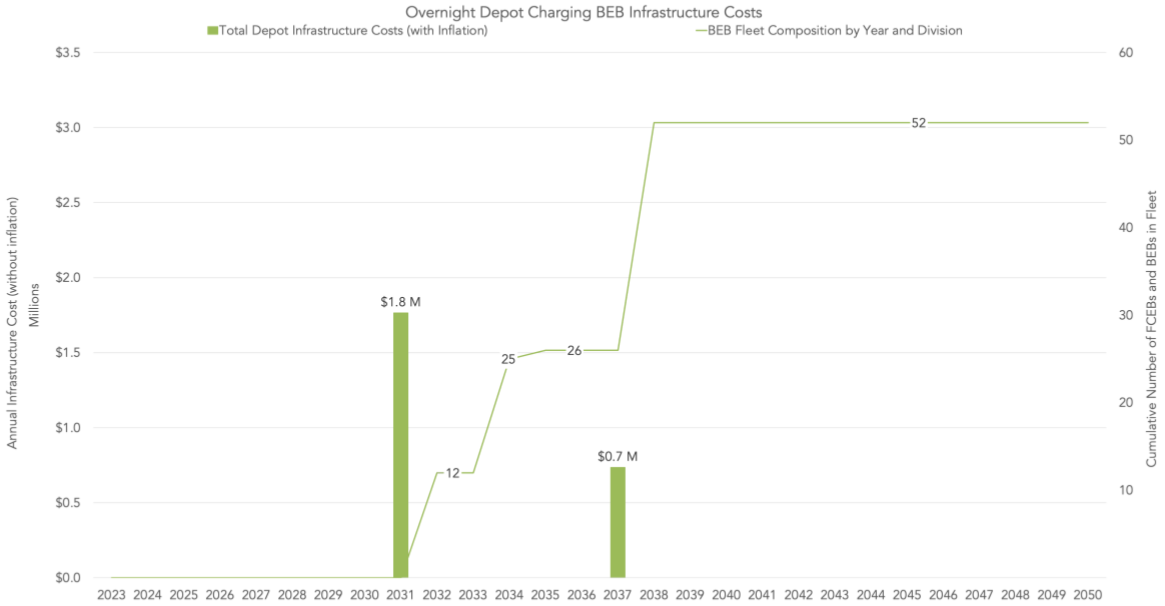


Figure 67: ***Estimated Infrastructure Costs for Dial-A-Lift – Depot Overnight Charging***

Overnight and Midday Charging

For the Overnight and Midday Charging scenario, two additional chargers beyond what is required for the Depot Overnight Charging Only scenario were identified. Results indicate a total cost of approximate $2.6M to install charging infrastructure to support the Dial-A-Lift service at the Pattison Street facility, including overnight and midday charging as depicted in **Figure 68.**

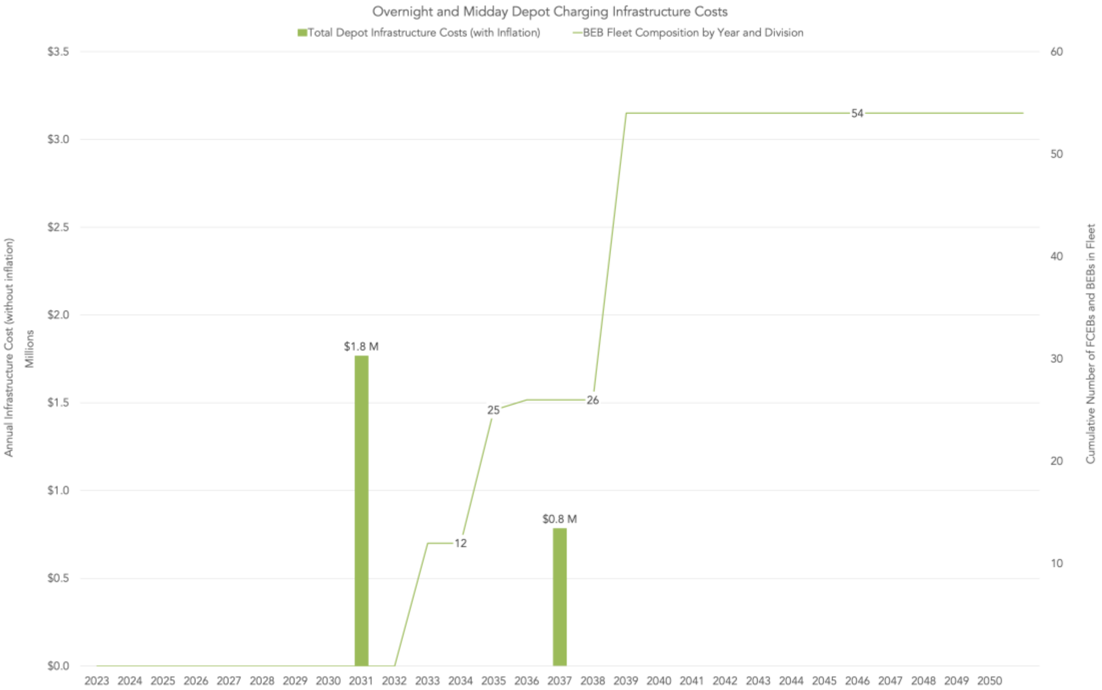


Figure 68 - Estimated Infrastructure Costs for Dial-A-Lift –Overnight and Midday Charging

Mixed Fleet

In a mixed fleet scenario, level 2 chargers would be used to charge battery-electric cutaway vehicles while hydrogen fueling infrastructure installed to support a fixed-route deployment of FCEBs would be used to fuel hydrogen fuel cell cutaways. Additional compression equipment to compress the hydrogen to 700 bar and a separate dispenser to support the cutaways would be required in this scenario. Fuel cell cutaways would only be deployed if hydrogen fueling is built out to support the fixed route service.

A ROM cost estimate was developed to build out both the level 2 charging and hydrogen fueling infrastructure at the Pattison Street facility to support a mixed fleet of Dial-A-Lift vehicles. The cost estimate should be considered Class IV for a feasibility study estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates for the Mixed Fleet scenario for Dial-A-Lift, to include both charging and hydrogen fueling infrastructure, are provided in **Appendix A**. Estimated costs for the charging infrastructure are approximately $2.5M while the additional hydrogen fueling infrastructure is estimated at approximately $2.3M for a total infrastructure cost of approximately $4.8M as provided in **Figure 69.**

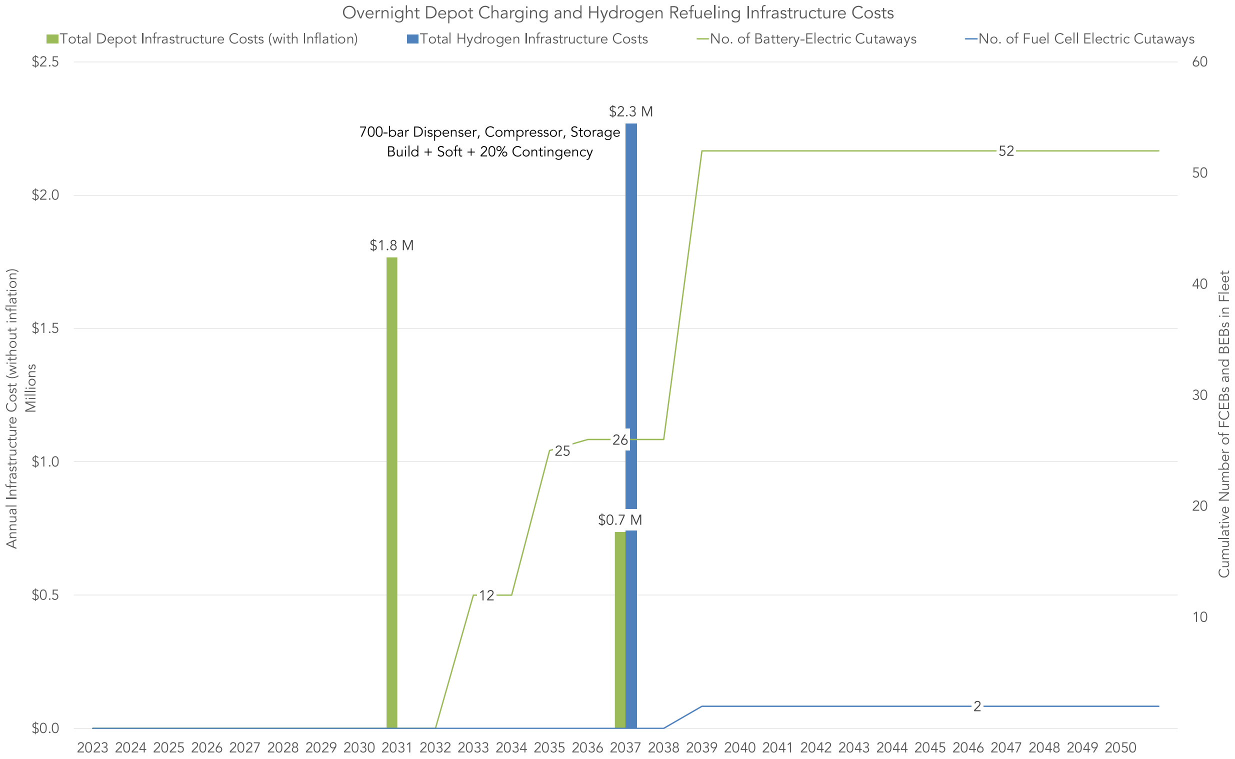


Figure 69 - Estimated Infrastructure Costs for Dial-A-Lift – Mixed Fleet

Fuel Cell Only Fleet

As discussed for the Mixed Fleet, as fuel cell cutaways would only be implemented if larger scale hydrogen fueling equipment was installed to support the fixed-route service, additional hydrogen fueling infrastructure would only include compression equipment to compress the hydrogen fuel to 700 bar for fueling of the cutaways and an additional dispenser location. A ROM cost estimate was developed to build out this additional hydrogen fueling infrastructure to support the Dial-A-Lift service. The cost estimates should be considered Class IV for a feasibility study estimated with an accuracy range of -30% to +50%. Inflation, at a rate of 3% year over year, was applied to the infrastructure costs through 2050 based on historical CPI for labor. Detailed infrastructure cost estimates for hydrogen fueling infrastructure for Dial-A-Lift are provided in **Appendix A**. Estimated costs are provided in **Figure 70.** Results indicate a total cost of approximate approximately $1.9 million.

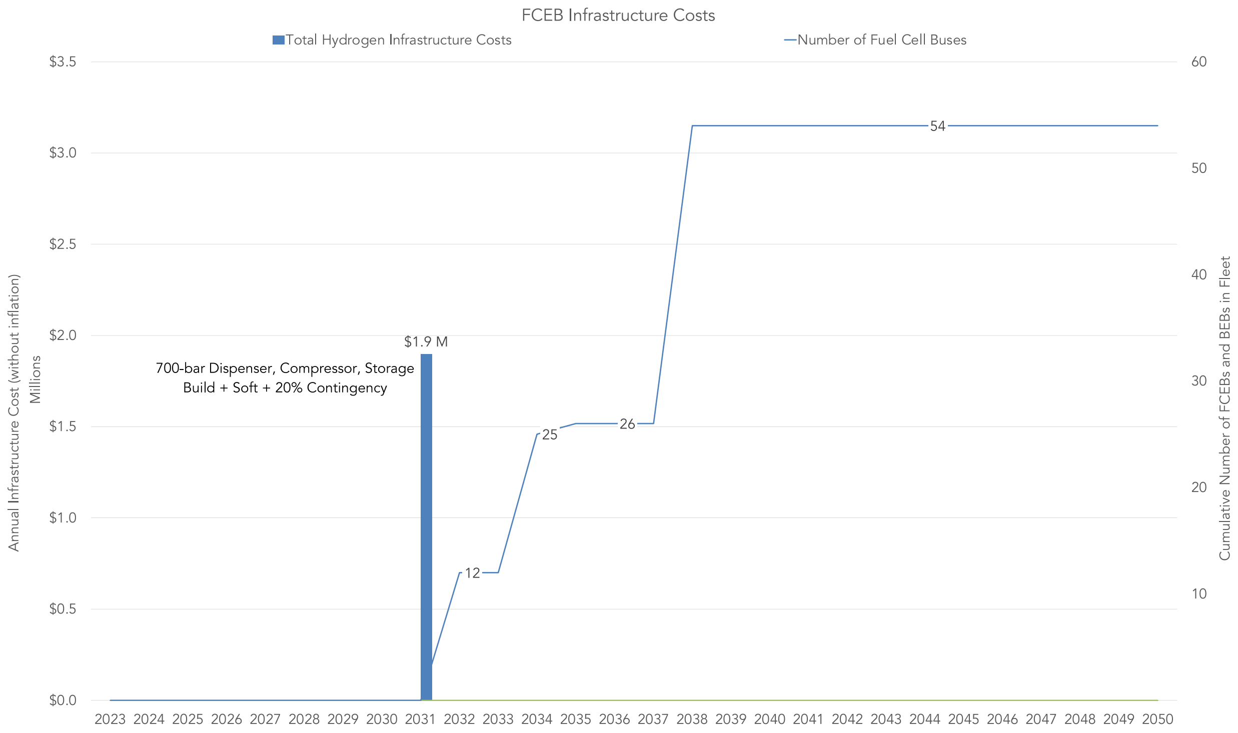


Figure 70: Estimated Infrastructure Costs for Dial-A-Lift – Fuel Cell Only Fleet

Infrastructure upgrade costs for the different transition scenarios evaluated are provided in **Table 31**. Please note that there are no capital costs associated with the Baseline as all of the infrastructure associated with baseline operations is already in place. On-going maintenance costs for fueling infrastructure are included in the fuel cost evaluation as a component of the fuel cost.

Table 31: Infrastructure Cost Evaluation for Dial-A-Lift (ROM Estimates, -30% to +50% Range)

Category	Depot Overnight Charging Only	Overnight and Midday Charging	Mixed Fleet	Fuel Cell Only Fleet
Infrastructure	$2.5M	$2.6M	$4.8M	$1.9M
% of Blocks Achievable with ZEBs by 2050	96%	100%	100%	100%

6.7 - Dial-A-Lift Total Cost of Ownership

The Total Cost of Ownership compiles the results from the Service, Fleet, Fuel, Maintenance, and Facilities assessments to provide estimated costs for the Dial-a-Lift fleet throughout the transition period. It includes selected capital and operating costs of each transition scenario over the transition timeline. There may be other costs incurred (i.e., incremental operator and maintenance training); however, these four assessment categories are the key cost drivers in ZEB transition decision-making.

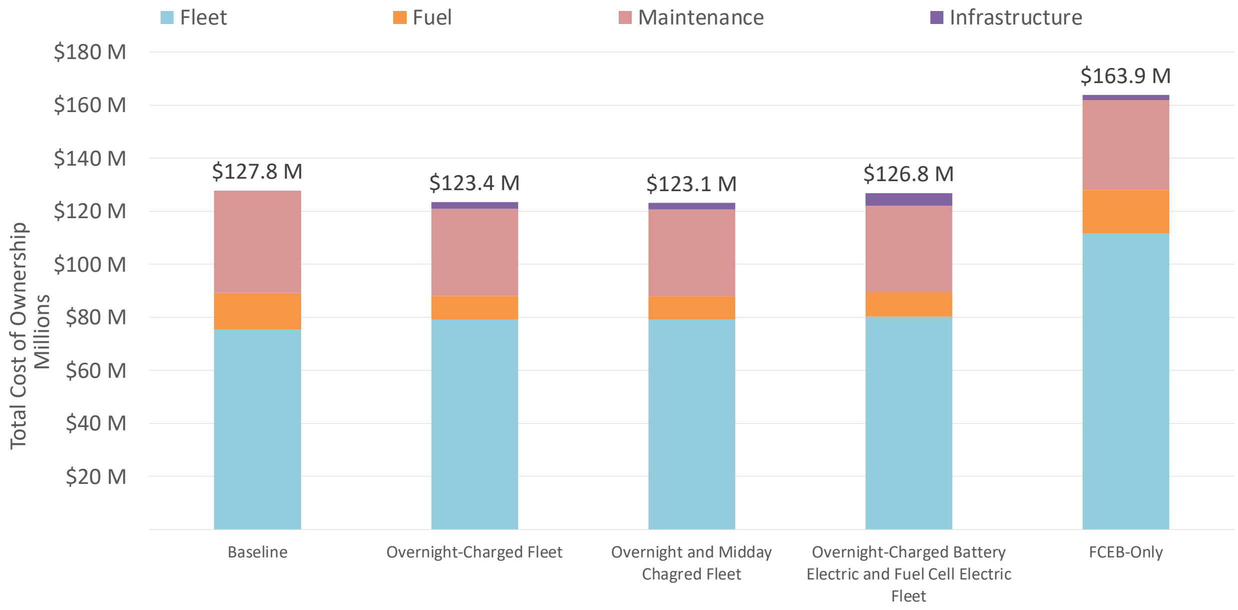
It is important to note that cost reductions are not considered for economies of scale related to zero emission technology growth because there is no historical context with which to estimate. The provided costs are an estimate, informed by detailed analysis using assumptions explained throughout this study. The estimated Total Cost of Ownership for Intercity's Dial-a-Lift zero emission transition as detailed in this analysis are provided in **Table 32** and **Figure 66**.

Results from the total cost of ownership analysis indicates costs range from a potential savings of approximately $4.6M to an additional cost of approximately $36.1 million more than Baseline to support a transition to zero-emission technology for the Dial-A-Lift service.

Table 32: Total Cost of Ownership for Zero Emission Transition for DAL Fleet (2023-2050)

Category	Baseline	BEB Overnight Charging Only	BEB Overnight and Midday Charging	Mixed Fleet	FCEB Only Fleet
Fleet	$75.3M	$79.2M	$79.3M	$80.3M	$111.7M
Fuel	$13.9M	$8.9M	$8.7M	$9.1M	$16.3M
Maintenance	$38.6M	$32.8M	$32.6M	$32.7M	$34.0M
Infrastructure	$-	$2.5M	$2.6M	$4.8M	$1.9M
Total	$127.8M	$123.4M	$123.1M	$126.8M	$163.9M
Compared to Baseline	$-	-$4.4M	-$4.6M	-$951k	+$36.1M
% of Blocks Achievable with ZEBs by 2050	0%	96%	100%	100%	100%

Figure 48: Total Cost of Ownership for Zero Emission Transition for Dial-a-Lift Fleet (2023-2050)



6.8 - Dial-A-Lift Risks and Challenges

Zero-emission cutaways are an emerging market that is still in the early stages of development and use. The fuel cell-electric market is in the earlier stages of development as compared to the battery-electric market, as there are currently only demonstration fuel cell-electric cutaways in transit service in the U.S. The battery-electric cutaway market offers more developed options, but current range abilities of these vehicles is a limiting factor. It is expected that considerable development will occur in the market in the next several years due to requirements for California transit agencies to begin transitioning cutaway vehicles as early as 2026 as a result of the Innovative Clean Transit (ICT) Rule.

It will be important for Intercity to continue to monitor new zero-emission technologies that enter the market that could help Intercity meet more of its service demand across the transition period and ensure Intercity reaches 100% emission to zero emissions technology in 2050.

Section 7 – Vanpool Fleet

Intercity's van services include Vanpool, Community Vans, and Village Vans. These various services are outlined below:

- **Vanpool**: Intercity's Vanpool program provides vans, maintenance, tolls, fuel, and insurance to groups of three or more commuters who share a similar commute. Vans are kept at a driver's home or other secure location. Intercity owns 187 gasoline vans for Vanpool service, a combination of minivans and 12-passenger vans.
- **Community Vans:** The Community Vans program provides vans for up to 12 people for nonprofit groups and government agencies with transportation needs. Drivers of the vans are volunteers from the nonprofit groups and government agencies that are approved, trained, and certified by Intercity. Community Vans are stored at Intercity's depot. Intercity has eight 12-passenger gasoline vans for this service.
- **Village Vans:** The Village Vans program provides free transportation for employment-related activities to those with low incomes in certain areas of Thurston County, as well as a free driver and job skills program. Village Vans are stored at Intercity's depot. Intercity has six 12-passenger gasoline vans for this service.

Vanpool Electrification Feasibility

Intercity's vanpool service has an average daily mileage of 47 miles, with a max daily commute mileage of approximately 200 miles. The vehicles that make up Intercity's different van services are a mixture of minivans and 12-passenger vans. There are a number of available five-passenger electric vehicles with range capabilities significantly greater than 47 miles on a single charge, but these vehicles do not meet the seven-passenger federal definition of vanpool, which may restrict access to funds to purchase the vehicles. There are several battery electric passenger vans on the market today that could be replacements for the 12-passenger gasoline vans currently in Intercity's fleet. However, there are currently no fuel cell vehicles readily available on the market that would serve as replacements for Intercity's current vanpool vehicles.

The limited supply of zero-emission vehicle options for Intercity's vanpool is a current roadblock to transitioning this fleet although this is expected to change over the next few years as additional vehicles become available on the market. A primary challenge with transitioning the vanpool fleet to zero emission technology is determining where fueling will occur. The majority of the vanpool vehicles are parked overnight at private residences rather than the centralized Intercity depot. Workplace fueling would be the most efficient fueling strategy for the vanpool fleet and supporting wider use of vanpool vehicles, but this type of infrastructure is largely beyond Intercity's control. Intercity should start conversations now with workplaces to encourage the incorporation of workplace charging. Determining how the vanpool vehicles can be fueled will be one of the biggest obstacles that Intercity will need to address before the vanpool fleet can be feasibly transition to zero-emission technology.

The fourteen (14) current 12-passenger gasoline vans that support the Community Van and Village Van program could be replaced with existing options on the market including the Lighting ZEV3 Zero Emission Transit Passenger van, with a maximum capacity of 15 passengers and battery capacities between 80 kW and 120 kW. These vans could be charged at the depot using the same 20 kW level 2 chargers as the Dial-A-Lift service.

Section 8 – Non-Revenue Vehicles

Intercity has a variety of non-revenue staff vehicles, ranging from passenger cars and trucks to street sweeper vehicles. Table 33 below provides an overview of the non-revenue fleet. The focus of this zero-emission analysis was on Intercity's revenue fleet, as detailed in the sections above, however a brief market analysis was conducted for the non-revenue vehicles. There are zero emission vehicles options available on the market today that could be replacements for some of Intercity's non-revenue vehicles. Several all-electric pickup truck, sedan, and SUV options are available, as well as two fuel cell passenger car options available only in California. There are currently no zero emission minivan options available, only hybrid options. There are both battery electric and fuel cell electric street sweepers available today for purchase. Electric forklifts and utility vehicles are widely available today.

ZEB technologies for non-revenue vehicles are in a period of rapid development and change, just like the other vehicles types. Most of today's options will require significant capital investment, as costs are significantly higher than the conventionally fueled counterparts. There are some cost-effective replacement options for passenger cars, forklifts, and utility vehicles, but other vehicle types currently require significant capital cost increases when transitioning to zero-emission.

Table 33: Intercity's Non-Revenue Fleet Vehicle Summary

Vehicle Type	Quantity	Fuel Type	Production Zero-Emission Replacement Vehicle Available?
SUV/Sedans	2	Hybrid	Yes
	16	Gasoline	
	1	Electric	
Light-Duty Trucks	8	Diesel	Yes
	2	Gasoline	
Medium-Duty Trucks	2	Diesel	Yes
	4	Gasoline	
Street Sweepers	1	Diesel	Yes
Minivans	2	Gasoline	No
Medium-Duty Van	1	Diesel	Yes
	2	Gasoline	
Forklift	1	Propane	Yes
Utility Vehicle	1	Electric	Yes

Section 9 – Emissions Analysis

9.1 - Background and Purpose

Intercity is committed to a zero-emission transition by 2050. The purpose of this analysis is to assess the impact of different fuel or energy sources on Intercity's overall emissions profile. To capture the full impact of fuel selection on greenhouse gas (GHG) emissions, this analysis is focused on well-to-wheel emissions. Well-to-wheel emissions consider the total emissions of a fuel throughout extraction, refinement, and transportation, in addition to the final emissions released when the fuel is used to move Intercity's vehicles. The models developed for this analysis provide insight into what mix of fuels would best align with Intercity's goals and support the current state of operations.

9.2 – Assumptions and Methodology

Historical Emissions

The first step of this analysis was to understand Intercity's historical GHG emissions using data from 2010 to 2022. Nelson\Nygaard initially conducted research from the EPA on emissions factors for diesel, gasoline, and propane gas used by Intercity Transit's fleet in **Table 34**.

Table 34: Emissions Factors for Historical Emissions Assessment

Fuel Type	Lifecycle Emission Factor (Kg CO2e/gallon)
Diesel B5	13.02
Diesel R10	12.89
Diesel R50	10.91
Diesel R99	8.42
Propane	5.78
Gasoline	12.28
Diesel Mix 2020(a)	12.95
Diesel Mix 2021(b)	12.39

(a)In 2020, Intercity's Fleet used Diesel B5 for half of the year and Diesel R10 for the rest of the year

(b) In 2021 Intercity's Fleet used Diesel R10 for three quarters of the year and Diesel R50 for the remainder.

Source: Environmental Protection Agency, U.S. Renewable Fuel Standard (RFS) program

Next, Intercity’s carbon footprint was calculated based on fuel consumption of each vehicle in the fleet and the carbon content of each fuel type defined by its emissions factor. The results of the analysis show GHG emissions results by mode service and fuel type.

Future Projections

Intercity’s future fixed-route carbon footprint was estimated from 2023 through 2050 based on an all-diesel fleet projection (baseline) and a variety of different zero emission fleet scenarios. Nelson\Nygaard developed an Excel-based calculator to allow Intercity to regularly evaluate their GHG emissions as they incorporate new fuels and zero emission vehicles into their fleet. Nelson\Nygaard also documented factor emissions factors and their applicability to be included in the calculator.

Key Assumptions

This analysis is predicated on the baseline and four fleet adoption scenarios developed for the transition analysis. More details on these scenarios can be found in **Section 3** of this report. The four scenarios examined were:

- **BEB Depot Charging Only:** Transitions Intercity’s existing vehicles to BEBs based on block feasibility assuming overnight depot charging only.
- **BEB Depot and On-Route Charging:** Transitions Intercity’s existing vehicles to BEBs based on block feasibility assuming overnight depot charging and on-route charging.
- **Mixed Fleet (BEB/FCEB):** Transitions Intercity’s existing vehicles to a mixed FCEB and BEB fleet, with BEBs utilizing overnight depot charging where feasible. Blocks not feasible with BEBs utilizing overnight depot charging are transitioned to FCEBs.
- **FCEB Only Fleet:** Transitions Intercity’s existing vehicles to FCEBs based on block feasibility.

The lifecycle GHG emissions for the various fuel type alternatives are predominantly based on 2023 existing conditions. Diesel fuel is assumed to be renewable diesel (R99) through 2050. Electricity in the model considers current and expected PSE generation mix. PSE has set the goal to eliminate coal from its grid mix by 2025 and reach a carbon free electric supply by 2045. PSE also projects that its emissions will decline by half of 2025 levels by 2035. PSE’s projected emission factors through 2045 are shown in **Figure 67**.

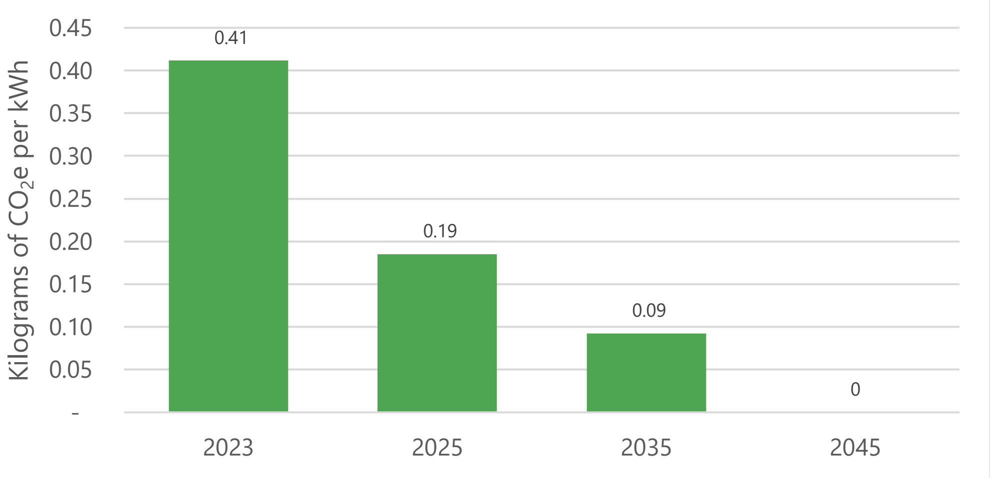


Figure 49: PSE Estimated Emissions Factors (Electricity Generation)

Hydrogen emissions include assessment of grey, blue, and green hydrogen. Grey hydrogen assumes a methane leakage of 1.5% (U.S. average) and no carbon sequestration. Blue hydrogen assumes the same methane leakage rate and a 55% carbon sequestration rate. Projected hydrogen emission factors through 2045 are shown in **Figure 68**. Note that green hydrogen is full zero-emissions, so the green bar is not visible in the figure.

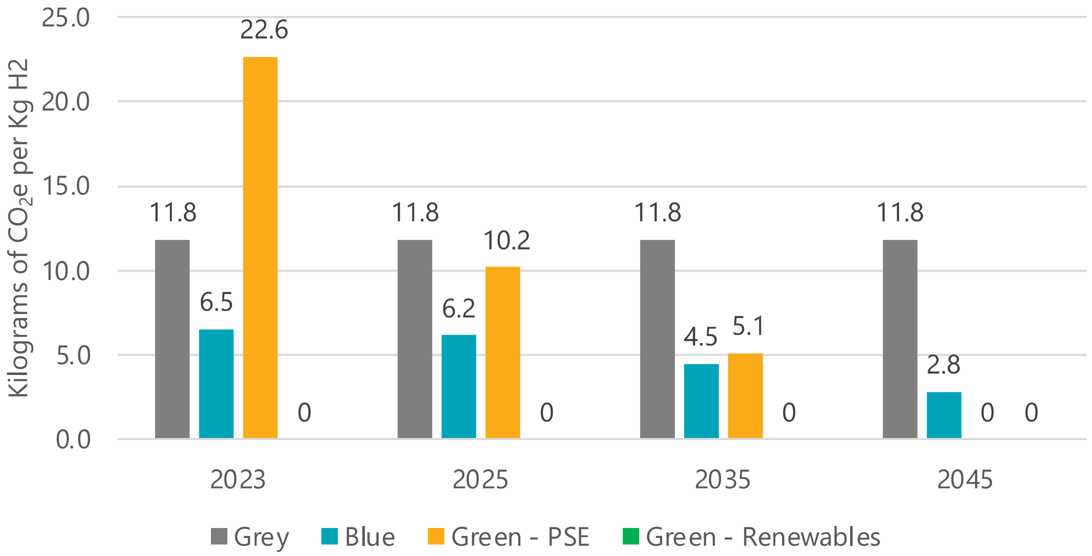


Figure 50: Estimated Hydrogen Emission Factors

9.3 - Results

Historical Emissions

The historical analysis found that Intercity's full fleet emissions were relatively constant between 2010 and 2019. Intercity began using Diesel B5 in 2008, before transitioning to Diesel R10 in 2020, and Diesel R50 in 2021. However, the COVID-19 pandemic curbed emissions in 2020 to approximately 60% of the previous years' emissions primarily due to reductions in fixed route service as depicted in **Figure 69**.

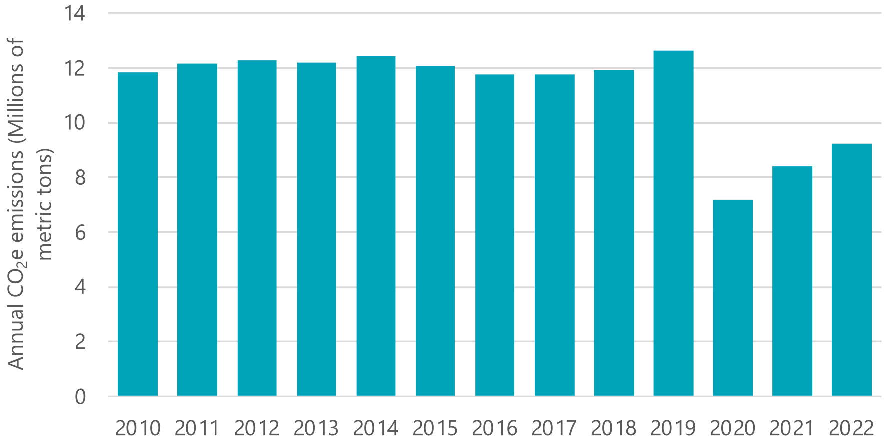


Figure 51: Total Baseline Emissions, 2010-2022

Emissions by mode remained relatively stable over the last 10 years, with fixed-route service contributing the largest share of emissions followed by vanpool, demand response, and staff vehicles as shown in **Figure 70**. The share of emissions attributed to demand response vehicles increased in 2020, presumably as a result of demand response programs running additional services during the pandemic.

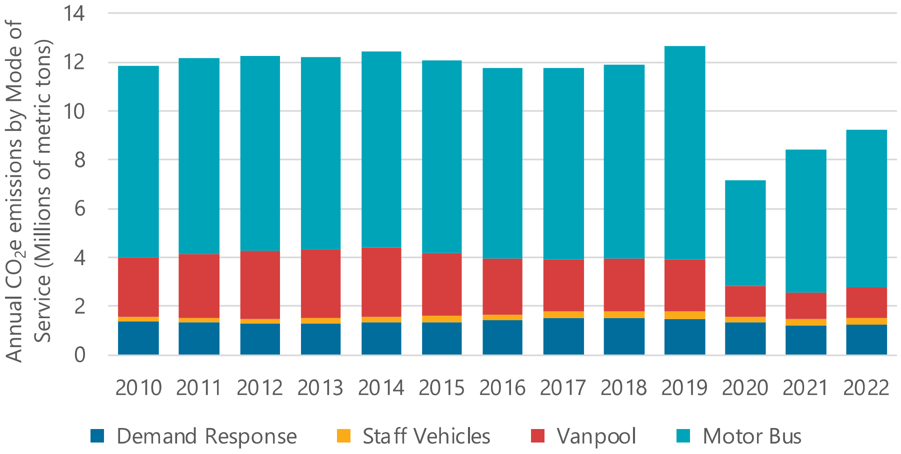


Figure 52: Baseline Greenhouse Gas Emissions by Mode, 2010-2022

The impact of Diesel R50 is noticeable in 2022, as total emissions increased as service returned post-COVID, but emissions per vehicle-mile decreased as shown in **Figure 71**.

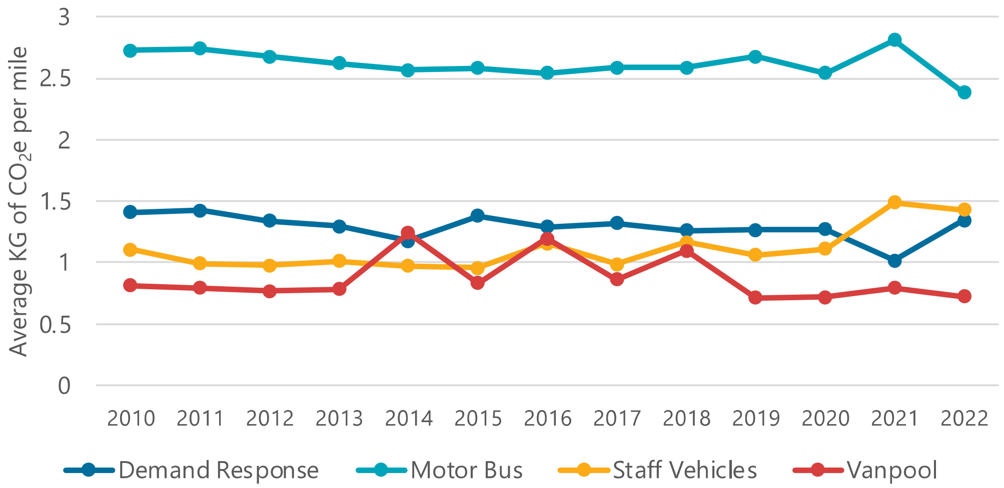


Figure 53: Share of Total Baseline Emissions per Vehicle-Mile by Mode, 2010-2022

Projections

Figure 72 shows the projected impact of BEBs on Intercity's emissions profile. The scenario with depot charging only would see a 45% reduction by 2036 with just over half of the fleet electrified, and a 77% reduction in emissions by 2048, with an 83% electrified fleet. The depot and on-route scenario would see a 100% reduction in lifecycle emissions by 2050, should PSE hold to its commitment to use 100% clean energy by 2045. Because of the established timelines for fleet replacement, combined with the distance profile of feasible blocks, the scenario with on-route charging allows for a faster reduction starting in 2030 and would reach a fully electric fleet by 2036. While this model shows the expected impact based on current emissions projections, the BEB scenarios will achieve greater reductions once PSE implements its plans for more renewable energy.

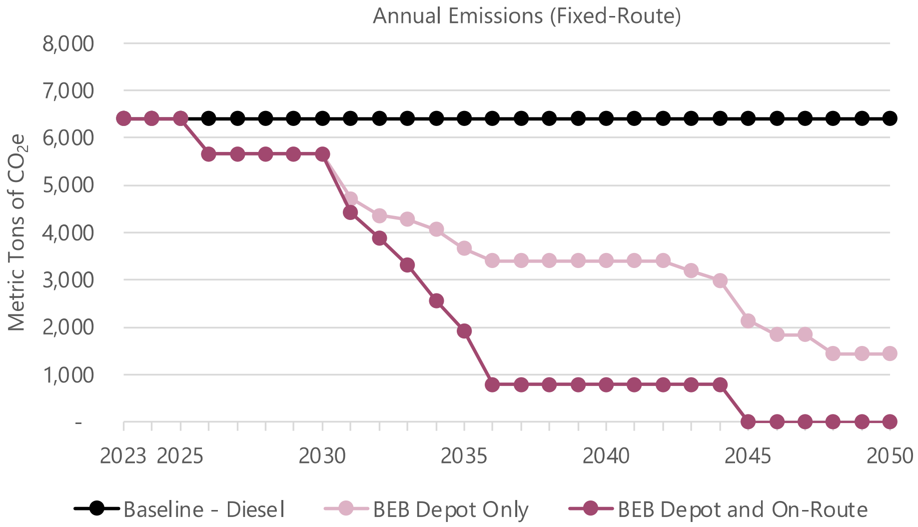


Figure 54: Battery Electric Bus Projected Annual Emissions, 2023 to 2050

Figure 73 shows the anticipated emissions impact of a mixed fleet, using both BEB and FCEB. The two scenarios convert the diesel fleet to either BEB depot charging or FCBE by 2036. The only difference in the emissions depicted are related to the hydrogen source.
Use of grey hydrogen would see an emissions reduction of more than 50% by 2050. However, the grey hydrogen emissions would still be more than double that of the depot only BEB scenario because of the fuel’s well-to-wheel emissions. The blue hydrogen scenario would see a 72% reduction by 2050.

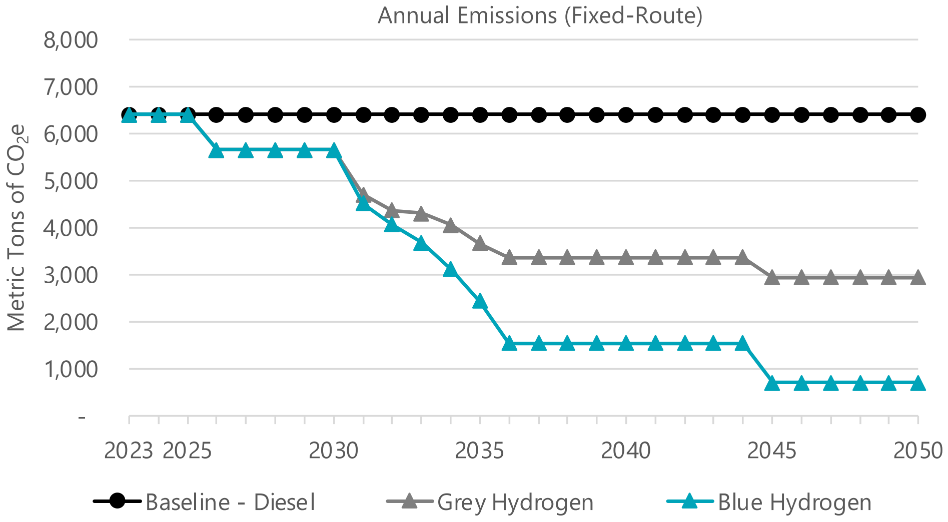


Figure 55: Mixed-Fleet Projected Annual Emissions, 2023 to 2050

The FCEB only scenario shown in **Figure 74** offers the fastest path to zero-emissions if green hydrogen, produced through electrolysis and utilizing carbon-free electricity, is deployed.

However, if grey hydrogen is used, there is virtually no difference in lifecycle emissions from the baseline R99 diesel projections.

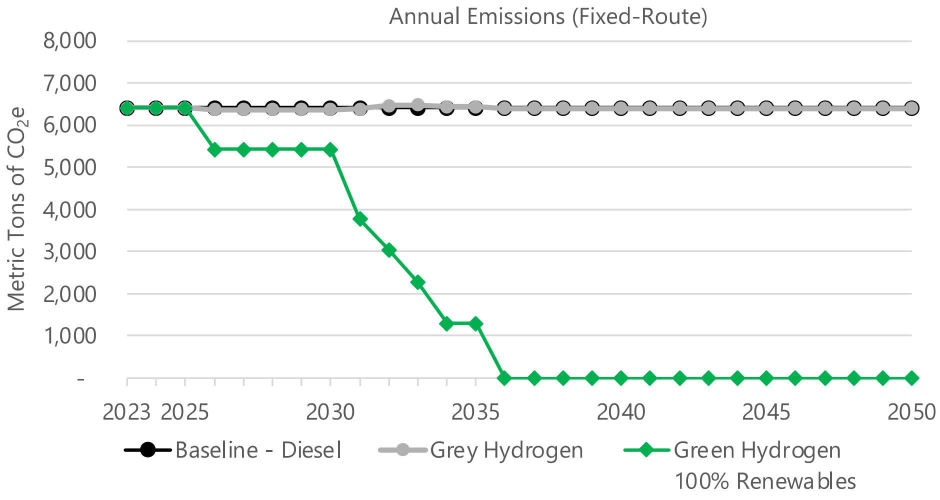


Figure 56: FCEB Only, Grey & Green Hydrogen, 2023 to 2050

9.4 - Key Takeaways

Figure 75 shows a comparison of all the possible scenarios and fuel mixes.

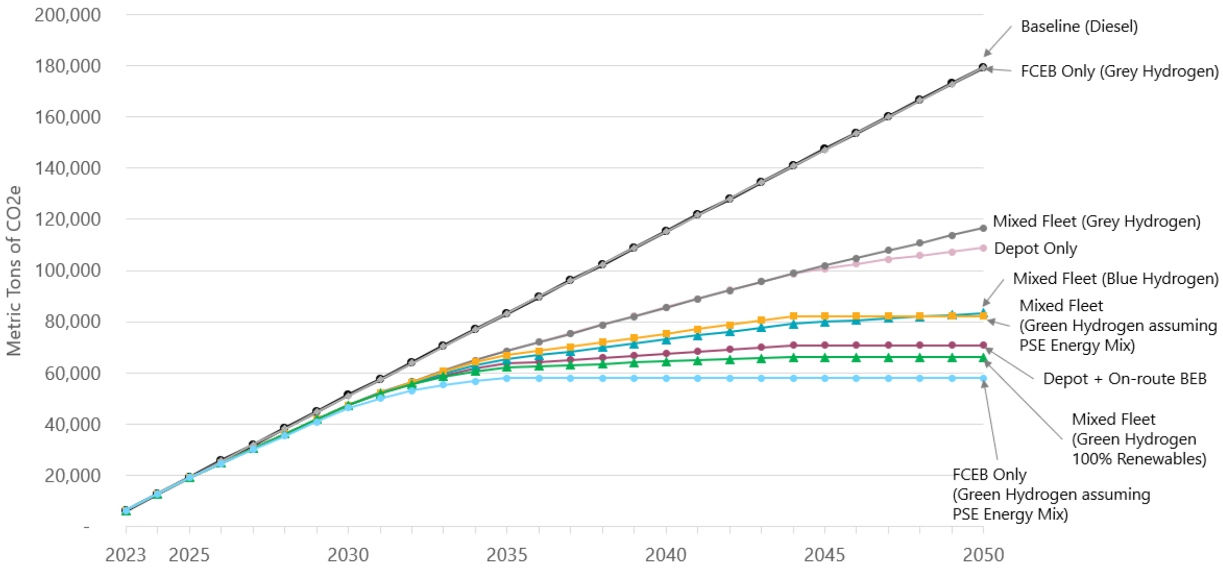


Figure 57: Cumulative Emissions, All Scenarios

Key takeaways from the analysis are as follows:

- The FCEB only, green hydrogen scenario has the most significant emissions reduction from the diesel baseline, followed by mixed fleet (BEB and green hydrogen FCEB), and then BEB only with depot and on-route charging.
- The lifecycle emissions of hydrogen have a significant impact on the overall GHG emissions. Green hydrogen has the most potential to reduce Intercity's emissions, whereas grey hydrogen has a nearly identical emissions profile to that of the diesel baseline. This highlights how important is to procure hydrogen with the lowest possible carbon footprint to ensure potential emissions reductions from FCEB deployment are realized.
- The influence of energy selection also affects the emissions profile of any scenario that uses battery electric buses as it depends on PSE's electricity generation mix. If PSE adopts zero-emissions generation sources more quickly, then the emissions profile of BEB scenarios decreases more quickly. However, the converse is also true; if PSE fails to meet its sustainable electricity generation targets, then Intercity Transit will fail to see the full potential of the BEB scenarios.

9.5 - Next Steps

As Intercity Transit continues to explore all of the possible scenarios for a zero-emission future, it will be important to pay close attention to the lifecycle emissions of its energy sources and regularly consult and update the emissions model developed by Nelson\Nygaard to ensure that the agency makes its decisions based on the most up to date and relevant data.

Section 10 – Change Management Summary

10.1 - Background and Purpose

In the transit industry, the transition from a fossil fuel-powered to a zero-emission fleet is a transformative innovation that requires significant pre-planning and accommodation to ensure a smooth operational change.

As Intercity is developing a transition plan, there are many aspects of service provision that the agency must consider beyond procurement of new vehicles. By planning for change well in advance of its arrival, Intercity can facilitate a smooth transition while maintaining its levels of service and overall operational efficiency. Intercity should also consider the public perception of electric vehicles as they decide what kind of vehicles to procure and the pace of deployment.

This section highlights areas where change may be needed and proposes strategies for proactively addressing challenges or obstacles that may arise in the run up to and the roll out of a fleet transition. It also summarizes scholarly research and customer sentiment survey results from around the world that describe customer perception of ZEVs.

10.2 - Change Management Considerations

Shifting the composition of the fleet requires changes in all aspects of the operation. Considerations are broken down into the following subject areas: Operations, Maintenance, Planning and Scheduling, and Administration.

Operations

Daily Operations and Dispatch: It is a common practice in transit operations for a dispatcher or controller to request that an operator use the bus they are driving to extend their working day to cover an unplanned trip. This is most often because the operator or the bus that was planned to operate the route needs to retire sooner than planned due to operator issues (e.g., illness) or mechanical issues with the bus. This practice becomes more challenging with BEBs, as they operate with a limited range and must maintain a minimum state of charge. This is not an issue with diesel buses as they carry more fuel than is required for a service day. In a predominantly BEB fleet scenario, Intercity will need to consider the remaining energy level on a replacement bus to ensure it has enough energy to accommodate a longer day.

Vehicle Charging: One of the most significant operational considerations pertains to BEB charging, both at the depot and at on-route facilities. With a full fleet of BEB vehicles, the layout of the depot will need to be configured to accommodate simultaneous charging, and to ensure that vehicles are ready for operations at the beginning of the service day and, perhaps, through the course of the service day. It may also be necessary to require more depot space as discussed in **Section 4.7** of this report. Intercity may also need to employ additional staff or reconfigure operator and/or maintenance personnel schedules so that there is adequate capacity to move vehicles around at the depot during the day to ensure buses have enough charge to deliver scheduled service.

Hydrogen Fueling: Fuel cell electric vehicles (FCEVs), powered by hydrogen, also have unique fueling considerations. Intercity would need to identify fueling locations, install hydrogen fueling and safe storage equipment, and train staff to safely use the equipment.

Driver Habits/Training: Operating a ZEB is more nuanced than a traditional diesel or diesel hybrid coach. In order to prepare for the fleet transition, Intercity should retrain drivers to operate electric buses efficiently. Operator driving habits, like unique driving behaviors tied to harder acceleration and braking, can significantly impact a ZEB's range. This could deplete batteries below minimum charge limits, which could require additional charging time or a vehicle swap/replacement.

Safety for Bikes and Pedestrians: ZEBs are quieter than traditional diesel or diesel hybrid buses, which can pose an increased safety risk for people walking and biking if they are not watching the road closely, or as the bus passes people riding in an unprotected bike lane. These safety hazards should be addressed in driver training and continuing education requirements. Buses could also be equipped with acoustic alerts when turning and/or artificial ambient vehicle noise that can help people driving, walking, biking, and rolling increase their spatial understanding of where buses are on the road. Intercity should also consider running a public awareness campaign to increase operator and public awareness of proper safety protocols for preventing collisions with quieter vehicles.

Maintenance

Staff Training: ZEBs are fundamentally different machines than internal combustion engine buses and require a different set of skills, tools, safety training and procedures, and equipment to maintain. Intercity will need to invest time and money to train maintenance staff to work on new electrical propulsion systems. There may also be a need to hire additional staff to operate and manage the charging/refueling infrastructure.

Worker Safety: It will also be important for Intercity to establish new worker safety measures, as new systems come with new vulnerabilities and hazards. The electric industry has developed many best practices in worker safety for working around high voltage. Many of these safety practices will need to be the subject of training, as well as development of new habits for existing employees. Other considerations should include measures to protect against falls, as many electric buses have components of the power systems on the roof of the vehicle which require routine inspection and maintenance. This is even more true if the buses are equipped to charge from overhead pantograph rail systems. Training in best practices and occupational safety requirements to prevent injury from the electrical systems themselves as well as working at heights will be required.

Maintenance Protocols: As more ZEBs are incorporated into Intercity's fleet, the agency should begin to develop and maintain an inventory of spare parts and tools that can be used on the new vehicles. Similarly, Intercity will need to institute new routine inspection protocols and preventative maintenance cycles that are tailored to the needs of the fleet. It may also be beneficial to reassess the work order system, both for submitting and prioritizing repairs, and to reevaluate the estimated amount of time that routine maintenance and repairs will take, especially during the transition period when maintenance staff are familiarizing themselves with the new systems and both fossil fueled vehicles and electric powered vehicles are present in the fleet.

Planning and Scheduling

Routing and Scheduling: If Intercity elects to use BEBs, bus routing and scheduling will be constrained by vehicle range and the location of on-route charging facilities, particularly during harsh (cold) weather. Intercity will have to do comprehensive analysis and planning at each service change to ensure vehicles have adequate range to complete their scheduled blocks. Constraints on vehicle range may mean that Intercity needs more buses and/or operators, or changes in scheduling practices related to operator reliefs and layover periods, to deliver the same level of service or to expand service hours or service area. Intercity should also consider triggers for future expansion of charging capacity, as fleet or service area augmentations may require creative solutions.

Limitations in energy delivery may constrain the rate at which services can grow. Fossil fuels tend not to create this limitation, so as service expansions are planned, consideration of energy usage will need to become a routine part of the plan, just like establishing new bus stops. However, the lag time between recognizing the need for additional energy transfer and capacity, and the ability to have it available, may be much longer than any other service planning time constraint considered. The impact of these limitations is minimal with FCEBs.

Emergency Contingencies: Reliance on the electric grid or a less common fuel source like hydrogen exposes Intercity to vulnerabilities, especially when there is a significant disruption in the grid or to the broader energy supply chain. Intercity should develop a contingency plan for continuation of service in the event of a power outage, inclement weather, natural disaster, or when charging infrastructure needs maintenance.

Administration

Electricity Procurement: One of the most significant changes to transit administration during and after a transition to a predominantly electric fleet is the procurement of energy. This will require more of Intercity's staff time than is currently required with diesel fuel procurement. It will also require significantly more frequent communication and negotiation with regional electricity providers such as PSE. Electricity is often priced dynamically based on demand across a service area. Intercity will likely have to work with PSE to negotiate appropriate peak and off-peak period usage charges and/or demand-based charges. It may also be necessary to negotiate different rates based on energy used to charge fleet vehicles and electricity for administrative buildings and passenger facilities.

Because rates may be dynamic and Intercity will be using a significant amount of electricity, it is important that the agency has adequate staff capacity to audit billing from PSE and ensure that it complies with mutually agreed upon billing practices, and to regularly check meters across Intercity facilities.

There is also the possibility that buying electricity at the consumer level moves from utility pricing to commodity pricing. This is common on the wholesale power grid today but is largely transparent to electricity users. This may change in the future. There are already some leading indicators of this trend in the marketplace where some utilities offer consumers the option, at a higher price, to buy power produced by renewable generation sources. Essentially this is the beginning of electric power as a commodity, as opposed to a utility.

Hydrogen Procurement: Should Intercity choose to incorporate hydrogen-powered vehicles into its fleet, it will have to contend with more unknowns. Hydrogen is not yet an established market commodity, and therefore pricing and pricing prediction for hydrogen is less certain than for diesel or electricity. Intercity will have to establish a new supply chain to procure hydrogen for its fleet, including identifying clean hydrogen producers and arranging for safe and proper transportation and storage of the fuel. It might be advantageous for Intercity to become a member of a joint venture or production consortium to ensure it has access to a continuous supply. But even such a venture requires a significant change in business practices for the agency and requires careful evaluation of options to become part of a joint venture that is highly likely to be a public-private partnership. This possibility also has the potential to take on many of the same characteristics as hedge purchasing of carbon-based fuels, again representing a significant change in business practices and expertise.

Key Takeaways

- Preparation for and execution of a zero-emission transition will require significant staff time, and may require administrative, operations, and maintenance staff augmentation.
- New safety and maintenance protocols must be developed that consider the unique attributes of zero emission vehicles.
- Future service changes, including extended hours, increased frequency, and/or service area expansion, must consider the constraints of vehicle range and charging location and capacity.

10.3 - Customer Satisfaction

Another factor in Intercity's zero-emission transition is gauging customer sentiment towards and satisfaction with ZEBs. Nelson\Nygaard reviewed existing literature to understand if and how electric vehicles impact transit customer satisfaction. This research will support and inform future planning for Intercity's zero-emission transition.

Nelson\Nygaard consulted peer-reviewed journals, conference publications, think tank research, media coverage, and agency publications to understand the breadth of existing knowledge. Because zero emission transit is an emerging practice, published research on this topic is limited. Still, Nelson\Nygaard was able to find several articles and reports that touch on customer satisfaction and transit electrification.

Findings

There is some research to indicate that electric vehicle use in public transit systems has a positive impact on customer perception, satisfaction, and transit use. The following research supports this correlation:

- In Santiago, Chile, bus electrification is correlated with lower rates of fare evasion and graffiti[6].
- In 2019, customer satisfaction on Route 55 in Gothenburg, Sweden reached an all-time high after electrification. Customers enjoy the lower noise levels and environmental benefits. Further, because the route is electrified, many respondents reported they are more willing to travel on it. There has been a 10% increase in travel volumes on the route since electrification[7]. However, this research was conducted before the COVID-19 pandemic, and no more recent data has been shared to indicate how ridership has changed since then.
- A survey of RATP riders in Paris showed that 92% of users riding on electric buses think it will contribute to better air quality and 93% believe it enhances the image of the operator and shows that the operator cares for its customers[8].
- In a 2016 Swedish study, researchers surveyed transit riders, and found that most passengers felt the electric bus was quieter inside and out, produced fewer emissions, and was more comfortable than a diesel or CNG alternative[9]
- A 2020 study into what customers in Korea most value in electric buses showed safety, eco-friendliness, and comfort as the most important factors (**Figure 76**). Eco-friendliness was slightly more important to women than men[10]. Results were analyzed on a best-worst scale, which is a calculation of the difference between the frequencies of best and worst. Positive scores were more frequently selected as most important, and negative scores were more frequently selected as least important.

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[6] https://documents1.worldbank.org/curated/en/656661600060762104/pdf/Lessons-from-Chile-s-Experience-with-E-mobility-The-Integration-of-E-Buses-in-Santiago.pdf.

[7] https://www.volvobuses.com/en/news/2019/apr/electric-city-buses-increase-passenger-satisfaction.html

[8] *https://cms.uitp.org/wp/wp-content/uploads/2020/06/UITP-policybrief-June2019-V6-WEB-OK.pdf*

[9] https://www.diva-portal.org/smash/get/diva2:911643/FULLTEXT01.pdf

[10] https://doi.org/http://dx.doi.org/10.3390/en13102646

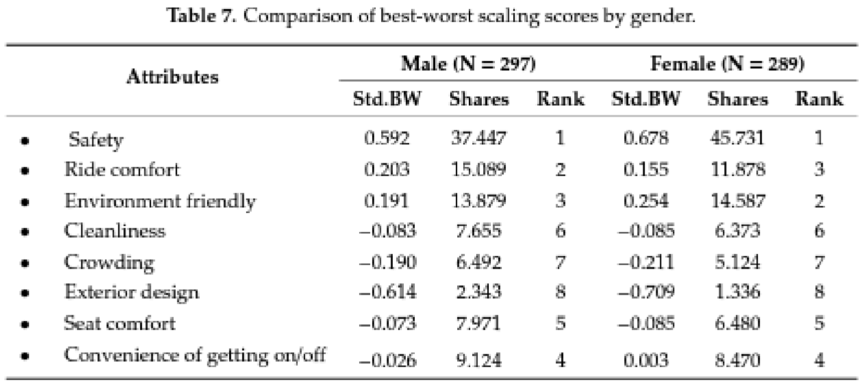

Table 7. Comparison of best-worst scaling scores by gender.

Attributes	Male (N = 297)			Female (N = 289)		
	Std.BW	Shares	Rank	Std.BW	Shares	Rank
• Safety	0.592	37.447	1	0.678	45.731	1
• Ride comfort	0.203	15.089	2	0.155	11.878	3
• Environment friendly	0.191	13.879	3	0.254	14.587	2
• Cleanliness	−0.083	7.655	6	−0.085	6.373	6
• Crowding	−0.190	6.492	7	−0.211	5.124	7
• Exterior design	−0.614	2.343	8	−0.709	1.336	8
• Seat comfort	−0.073	7.971	5	−0.085	6.480	5
• Convenience of getting on/off	−0.026	9.124	4	0.003	8.470	4

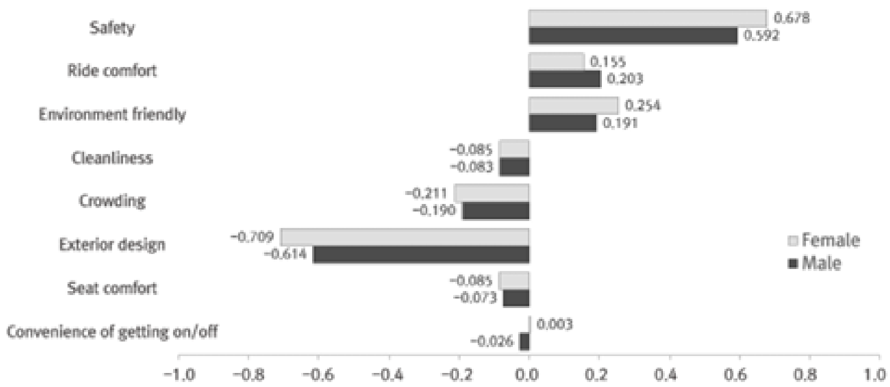

Figure 58: Survey Results on Customer Values Related to Electric Transit Vehicles

- In 2011, King County Metro Transit conducted a comprehensive evaluation of their trolley bus system to decide whether to purchase new trolley buses or replace the system with a different propulsion system. The literature review and system assessment showed that rider satisfaction is likely to be higher on electric buses than diesel hybrid because of smoother acceleration, lower interior and exterior noise levels, and lack of emissions. Feedback collected during the public engagement component of the project supported these conclusions; the public heavily favored preserving the trolley bus system over other alternatives because of lower noise and emissions levels[11].
- A survey conducted by The Go-Ahead Group's Zero Emissions Centre of Excellence in the UK found that 55% of respondents would be more likely to travel by bus if they knew a zero-emission bus was available[12]

Key Takeaways

While the literature on customer satisfaction and transit electrification is limited, existing research does indicate that transit users appreciate the environmental benefits, more

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[11] *http://metro.kingcounty.gov/up/projects/pdf/Metro_TB_20110527_Final_LowRes.pdf*

[12] https://www.intelligenttransport.com/transport-news/141964/zero-emission-buses-encourage-millions-public-transport-new-research/

comfortable ride, and lower noise level of electric buses. As Intercity plans for its transition to ZEBs, the agency has the opportunity to track customer satisfaction throughout the process and contribute findings to the discourse about the positive customer perception of sustainable transit systems.

Section 11 – Path Forward

ZEB technologies are in a period of rapid development and change. BEBs will require significant investment in facilities and infrastructure and may require changes to service and operations to manage their inherent constraints. On the other hand, FCEBs are believed to provide an approximate operational equivalent to diesel, however, the current incremental cost of buses, fueling infrastructure, and fuel places this technology at a disadvantage.

BEB charging only at the depot is expected to be able to support up to 83% of Intercity's fixed-route fleet by 2050. To reach a 100% zero-emission fleet, other alternatives such as on-route charging or the purchase of FCEBs would need to be implemented. In a mixed fleet scenario, FCEB costs are adversely impacted by the currently high FCEB capital costs. The cost of an FCEB is approximately two times that of a comparable diesel vehicle and hydrogen costs are currently estimated at over $8/kg.

The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. The technology requires significant development before it is ready to support fleetwide transitions. However, it is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission public transit. Ultimately, the ZEB technology that is most efficient and sustainable to operate will evolve into either the majority ZEB solution or the only ZEB solution.

As Intercity continues to move towards a zero-emissions fleet, it will be important to consider and plan for operational adjustments around operations, maintenance, planning and scheduling, administration, and customer sentiment. It is expected that the results from this analysis will be used by Intercity Transit Leadership and the Board of Directors to identify an approach for fleet electrification. Once the approach has been determined, a formal Zero Emission Transition and Implementation Plan will be prepared.

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Appendix A