City of Roseville
Zero Emission Bus (ZEB)
Business Plan
February 2020

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Summary of Acryonms

Acronym	Definition	Acronym	Definition
ADA	American with Disabilities Act	LCFS	Low Carbon Fuel Standard
APCD	Air Pollution Control District	LCTOP	Low Carbon Transit Operations Program
APTA	American Public Transportation Association	MW	Megawatt
AQMD	Air Quality Management District	NOx	Nitrogen Oxides
BaU	Business as Usual	OCPP	Open Charge Point Protocols
BEB	Battery Electric Bus	OEM	Original Equipment Manufacturer
BMTC	Bus Maintenance Training Committee	OSHA	Occupational Safety and Health Administration
CAA	Clean Air Act	PCTPA	Placer County Transportation Planning Agency
CaaS	Charging as a Service	PG&E	Pacific Gas & Electric
CalSTA	California State Transportation Agency	PLC	Programmable Logic Controller
CARB	California Air Resource Board	PPA	Power Purchase Agreement
CMAQ	Congestion Mitigation and Air Quality Improvement Program	PV	Photovoltaic
CNG	Compressed Natural Gas	RFP	Request for Proposals
CTE	Center for Transportation and the Environment	SCO	State Controller’s Office
DAC	Disadvantaged Community	SCRTTC	Southern California Regional Transit Training Consortium
DER	Distributed energy resource	SECAT	Sacramento Emergency Clean Air Transportation Program Guidelines
EBCA	Electric Bus Corridor Analysis	SOC	State of Charge
EUL	Expected Useful Life	TIRCP	Transit and Intercity Rail Capital Program
EV	Electric Vehicle	TOU	Time of Use
EVSE	Electric Vehicle Supply Equipment	UITP	International Association of Public Transport
FLR	Fixed Local Route	VW	Volkswagen
FTA	Federal Transit Administration	ZEB	Zero-Emission Bus
GGRF	Greenhouse Gas Reduction Fund	ZEP	Zero-Emission Propulsion
GHG	Greenhouse Gas	ZEV	Zero-Emission Vehicle
GVWR	Gross Vehicle Weight Rating		
HVAC	Heating Ventilation and Air Conditioning		
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project		
ICE	Internal Combustion Engine		
ICT	Innovative Clean Transit		
kW	Kilowatt		
kWh	Kilowatt-hour		

Executive Summary

The City of Roseville Zero Emission Bus Business Plan (ZEB Plan) is intended to guide Roseville Transit's ("Roseville") fleet transition from diesel fuel to zero emission fuel sources. This study is driven in part by California Air Resources Board (CARB) Innovative Clean Transit (ICT) rule which requires transit agencies to operate a fully zero-emission fleet by 2040; but also, this report is designed to evaluate the financial implications, and potential business case, of using electric buses versus diesel buses which Roseville currently operates. Two zero-emission bus technologies currently meet CARB ICT requirements: battery electric buses (BEBs) and hydrogen fuel cell buses. This report specifically evaluates BEBs because Roseville has currently secured FTA, SECAT, and LCTOP funding for five BEBs and associated chargers. Additionally, a preliminary review of current hydrogen fuel cell buses indicates that they will require significantly higher upfront capital costs for a fueling station and buses as compared to BEBs.

Key Highlights and Recommendations:

- Existing commuter route service requirements can be reliably met with BEBs available on the market today without on-route chargers. Interlined routes should be charged midday to reliably meet afternoon service requirements.
- Electrifying fixed local routes (FLR) should be delayed until CARB requires ZEB purchases in 2026, as current BEB capabilities cannot reliably meet the majority of FLR service requirements without on-route chargers. Willdan recommends reevaluating the technology's capabilities when it has developed further.
- Using BEBs is expected to be more expensive than diesel over 20 years, even after factoring in available incentives. The financial analysis, however, does not incorporate potential benefits and cost savings from installing on-site solar and battery storage.
- All commuter route BEBs and the three shortest fixed local routes BEBs can be charged exclusively at the depot with four to six plug-in chargers ranging in power from 60KW to 150KW. Based on current technology and existing route layouts, the remaining fixed local routes would require approximately three on-route chargers.
- The cost difference between the different power levels of chargers is negligible over 20 years, and Roseville should consider using chargers with a power level greater than 100KW to have the most flexible charging capabilities and to future-proof for other medium and heavy-duty electric vehicle charging.
- Roseville should consider purchasing a smart charging software, either from a charging vendor or 3rd party, to further optimize the charging schedules and peak demand than estimated in this report.
- This report is a solid foundation for Roseville's eventual CARB Rollout Plan, due by July 1, 2023. While ultimate submittal requirements may change this report includes many key elements required in the legislation.

Willdan ran a 20-year financial analysis for new bus and charger purchases starting in 2020 using the phase-in plan noted above with chargers ranging in power level from 60KW to 150KW to evaluate the financial implications of the different chargers over time. The financial analysis includes a business-as-usual scenario that assumes diesel buses will be exclusively used through 2040 as a reference point, even though it is not compliant with CARB's ICT regulation. Without incentives, BEBs will cost approximately $10 million more than diesel buses over 20 years. Even after factoring in HVIP rebates and LCFS credits, BEBs will still cost $2-3 million more than diesel buses over 20 years. This is generally due to the higher purchase prices of BEBs and the capital costs associated with charging infrastructure. Operating and maintenance costs of BEBs are expected to be significantly lower than diesel buses; however, these savings are less than the increase in the upfront capital costs of an electrified transit fleet. Roseville should note that funding availability is subject to change and Roseville may not be able to leverage the funding sources as described in this report. The different power levels of the chargers do not significantly affect the overall BEBs costs, steering our recommendations towards installing the highest power chargers possible to allow long-term flexibility in charging schedules.

Introduction

Roseville Transit "Roseville" operates a 37-bus transit fleet that serves the City of Roseville, California which has a population of approximately 139,110. It is the largest city in Placer County and is located approximately 16 miles northeast of the City of Sacramento. Roseville provides several transit services to its residents included fixed local service, Dial-A-Ride paratransit, a commuter service to downtown Sacramento, and "Game Day Express" to Sacramento Kings Games. Roseville currently operates 11 weekday fixed local service routes, five weekend fixed local service routes, and ten weekday AM and PM commuter runs serving over 330,000 riders per year.

Roseville's fleet operates out of the Roseville corporation yard located at 2075 Hilltop Circle, Roseville, CA. The corporation yard also houses the current diesel fueling station and other city services including refuse trucks and maintenance vehicles. City employees are responsible for the overall management, marketing, and planning of transit fleet operations, and fleet maintenance. The buses are operated through a private contractor.

With California's aggressive goals towards reduction in Greenhouse Gas (GHG) emissions and carbon free power, Roseville is looking to support the State's goals by exploring Zero Emission Bus (ZEB) options for its future rounds of transit vehicle purchases. This, in combination with CARB's upcoming Innovative Clean Transit Regulations, and other driving forces, caused Roseville to contract with Willdan to conduct a feasibility study of fleet conversion to ZEB technologies, as well as to address the site's needs to continue to support (fuel and service) future fleets of vehicles.

To date, Roseville has successfully secured $3.4 million in funding from Buses and Bus Facilities Formula Program 5339(a), FTA Buses and, Bus Facilities Infrastructure Investment Program 5339(b), FTA Urbanized Area Formula Grants 5307, Sacramento Emergency Clean Air Transportation (SECAT) Program, and local transit funds to purchase 4 EV buses. Roseville has secured additional funding through the Low or No Emission Vehicle Program 5339(c) to procure a 5th Battery Electric Bus (BEB) intended to be used to expand existing commuter service. Roseville's goal is to have the BEBs delivered by early 2022 and brought into revenue service by mid-2022. To ensure that they are thinking holistically in the greater scope of zero emission fleet conversion, Roseville Transit has commissioned Willdan to perform a ZEB Business plan, to evaluate the business case behind transitioning to BEBs.

This report will explain the background of implementing a Battery Electric Bus (BEB) fleet, including relevant regulations, a financial assessment for fleet conversion, assumptions used to model fleet conversion, a high-level infrastructure needs assessment, potential solutions for Roseville to explore further, and potential funding sources for Roseville to explore to reduce the upfront costs of fleet electrification. Willdan briefly considered hydrogen fueled buses, however, hydrogen fueling stations can cost over $5 million dollars, hydrogen buses are more expensive than BEBs, and hydrogen fuel supplies may be unreliable[1]. As a result, this report focuses on the costs and implications of a purely BEB fleet with currently available technology.

Relevant Regulations

California Air Resources Board Innovative Clean Transit Regulation

In December 2018, the California Air Resources Board passed the Innovative Clean Transit Regulation (ICT) requiring transit agencies in California to start phasing in zero-emission buses (vehicles over 14,000 lbs GVWR) in their fleets. The ICT regulation was approved on August 13, 2019 and is effective as of October 1, 2019[2]. Under ICT, all transit agencies must operate a 100% zero-emission fleet by 2040. Currently, ICT defines zero-emission as true zero source emission technologies such as hydrogen fuel cell buses or battery electric buses. The legislation

[1] https://h2stationmaps.com/costs-and-financing
[2] https://ww3.arb.ca.gov/regact/2018/ict2018/ictfro.pdf

sets different phase-in requirements depending if a transit agency is defined as a large transit or small transit agency. Roseville does not operate in either the South Coast Air Basin nor San Joaquin Valley Air Basin and operates less than 100 buses in annual maximum service; therefore, Roseville is considered a small transit agency (by CARB standards) and must comply with the following milestones:

- Submit a ZEB Rollout plan to CARB by July 1, 2023.
- Starting January 1, 2026 at least 25% of new bus purchases in each calendar year must be zero-emission.
- Starting January 1, 2029 all new bus purchases must be zero-emission.
- By 2040 all operating buses must be zero-emission.

Per ICT legislation, a "Bus Purchase" means Roseville has identified, committed and incumbered funds and executes one of the following:

A. A written "Notice to Proceed" executed by a transit agency to a bus manufacturer to begin production of a bus either:
    1. Under a previously-entered purchase contract
    2. To execute a contract option
B. If no Notice to Proceed is issued, a written purchase agreement between a transit agency and a bus manufacturer that specifies the date when the bus manufacturer is to proceed with the work to manufacture the bus
C. A signed written lease agreement between a transit agency and a bus manufacturer or sales representatives for a new bus to be placed in revenue service for a contract term of five years or more

Roseville has mentioned potentially maintaining a contingency fleet once the existing fleet is fully electrified. California regulations define an "emergency contingency vehicle" as a revenue vehicle removed from an active bus fleet for local emergencies after the revenue vehicle has reached the end of its normal minimum useful life. According to this definition Roseville may be able to maintain a few retired diesel buses on site for emergency purposes after their FTA 12-year minimum normal useful life. Buses retired before their FTA minimum normal useful life may not be kept as contingency vehicles.

Figure 1. Roseville Dial-A-Ride Bus

Per the CARB ICT legislation at the time of this report, purchases of cutaway, over-the-road, double decker, or articulated buses are subject to the zero-emission bus purchase requirements on or after January 1, 2026, if the cutaway, over-the-road, double-decker, or articulated bus type has a model that has passed the bus testing procedure and obtained an Altoona Testing Report for a given weight class. Roseville operates 11 cutaway buses for its Dial-A-Ride service (see **Figure 1**) which may be subject to CARB ICT's ZEB purchasing requirements starting January 1, 2026. Some manufacturers have started offering cutaway buses for paratransit or shuttle service; however, there are no Altoona reports for cutaway buses at the time this study was conducted. A high level review of electrifying DAR buses has been included in this report for initial planning estimates.

Data Collection and Assement

Route Modelling Assumptions and Inputs

Roseville's commuter and fixed local routes were modelled using CALSTART's proprietary Electric Bus Corridor Analysis (EBCA) tool. The tool uses bus specifications and inputs including curb weight, frontal area, fuel economy in commuter and arterial cycles, route path, elevation change, local temperature, average speed and ridership to determine the efficiency (kWh/mi) of an electric bus running that route. **Table 1** and **Table 2** summarize the inputs and assumptions used in CALSTART's model for the commuter routes and fixed local routes.

Table 1 – Summary of Commuter Route Model Inputs and Assumptions

Description	Input/Assumption	Comments
Bus	Representative 440 kWh 40' transit bus	Reference commuter bus[3]
Existing Route Path	Current Route Maps, Schedules, Ridership, and Speeds	Provided by Roseville
Alternate Route Path	Expected Path, Schedules, Ridership, and Speeds	Provided by Roseville and estimated from Placer County Transit data
Ambient Temperature	From Weather Underground	
Depot Charging	Yes	
On-route Charging	None	

Table 2 – Summary of Fixed Local Route Model Inputs and Assumptions

Description	Input/Assumption	Comments
Bus	Representative 440 kWh 35' transit bus	Reference FLR bus[4]
Existing Route Path	Current Route Maps, Ridership, and Speeds	Provided by Roseville
Ambient Temperature	From Weather Underground	
Depot Charging	Yes	For L, R and S routes
On-Route Charging	300 KW Pantograph	For A, B, D, M, and CGFE routes

EBCA Results and Recommendations

Complete EBCA results have been provided in Appendix A. Each individual AM, PM, and interlined commuter route was modelled separately. Similarly, each unique fixed local route (see **Figure 2**) was modelled separately. Two models were completed for each bus running the A and B routes based on their specific operating schedules. The R and S routes were each broken up into two models to account for the different energy usages during the different parts of the day they operate.

Commuter routes utilized a reference 40' transit bus with a 440 kWh battery. While Roseville may end up operating a bus with different specifications, CALSTART determined this representative sample bus would be useful for modelling purposes to understand the efficiency differences between routes. The model utilizes service times, route path, pull in distances, and pull out distance based on information provided by Roseville. Local climate data is referenced from Weather Underground.

[3] Representative commuter bus assumes a 440 kWh 40' Proterra Catalyst E2

[4] Representative FLR bus assumes a 440 kWh 35' Proterra Catalyst E2

The model calculates bus efficiency across different seasons because bus efficiency is affected by the ambient temperature. The seasonal efficiencies are based on the following months:

- Winter: December
- Spring: March
- Summer: June
- Fall: September

Figure 2. Sample Route Map used in EBCA

The model does not account for potential battery degradation over time. Battery electric buses are relatively new; therefore, there is not reliable industry data available regarding the potential degradation over time. General guidance from battery manufacturer recommendations indicate that battery state of charge (SOC) should not fall below 20%. We apply and additional 10% buffer as a margin of safety to help ensure that the buses will continue to provide reliable service throughout their 12-year service life. As a result, our final recommendations and the EBCA model results are calibrated to show when the minimum state of charge (SOC) falls below 30%. It is recommended that Roseville request performance guarantees limiting battery degradation to a maximum of 20% over the useful life of the bus. This level of performance guarantee, combined with the recommendations to keep operating SOC above 30%, is expected to allow the buses to provide reliable service throughout their useful life even while not modeling battery degradation.

Roseville is considering expanding future commuter route service. The first expansion with the purchase of the 5th bus will be an additional AM/PM route. Roseville is also considering expanding service to include a midday reverse commuter route. Because both routes are still in development and since service stops and times are not established, they cannot be precisely modelled. The additional AM/PM route is assumed to have similar operating times and route lengths as the existing commuter routes. As a result, energy consumption of the additional AM/PM route can be reasonably approximated from the other commuter route models and conservative estimates have been included in this analysis. A midday reverse commuter route may have similar route lengths as existing commuter routes but the operating times, and resulting ambient temperature, are not representative of the existing commuter routes. Ambient temperature and the expected load on the bus's HVAC system to maintain targeted internal temperatures significantly impact battery performance and resulting energy use; therefore, the AM/PM route energy consumption would not be representative of a midday reverse commuter route. It is also not clear yet how the fleet size and charging schedules may be impacted by adding this route. There may be different charging implications if an additional bus is purchased to serve this route versus using an AM commuter bus to run a midday reverse commuter route. For these reasons, the midday reverse commuter route would require a separate analysis and has been excluded from this report.

Commuter Routes

Buses that run an interlined route would fall below the recommended 30% SOC and therefore we recommend that they recharge during the middle of the day before they are deployed for PM commuter route service.

Commuter routes can be reliably operated with battery electric buses currently available on the market. For analytical and route electrification cost purposes we took the individual commuter route EBCA results and paired specific AM and PM routes together to determine if a bus can operate an AM and PM in the same day. The energy usages and final SOC for operating the paired commuter routes are summarized in **Table 3**. As a worst-case scenario, we assumed that the 2PM and 9PM routes would always be interlined. We have determined that a 40' transit bus with approximately 440 kWh battery capacity that can travel a minimum of 150 miles on Roseville's commuter routes with some remaining SOC, can meet Roseville's current commuter route service requirements. This can be accomplished with depot-based charging alone. Buses that run an interlined route would fall below the recommended 30% SOC and therefore we recommend that they recharge during the middle of the day before they are deployed for PM commuter route service. There are at least 6 hours of available charge time between AM and PM service; therefore, even with a 60KW charger, a bus can recharge up to 300 kWh during the day, accounting for average charge rates. This is expected to fully recharge any AM commuter bus.

The same operational conditions would apply to any commuter bus that is designated for a weekday Game-Day Express service. Weekday Sacramento Kings games occur during the evenings and it is effectively interlined after a single PM commuter route. While this specific route has not been modelled, other PM routes can serve as a useful, conservative proxy for the energy consumption since the game day bus runs a similar, but shorter route and stays in Sacramento until the game is over. Based on the recommended bus capacity and estimated energy consumption, any bus that is designated to provide Game-Day service (see **Figure 3**) should be recharged midday so it can complete both a non-interlined PM route and Game-Day route.

Table 3 – Summary of Commuter Route EBCA Results (40' 440 kWh)

Commuter Route Combination		Seasonal Total Daily Energy Usage (kWh/day)					Lowest Final SOC
AM	PM	Winter	Spring	Fall	Summer	Annual Average	
Interline 1 and 7	1	319.70	285.84	304.73	307.28	304.39	27.34%
Interline 2 and 10	7	362.30	315.10	347.68	347.29	343.09	17.66%
3	Interline 3 and 10	357.42	351.44	386.96	396.79	373.15	9.82%
4	4	225.21	215.83	235.74	240.29	229.27	45.39%
5	5	231.35	217.84	234.62	237.68	230.37	45.98%
6	6	214.39	201.66	219.18	222.40	214.41	49.45%
8	8	209.34	194.28	208.04	212.48	206.04	51.71%
9	Interline 2 and 9	328.72	324.80	359.41	368.56	345.37	16.24%

Roseville is considering altering its commuter route to take the I-80 and I-5 freeways into downtown Sacramento instead of the existing path of I-80 and Highway 160. This would avoid traffic coming into Sacramento and get riders to their stops more quickly and reliably than the current routes. While the exact stops have not been finalized and Roseville speed data is not available, CALSTART modelled some of the alternate commuter routes using proxy data from Placer County Transit. The estimated efficiency and energy usage for a sample of the alternate commuter routes are summarized in **Table 4**. The model used the same type of bus used in the existing commuter route models.

Table 4 – Summary of Sample Alternate Commuter Route EBCA Results (40' 440 kWh)

Route	Time	Seasonal Route Energy Usage (kWh)					Lowest Final SOC
		Winter	Spring	Fall	Summer	Annual Average	
2	PM	138.98	155.92	169.70	174.48	159.77	60.35%
3	PM	126.81	137.14	145.79	148.47	139.55	66.26%
4	AM	276.39	248.99	255.08	255.32	258.95	37.18%
10	AM	257.95	237.03	244.43	242.41	245.46	41.38%
Interline 2 and 10	AM	572.50	506.07	525.79	521.78	531.54	-30.11%
Interline 3 and 10	PM	294.68	320.70	348.75	358.60	330.68	18.50%
Interline 2 and 9	PM	287.65	312.44	339.71	348.92	322.18	20.70%

Alternate commuter routes would require a 660 kWh battery, more midday charging, and potentially on-route charging in Sacramento. Operating alternate commuter routes would result in higher capital and operating costs compared to existing commuter routes.

The alternate commuter routes are longer than the existing commuter routes and the buses travel faster on this route. Both factors substantially increase the total energy required for the bus to complete this route. While not all the routes have been modelled, based on the initial results from the interline routes, a 440 kWh battery will not have enough capacity to handle all the possible routes. A 660 kWh battery would likely be required to complete the Interlined 2 and 10 routes, or on-route charging would need to be considered. Midday charging would be recommended between any AM and PM alternate commuter route because of the higher energy requirements to run these longer, harder routes. Overall, this will result in higher capital costs for the larger batteries, higher energy costs, and less flexible charging schedules.

Figure 3 Game Day Express Bus

Fixed Local Routes (FLRs)

The fixed local routes will be significantly more difficult to electrify using off-the-shelf products today without operational changes compared to the commuter routes. While individual service lap lengths are relatively short, the quantity of service laps in a day and lengthy service times result in local route buses requiring more energy than the commuter routes. Since Roseville's existing FLRs use a 35' bus now, these routes were modelled using a reference 35' transit bus with a 440 kWh battery, which is near the maximum available battery capacity on 35' buses currently on the market. **Table 5** shows the total energy required to complete a full day of service including pull in and pull out distance, during each season. The table also shows on average how many complete laps can be completed on a given route before the SOC falls below 30%. This will vary throughout the year as ambient temperature changes. Only the L, R and S routes can be completed on a single charge. The A2 and B1 laps could complete the full-service requirements but would fall below the recommended 30% SOC. The longest routes: A1, B2, CGFE, D and M would all require on-route charging or other solutions meet service requirements.

Table 5 – Summary of Weekday FLR Seasonal Energy Usages (35' 440 kWh)

Route	Winter Total kWh/day	Spring Total kWh/day	Summer Total kWh/day	Fall Total kWh/day	Annual Average kWh/day	Lowest Final SOC	Daily Service Laps	Average laps completed before 30% SOC
A1	427.65	386.94	459.82	443.61	429.51	-4.50%	16	11
A2	321.51	299.95	353.46	341.99	329.23	19.67%	12	10.5
B1	332.19	310.54	365.89	355.40	341.00	16.84%	13	11.5
B2	405.85	366.51	436.28	420.81	407.36	0.85%	16	11.5
CGFE	511.75	486.62	533.71	532.30	516.10	-21.30%	6	4
D	445.54	415.47	474.47	463.16	449.66	-7.84%	13	8.5
L	264.99	242.21	285.67	278.36	267.80	35.08%	11	11
M	603.37	535.37	613.05	594.56	586.59	-39.33%	16	8
R	145.37	132.08	150.14	145.10	143.17	65.88%	4	4
S	209.48	205.13	232.36	225.54	218.13	47.19%	8	8

Willdan considered an alternate scenario of buying the largest battery capacity bus currently available on the market, a 40' transit bus with a 660 kWh battery, to see if on-route charging could be avoided. Roseville should note that no 35' BEB on the market is available with this level of battery capacity, so a 40' bus must be used. Furthermore, there is only a single manufacturer that currently provides 40' BEB with this level of battery capacity. **Table 6** shows the total energy required to complete the weekday FLR service requirements using a 40' 660 kWh bus. The total energy needs include the pull in and pull out distances to the corporation yard. Even with the larger battery capacity the M and CGFE routes fall below the manufacturer recommended 20% SOC. Routes A1, B2, and D would complete a full day with at least 20% SOC but are at or below 30% SOC. These routes may not reliably meet service requirements as batteries degrade over time. The FLR routes would still require at least two on-route chargers for routes CGFE and M; therefore, there is little added benefit from pursuing oversized buses and batteries for the FLRs. Total energy needs are higher with this bus because of the added weight with the larger bus and extra battery packs. Another issue is if Roseville pursued 40' buses for the FLRs, they will not fit in their current parking spaces.

Using 660 kWh BEBs, the FLR routes would still require at least two on-route chargers for routes CGFE and M; therefore, there is little added benefit from pursuing oversized buses and batteries for the FLRs.

Table 6 – Summary of Weekday FLR Seasonal Energy Usages (40' 660 kWh)

Route	Winter Total (kWh/day)	Spring Total (kWh/day)	Summer Total (kWh/day)	Fall Total (kWh/day)	Annual Average (kWh/day)	Lowest Final SOC	Daily Service Laps	Average laps completed before 30% SOC
A1	446.03	399.78	479.86	462.34	447.01	27.29%	16	16
A2	335.37	310.59	369.39	357.04	343.10	44.03%	12	12
B1	346.83	321.95	382.85	371.65	355.82	41.99%	13	13
B2	423.74	379.03	455.82	439.10	424.42	30.94%	16	16
CGFE	528.93	530.02	555.83	547.35	540.53	15.78%	6	5.5
D	463.27	428.90	494.53	482.27	467.24	25.07%	13	12.5
L	277.74	251.69	300.23	292.27	280.48	54.51%	11	11
M	626.76	549.85	635.75	615.67	607.01	3.67%	16	12
R	150.02	134.95	154.71	142.39	145.52	76.56%	4	4
S	217.38	212.22	244.75	232.67	226.76	62.92%	8	8

Figure 4. Roseville Fixed Local Route transit bus

Charging Solutions

Assuming that all commuter routes, including the expanded service, and the shortest FLRs are charged exclusively at the depot, there are several iterations of viable depot charging solutions each with their own benefits and drawbacks. The different options with some budgetary cost estimates are presented in **Table 7**. The quantity of chargers needed in each scenario is determined based on the minimum number of chargers and ports needed to fully recharge each bus before its pull out time the next day. The analysis assumes that there are two interlined PM routes each day, for a total of 9 commuter buses and 3 FLR buses to be recharged each night. Each scenario has a minimum of 12 ports; therefore, no late night switching will be required. On days that the 2PM and 9PM commuter routes are not interlined, Roseville may need to perform one late night switch, consider fully recharging between AM and PM service, or consider purchasing an additional charger. Cost estimates for different power chargers are based on recent discussions Willdan has had with various charging vendor OEMs[5]. Typically, as the maximum power rating increases, cost increases. The 125 KW charger does not follow this trend, because

[5] OEMs Willdan received charger price estimates from ABB, Siemens, and Proterra

currently only one manufacturer produces a 125KW charger and cost estimates are based only on that manufacturer's current prices. Utility costs are estimated using current Roseville Electric rates and schedules.

Table 7 – Full Electric Bus Fleet Depot Charging Solutions

Charging Scenario	Minimum Viable Charger (dual port)	High Power Chargers (three ports each)		
Maximum Charger Power (kW)	60	100	125	150
Charger Unit Costs	$45,000	$125,000	$100,000	$140,000
Charger Installation Costs*	$40,000	$40,000	$40,000	$40,000
Depot Chargers Needed	6	5	4	4
Potential Max Demand (kW)	396	550	552	660
Utility Rate	GS-2 (No TOU)	GS-3 (TOU)	GS-3 (TOU)	GS-3 (TOU)
Average time to charge a 440kWh bus from 20%-Full	7 hrs	4 hrs	3.3 hrs	2.75 hrs
Total Charger Cost Estimate	$450,000	$775,000	$520,000	$680,000
Annual Energy Cost (kWh only)	$91,905	$75,779	$75,779	$75,779
Annual Demand Charge (KW only)	$29,272	$54,494	$54,692	$65,393
Charger + Annual Utility Cost	**$571,177**	**$905,273**	**$650,471**	**$821,172**

*Installation costs have been inflated to account for infrastructure upgrade costs (trenching, conduit, etc)

While 60KW chargers may be the lowest cost option to charge the bus fleet, they result in the longest time to charge a bus which limits flexibility in the charging schedule and does not provide any buffer against charging delays or interoperability issues. It also may not provide enough power for other heavy-duty vehicles that could be electrified in the future. 150KW chargers, however, charge buses much more quickly allowing for additional flexibility and future-proofing against the power needs of other heavy-duty electric vehicles. They also tend to be less expensive on a per-KW basis and typically can have more available ports than 60KW chargers – providing additional flexibility. Charger manufacturers offer high power chargers with up to 4 ports in some cases.

Figure 5. Sample Overhead Pantograph

The drawback of higher power chargers is they can result in in higher demand chargers and may tip Roseville into Roseville Electric's GS-3 rate schedule. The GS-3 rate schedule is a time of use rate which has higher demand charges than the GS-2 rate. If the charging schedule is not carefully managed the high-power chargers could result in significantly higher energy costs from on-peak rates and demand charges. Using a smart charging software can limit charging to off-peak times and throttle demand appropriately to minimize energy costs while still fully charging the vehicles each day. With the BEB industry still in its infancy, it is difficult to estimate what a smart charging software would cost Roseville as these services have varying business models and are usually customized to each unique situation; though, smart charging vendors plan for a net overall savings to implement a smart charging system. Upon procurement, Roseville should compare any proposed pricing and potential savings to the energy costs we have estimated in this report (**Table 11-13**) to evaluate the value specific to Roseville. Regardless of the commuter bus charging solution chosen, we suggest Roseville procure one additional charger or consider adding an overhead pantograph, **Figure 5**, fast-charger, (>300kW) in the depot to serve as a backup.

> *Willdan's recommended path for electrifying the FLRs is to electrify the shortest FLRs with the 2026 replacements, when the first FLR retirements are required to be electrified under CARB ICT and reevaluate the available technology then. This strategy can delay Roseville's need to install on-route charging until 2029 when the longer FLRs will start to be electrified.*

Overall, the fixed local routes are much more challenging to electrify and charge. No battery electric bus on the market today can currently meet all of Roseville's fixed local routes service requirements. The shortest routes, namely L, R and S can be operated with our reference 35' 440 kWh bus. A1, and B2 could meet service requirements with that level of battery capacity; however, the final SOC would fall below our recommended 30%. The remaining fixed local routes, however, cannot be reliably operated all day on a single charge. Therefore, based on currently available technology the FLRs will require 2-3 on-route chargers. We then considered a scenario that used oversized buses and batteries to meet service requirements, but that was still not enough to meet all the service needs and would still require 2 on-route chargers. We also considered a scenario that requires purchasing extra FLR buses to avoid on-route charging entirely but the additional capital costs for extra buses is significantly greater than the overall charger savings; therefore, this is not a recommended solution. Willdan's recommended path for electrifying the FLRs is to wait until 2026, when the first FLR retirements are required to be electrified under CARB and reevaluate the available technology then. Even then, it is recommended to only electrify the shortest FLRs in 2026. This strategy can delay Roseville's need to install on-route charging until 2029 when the longer FLRs will start to be electrified. Waiting to install on-route charging gives Roseville Transit more time to discuss specific electric rates with Roseville Electric that may be more suited for a fully electrified transit fleet. On-route charging technology is still relatively new and further developments may make it a more appealing option in the future. Based on some initial field deployments, on-route charging appears to be less reliable than depot charging and provides little to no redundancy when they are out of service; therefore, Willdan recommends waiting to install on-route charging until it is necessary. This will allow Roseville to take advantage of improvements in both charger and BEB technologies. Other types of zero-emission technology such as hydrogen could prove more viable in the future. Roseville should track the market as this technology develops to determine the best time to make these investments.

Dial-A-Ride Buses

Given limited commercially viable options and the lack of Altoona reports at the time of this report, Roseville's Dial-A-Ride buses and routes were not modelled as part of this study. A few manufacturers stated battery capacities ranges for cutaway buses include:

- Motive Shuttle Bus with a 127 kWh battery and range of 90 miles
- Phoenix Motor Cars Zeus 400 Shuttle bus with a 140kWh battery and range of 150 miles
- Lightning Systems E-450 Shuttle Bus with a 129 kWh battery and range of 110 miles

As demonstrated with the commuter and FLR route modelling, manufacturer stated capabilities may not be representative of real-world conditions and results. Electric cutaway buses use the same plug type as the electric buses and are expected to be compatible with the electric bus chargers.

According to Roseville, a maximum of 6 of the 11 buses are running routes at any given time, with peak service typically in the middle of the day. Willdan expects that cutaway buses not in service can be charged at the depot outside of peak times when the commuter buses and FLR buses are running their respective routes. As a result, Willdan does not anticipate Roseville will need to build out its electric vehicle charging infrastructure much more than what is needed to meet the commuter and FLR BEB needs. When the time comes to electrify Dial-A-Ride buses, further research would be needed to confirm exact infrastructure and charging needs for the Dial-A-Ride fleet.

Infrastructure Requirements and Recommendations

First Five Commuter Buses and Full Fleet

According to Roseville Electric, the electrical branch circuit serving the corporation yard consists of two 1/0 cables following Hilltop Circle. The system voltage is 12,000V and each cable has a maximum capacity of 120A and 2.5MW. The corporation yard currently has ten transformers ranging in capacity from 150 kVA to 500 kVA, including an unused 300kVA transformer in the southeastern part of the yard. During peak times (4-7PM) the corporation yard currently experiences a peak demand of approximately 800KW and has the capacity to handle an additional 50A and 1MW of load during peak times. Assuming a split of depot and on-route charging as previously mentioned, the peak demand from the commuter and fixed local transit buses at the depot is not expected to exceed 1MW and will occur outside of peak times. Additional load from DAR vehicles have not been modelled; however, based on their typical duty cycles, they can likely be charged at the depot outside of peak times when other transit vehicles are in service. As a result, Willdan does not expect DAR vehicles will substantially increase the peak load we have modelled. Roseville should also consider how conversion of other parts of the City fleet to battery electric could increase peak demand and affect infrastructure requirements at corporation yard. Willdan generated charging schedules for commuter and fixed local route transit buses for each level of depot charger (shown in the financial assessment section of this report) and all of the charging occurs after 7PM when there is adequate capacity at the corporation yard. The time and demand of depot charging can be controlled even more with smart Charging software providing additional mechanisms to ensure minimal impacts to existing infrastructure.

Specific infrastructure requirements for the first five commuter buses will inevitably depend on how vendors respond to the RFP, the type of chargers Roseville procures, and where the chargers will be located. Willdan recommends Roseville pursue the high-power depot chargers, in the 125-150KW range, because they can provide more flexible charging schedules now and can future-proof for other types of electric heavy-duty vehicles. Roseville has banked approximately $400,000 in LCTOP funds to date to be used for BEB chargers. Based on initial price estimates from vendors, this is expected to be enough funding to purchase two high power (150 KW) chargers with three ports each and a new transformer. This configuration will create six charging ports, which is enough for the first five commuter BEBs. Roseville may need to consider additional funding sources to procure an additional backup charger. Willdan suggests that Roseville consider purchasing an additional depot charger. Roseville does not have to purchase all three dispensers at the time the spare charger is procured, as vendors have indicated they can offer additional dispensers as add-ons in the future. Roseville can purchase a backup charger with one, two, or three dispensers depending on the level of flexibility and initial build-out desired by the City. The backup charger can provide additional redundancy and can act as a safeguard if a bus has unexpected delays and cannot fit into the designed charging schedules.

> *Willdan suggests that Roseville consider purchasing an additional depot charger. This can provide additional redundancy and can act as a safeguard if a bus has unexpected delays and cannot fit into the designed charging schedules.*

Roseville Transit has had some initial discussions with Roseville Electric and Engineering discussing site upgrades required at different potential charger locations, discussed further in the implementation section of this report. In all potential charger locations discussed, Roseville Electric will install a new transformer to support the BEB fleet. Roseville Electric estimates that a 1 MW transformer will cost approximately $50,000 to supply and install, the full cost of which will be passed onto Roseville Transit. A 1 MW transformer would provide more than enough capacity for the depot charging as estimated in the proposed charging scenarios. If battery technology improves enough such that all FLRs could be charged overnight at the depot, the peak demand at the depot could reach a peak of 1.1MW, which may require providing additional capacity. This does not account for additional load from DAR vehicles; however, as noted before DAR vehicles can likely be charged at the depot when other transit buses are running their typical routes. Roseville Transit and Roseville Electric should also consider other potential fleet electrifications efforts from other departments that share the corporation yard, as that may impact the final infrastructure requirements. Ultimately, Roseville Transit will need to work with Roseville Electric, Engineering and potentially other parties to determine the best solution for charging the buses. This report aims to inform that conversation with the potential charging needs of the Transit fleet. The City will hire a design engineer that will coordinate with Roseville Electric and City staff to develop a charging station design

Future Solar and Battery Storage Systems

The financial assessment in the scope of this report does not consider the potential capital costs and long-term savings of installing distributed energy resources (DERs) such as solar and/or battery energy storage systems on site. To evaluate this, Willdan suggests Roseville Transit conduct a separate DER integration study on how a potential solar and energy storage system can reduce overall energy and demand costs associated with transit fleet charging over time. This study would be most useful after Roseville operates the first five electric buses for at least 12 months to have actual operational data to evaluate. Roseville Electric currently does not allow excess solar generation to be shared between meters or accounts; therefore, a PV and storage system would be most beneficial once there is a significant load from an EV bus fleet to offset. The DER integration study, along with the BEB phase in plan and load growth forecast in this report will help coordinate DER installation timing, allowing Roseville adequate time to conduct the necessary capital improvement planning and also to secure funding for these projects.

There is a developing market for second-life EV batteries that many EV and battery manufacturers are expected to participate in. Retired EV batteries, for light duty and heavy duty vehicles, can still retain up to 80% of their initial capacity, so while they may not have the capacity to reliably meet transportation needs, the batteries are a valuable resource for energy storage. EV and battery manufacturers are actively working to repurpose/recycle the retired batteries and generate secondary revenue streams[6]. Retired bus batteries may be a low-cost option for Roseville to implement future on-site energy storage. As an example, the storage capacity for every three 440 kWh buses retired can exceed 1 MWh, assuming 80% of the original capacity is available. Roseville should engage with their electric bus manufacturer to evaluate using retired or replaced electric bus batteries for on-site energy storage. Once Roseville starts preparing the site for the first five chargers, Roseville should also consider preparing the site for future solar and battery installations and coordinating any electrical infrastructure upgrades or underground conduit needed to support EV charging and/or DERs.

Financial Assesment

Willdan understands that buses are not tied to specific routes and maintenance costs are tracked to individual buses so the cost of operating a particular bus may be more variable than the cost of operating a particular route. However, for the purposes of this business plan we calculated the operating costs of electrification on a route by route basis, as opposed to bus by bus. Our reasoning is that different routes have different energy requirements and therefore different operating costs. In addition, because the first phase of bus purchases is not sufficient to electrify the entire fleet, a route by route analysis may be more valuable to help prioritize which routes the electric buses should service.

Proposed Conversion Schedule

Roseville provided their current fleet replacement schedule and additional input on future EV bus purchases beyond the first five commuter EV purchases. Based on an assessment of available technology and existing operations the following proposed conversion schedule is shown in **Table 8**. This schedule assumes that new buses (diesel and EV) are replaced every 12 years, in line with FTA useful life requirements. Dial-A-Ride buses are assumed to be replaced every 8 years. The proposed conversion schedule prioritizes electrifying the commuter

[6] https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire

routes because our analysis indicates those can be reliably operated with currently available technology. They are also Roseville's highest ridership routes, maximizing the benefits to the community and exposing the greatest number of riders to a zero emissions bus. Roseville should note the following key factors with the proposed conversion schedule:

- The local route buses retired in FY19/20 will be kept as contingency vehicles
- Roseville will be expanding the commuter service with 3 buses between 2020-2-22, one of which will be ZEB
- Willdan recommends delaying electrifying the FLR retirements in FY20/21 until FY 32/33
- In 2026-2028, CARB ICT requires 25% of new bus purchases to be ZEB; however, Roseville prefers to not split the procurement between different types of buses.
- City may elect to repower the diesel FLR buses due for retirement in FY 28/29 based on a review of the available technology. If repowered, they will be replaced with ZEBs in FY 30/31.

Table 8 – Proposed Roseville ZEB Conversion Schedule

Vehicle	Current Year	Type	Mode/ Service	FY 19/20	FY 20/21	FY 21/22	FY 22/23	FY 23/24	FY 24/25	FY 25/26	FY 26/27	FY 27/28	FY 28/29	FY 29/30	FY 30/31	FY 31/32	FY 32/33	FY 33/34	FY 34/35	FY 35/36	FY 36/37	FY 37/38	FY 38/39	FY 39/40
BUS FLEET																								
01-377	2001	Gillig	Local	Spare																				
01-400	2001	Gillig	Local	Spare																				
09-414	2009	Gillig LF	Local		Replace with (6) Diesel Buses												Replace with (6) ZEBs							
09-415	2009	Gillig LF	Local																					
09-416	2009	Gillig LF	Local																					
09-417	2009	Gillig LF	Local																					
09-418	2009	Gillig LF	Local																					
09-419	2009	Gillig LF	Local																					
14-475	2014	Gillig LF	Local							Replace with (4) ZEBs												Replace with (4) ZEBs		
14-476	2014	Gillig LF	Local																					
14-477	2014	Gillig LF	Local																					
14--478	2014	Gillig LF	Local																					
17-470	2017	Gillig LF	Local										Replace with (4) ZEBs*											
17-471	2017	Gillig LF	Local																					
17-472	2017	Gillig LF	Local																					
17-474	2017	Gillig LF	Local																					
11-460	2011	ARBOC	DAR		Replace with (3) Gasoline Buses						Replace with (3) ZEBs**								Replace with (3) ZEBs					
11-463	2011	ARBOC	DAR																					
11-473	2011	ARBOC	DAR																					
14-444	2014	ARBOC	DAR				Replace with (8) Gasoline Buses								Replace with (8) ZEBs								Replace with (8) ZEBs	
14-445	2014	ARBOC	DAR																					
14-446	20 14	ARBOC	DAR																					
14-447	2014	ARBOC	DAR																					
14-466	2014	ARBOC	DAR																					
14-467	2014	ARBOC	DAR																					
14-468	2014	ARBOC	DAR																					
14-469	2014	ARBOC	DAR																					
00-461	2000	Gillig	Commute		Replace with (4) ZEBs												Replace with (4) ZEBs							
00-462	2000	Gillig	Commute																					
00-464	2000	Gillig	Commute																					
00-465	2000	Gillig	Commute																					
09-408	2009	Gillig LF	Commute				Replace with (7) ZEBs												Replace with (7) ZEBs					
09-409	2009	Gillig LF	Commute																					
09-410	2009	Gillig LF	Commute																					
09-411	2009	Gillig LF	Commute																					
09-412	2009	Gillig LF	Commute																					
09-497	2009	Gillig LF	Commute																					
09-498	2009	Gillig LF	Commute																					
EXPANSION			Commute		Expand with (2) Diesel Buses												Replace with (2) ZEBs							
EXPANSION			Commute																					
EXPANSION			Commute			Expand with (1) ZEB												Replace with (1) ZEB						
			Total	-	15	1	15	-	-	4	3	-	4	-	8	-	12	1	10	-	-	4	8	-

*Based on a review of the available technology the City may repower the buses. If so, they will be converted to ZEB in 2030

**Assuming Altoona reports are issued before 2026.

Because of the uncertainty surrounding viability of a BEB solution for FLRs, the proposed replacement schedule also delays purchasing electric buses until 2026. This will allow zero-emission technology more time to mature, ideally leaving Roseville with more options that can meet Roseville's FLRs needs without on-route charging. Per ICT requirements, only one of the four bus purchases in 2026 must be ZEB; however, Roseville has indicated they intend to procure all ZEBs at this time. If on-route charging will still be required in 2026, Roseville can operate the first round of BEB FLR buses on the shortest routes. Roseville would then have approximately three more years to determine exactly where on-route chargers could be placed, the associated timelines to get the sites ready, and adjust route schedules to allow buses to charge at certain stops.

Recommended Solution Cost Analysis

Willdan's financial analysis is designed to be conservative, using data points, pricing information and assumptions from technology available today. Our aim was to create a "do-no-worse-than" analysis which would improve with time as BEBs are expected to become more efficient and decrease in cost as the market matures. **Table 9** summarizes the key assumptions and inputs used in the financial assessment. These inputs are further explained and justified in the following sections.

- Twelve 40' commuter buses, with at least 440 kWh capacity
- Fourteen 35' fixed local route buses, with at least 440 kWh capacity
- Three on-route chargers
- High power depot chargers (Cost analysis considers the different depot charger from 60KW to 150KW to show the financial implications of higher power chargers)
- Dial-A-Ride buses and any additional chargers they may require are not included in the financial analysis

Table 9 – Financial Assumptions

Description	Cost/Assumption	Comments
40' Electric Commuter Bus	$850,000	Assume no change over time
35' Electric Fixed Local bus	$750,000	Assume no change over time
Diesel Bus	$500,000	Assume no change over time
Bus EUL	12 years	FTA requirements
Charger EUL	20+ years	Per charger OEMs, entire replacement not likely over 20 years, potential component replacements
60 KW Charger	$85,000	With 2 ports, includes installation, excludes any site upgrades
100KW Charger	$165,000	With 3 ports, includes installation, excludes any site upgrades
125 KW Charger	$140,000	With 3 ports, includes installation, excludes any site upgrades
150KW Charger	$180,000	With 3 ports, includes installation, excludes any site upgrades
300KW Pantograph Charger	$565,000	Includes installation and cost of new transformer ($75,000)
New Transformer	$75,000	For on-route chargers and corporation yard upgrades
Electricity Rate Schedules	GS-2, GS-3	GS-3 for any scenario with >500 KW peak demand
Annual Utility Escalation Rate	3%	
Charging Schedules on GS-2	Starts after 7:30PM	Sets charging after 4-7PM peak demand period at the corporation yard

Description	Cost/Assumption	Comments
Charging Schedules on GS-3	Start after 10PM	To take advantage of off-peak rates
Average Effective Charge Rate	85% of maximum rating	To estimate average depot charge times
Charger Efficiency Loss	10%	To estimate peak demand and utility costs
EV Maintenance costs	Half of diesel	Rough estimate of expected savings

Bus and Charger Costs

Willdan contacted BEB and charger manufactures to estimate current equipment and installation costs and compiled this information to determine conservative estimates Roseville can expect when they procure the first round of buses and chargers. Actual prices will vary based on the manufacturer and the options (pantograph compatibility, charge management software, etc.) selected. EV buses and associated equipment have decreased in price over time and are expected to fall over the next 20 years; however, to keep the financial analysis conservative bus and charger costs are held constant over time.

At the direction of Roseville and based on the existing fleet sizes and accounting for planned expansion of commuter services the cost analysis assumes a final fleet size consisting of twelve 40' BEBs with 440 kWh (or comparable) battery capacity for the commuter routes and fourteen 35' BEBs with 440 kWh (or comparable) battery capacity for the fixed local routes. The proposed charging scenarios use the following sets of depot chargers which are the minimum number needed to meet expected charging needs. The following combinations can meet the charging requirements for all the commuter routes, including the expanded service, and local routes R, S, and L.

- Six 60KW chargers with two port each
- Five 100 KW chargers with three Ports each
- Four 125 KW chargers with three ports each
- Four 150 KW chargers with three ports each

The cost analysis does not account for any extra backup depot chargers Roseville may purchase and it also assumes the chargers have a 20 year life expectancy so they will not require replacement within the analysis horizon. Based on Willdan's discussion with various charger OEMs, chargers may require some preventative maintenance and component replacement such as motors and fans throughout their useful life.

The following routes will require on-route charging: A, B, CGFE, D and M. Assessing existing routes and their intraline transfer points, initial analysis indicates that Roseville will need 2-3 on-route chargers to provide reliable service using BEBs on their FLRs. For cost analysis purposes, and at the direction of Roseville, Willdan selected three sites, the Sierra Gardens Transfer Point, the Civic Center Transfer Point, and the Galleria Transfer Point.

Charging Schedules and Load Profile

Willdan determined Roseville's final weekday charging schedules and load profiles at the depot for a fully electrified bus fleet for each charger scenario. In all cases, every commuter route and FLRs R, S, and L are assumed to be charged at the depot. The remaining FLRs are assumed to be charged entirely from the on-route chargers. The EBCA results show how long stops would need to be to maintain a final SOC of at least 80% throughout the day. To replenish any daily net decrease in battery SOC to be ready for the next day's operations, operators would extend either the last stop at the end of the day or the first stop early the next morning; therefore, in this scenario, there is no expected load at the depot from BEBs running the longer fixed local routes. We assume weekend FLRs follow the same charging strategy as during the week. Only Route L would charge in the depot on Saturdays and the remaining FLRs would charge on-route on Saturdays.

Weekday depot charging schedules were developed using the highest energy consumption throughout the year for each route to develop a worst-case scenario and the longest charging times. Actual charging times will vary throughout the year consistent with the varying energy requirements. Roseville should note that the bus battery management systems ultimately determine the amount of power the batteries receive at any given time and overall charging time. Bus battery management systems typically accept a depot charger's maximum rated power when SOC is low and reduce the load as the SOC gets closer to 100%. This phenomenon is known as a charging curve, illustrated in **Figure 6**. Willdan estimated charging times for each route based on the input power of the charger and an estimated charging curve. Based on discussions with bus manufactures we estimated the total charging time by assuming the average power deliver to the battery during the charge cycle is 85% of the charger's maximum rated power. This accounts for the full power of the charger in the beginning of the charge cycle and the reduced power as the battery approach a full charge. For example, with a 100KW charger, we estimated charging times assuming the battery receives an average 85KW per hour. **Figures 7-10** demonstrate the charging schedules using the different charger scenarios.

For each charging scenario, routes are assigned specific chargers based on their expected charging times to maximize the available time for scheduled maintenance and ensure that each bus will be fully charged before its pullout time the next day. In general, interlined routes should be paired with non-interlined routes on the same charger to ensure there is adequate time to fully charge each bus. We assume that the 2PM and 9PM commuter routes are interlined every day, therefore, there are twelve buses that require charging each weekday.

As shown in the 60 KW charger scenario (**Figure 7)** each interlined route is paired with a non-interlined route. The expanded commuter route is assigned to fixed local route R, which has the fastest charging time. The interlined AM commuter routes require most of the midday break to fully recharge. The non-interlined routes typically require the longest charge times at night because they were not charged midday.

As shown in the 100 KW charger scenario (**Figure 8),** two of the five chargers are assigned three routes, while the remaining chargers are only assigned two routes. In this particular scenario, given the expected charge rate and energy consumption of the buses, four 100 KW chargers cannot fully charge three buses overnight and a fifth charger is required. Two of the interlined routes are each paired with two other non-interlined routes on a single charger. The remaining two interlined routes are paired with only one other non-interlined route or a fixed local route on a charger. The remaining two FLRs are paired to a single charger. There can be multiple configurations, but two interlined routes cannot be paired on a single charger.

As shown in the 125 KW and 150 KW charger scenarios (**Figure 9 and Figure 10)** there are three buses assigned to each charger. The first two chargers will have the same configuration as shown in the 100 KW scenario. There is flexibility in the specific configurations. The general condition for these scenarios is that Route L should not be paired with an interlined commuter route. We recommended that in these scenarios all the FLRs be paired on the same charger to help avoid this. Based on the expected charge rate of these chargers, one charger can handle two interlined commuter routes with a third non-interlined commuter route.

With lower power chargers, pairing multiple buses with long duty cycles increases the risk of not fully recharging the batteries before the bus needs to be deployed again. As the power level of the charger increases, there is increased flexibility in assigning buses to chargers.

In addition to the basic charging systems that typically come with depot chargers, Roseville should consider procuring an additional smart charging system. These smart charging systems will also manage the rate at which a battery will charge based on criteria that allow a minimization of the cost of power while maximizing the amount of power provided to a battery. A smart charging system is highly recommended to provide an additional layer of charging options that will take into consideration time of use and demand levels. Willdan suggests that Roseville request vendors (or indicate favorability) to include a smart charging system with the pilot bus and charger procurement. The software pricing can then be evaluated against the potential savings it can yield to help determine the value of the system to Roseville.

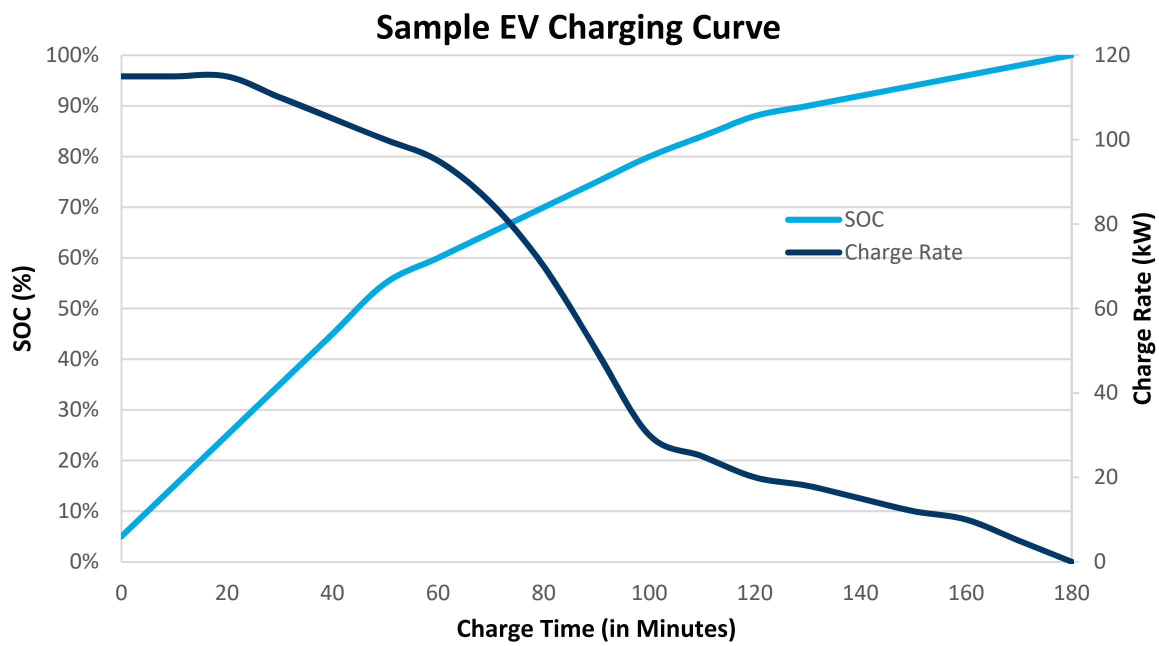


Figure 6. Sample EV Charging Curve

Figure 7. 60 KW Charging Schedule

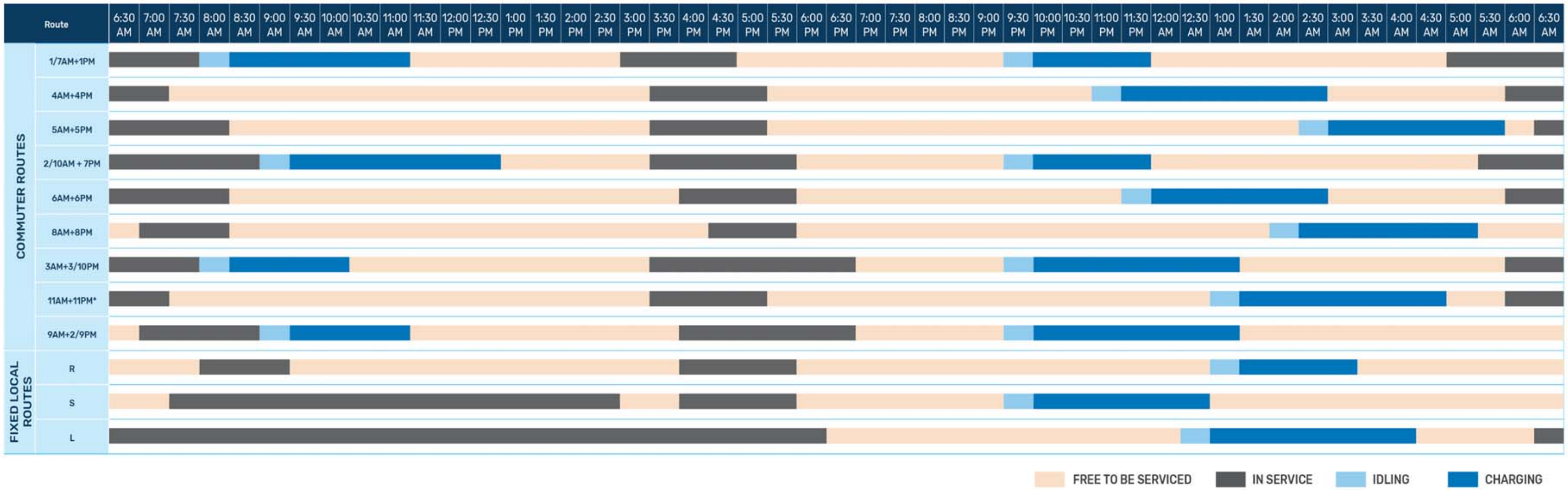


Figure 8. 100KW Charging Schedule

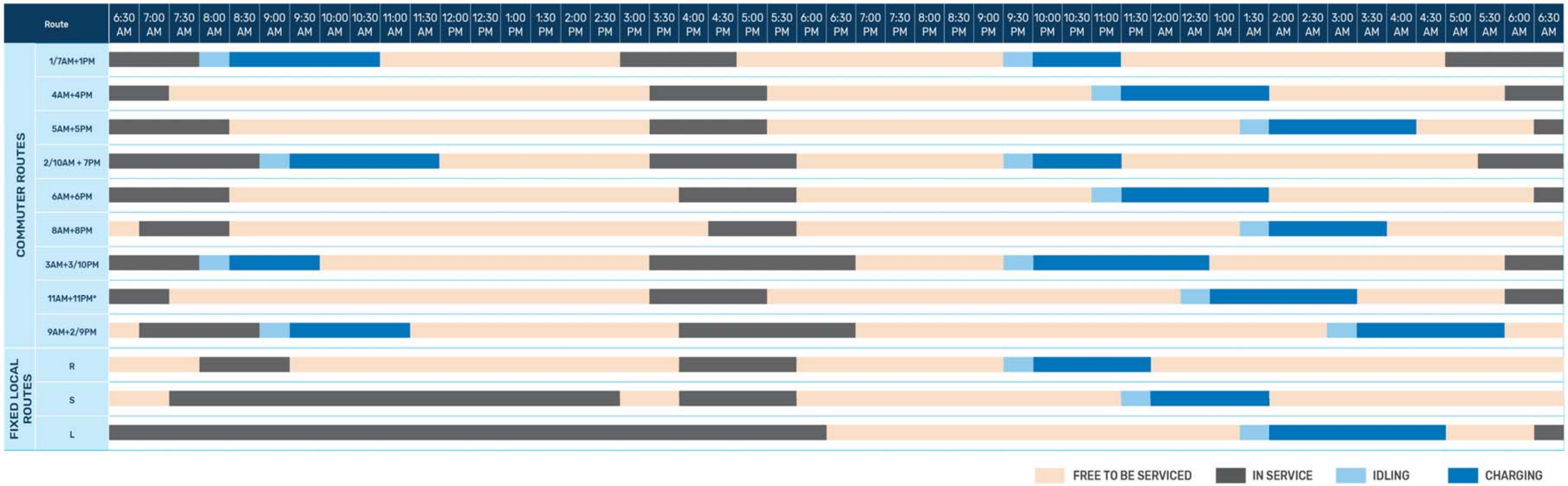


Figure 9. 125 KW Charging Schedule

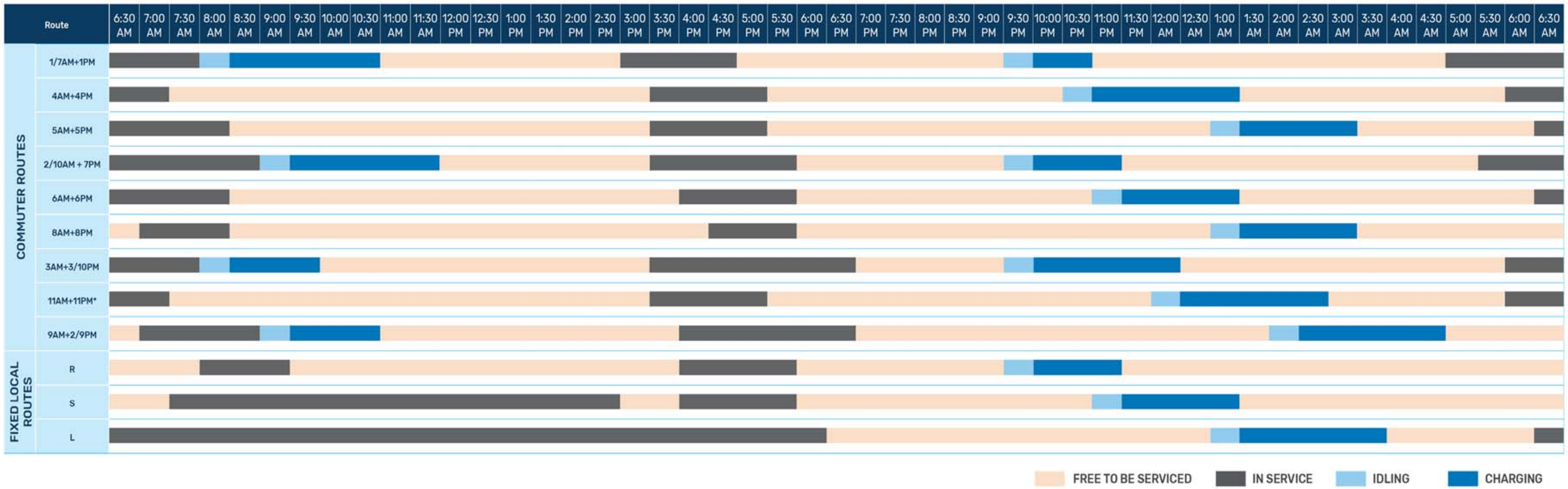


Figure 10. 150 KW Charging Schedule

The charging schedules are then turned into daily load profiles for each charger scenario, see **Figure 11**. The load during each time period is based on the number of buses charging in a given time period and the maximum power of the charger. To keep the load profile and associated demand charges conservative, we do not factor in the charging curve as the bus approaches a full charge. Lastly, to account for power losses that occur between the meter and the bus battery (due to inefficiencies of the charger) the load profile accounts for a 10% charger loss factor. For example, a 60KW charger is assumed to have an actual peak demand of 66KW on the grid.

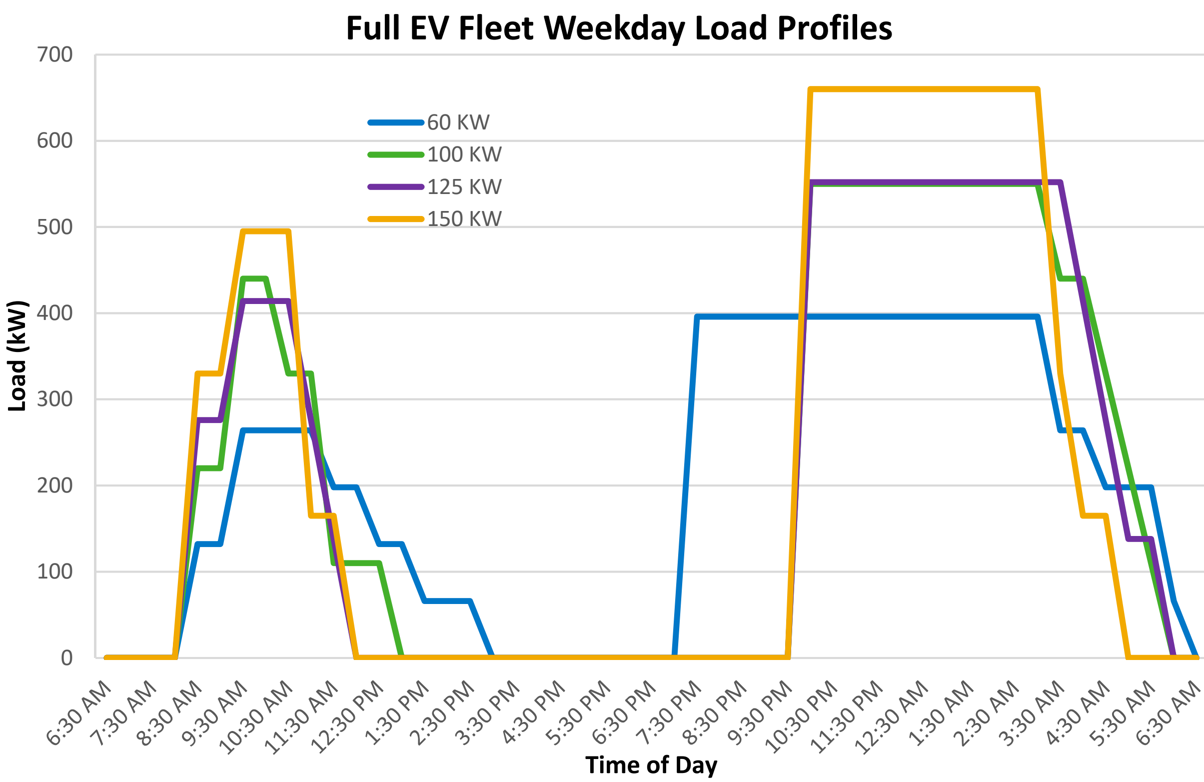


Figure 11 Weekday depot load profiles for EV transit fleet

Roseville should consider purchasing a smart charging software to minimize peak demand and associated demand charges while still ensuring buses are fully charged for service.

The 60KW chargers never trigger GS-3 and its associated TOU rate so power costs remain the same during all hours of the day. The benefit of a non-TOU rate, such as GS-2, is that buses can begin charging as soon as they return to the depot and not have to wait until 10PM for off-peak rates, which conveniently aligns with the longer charging times required when using a 60kW charger. Conversely, potential issues may arise if no regard is given to when buses are charging as electrical branch circuit capacity at the corporation yard is the lowest between 4-7PM. To account for this potential constraint, charging schedules for 60kW chargers were set to begin at 7:30PM, outside of the peak periods the corporation yard currently experiences. All the other charging scenarios using 100kW or greater chargers in the analysis start charging after 10PM to take advantage of the GS-3 off-peak rates. Considering that some buses do not leave the depot until 6:30AM, smart charging could better optimize this schedule to reduce the max demand estimated. As previously mentioned, according to Roseville Electric the corporation yard has about 1MW of capacity during peak times (4-7PM). While we expect the total BEB charging load at the depot to be less than 1MW and occur during outside of peak times, the circuit capacity constraint should be considered in conjunction other electrification efforts that may occur at the corporation yard. Roseville Electric has also indicated it will install a new transformer to support the BEB fleet.

Energy Costs and Demand Charges

Energy costs and demand charges are calculated using Roseville Electric's current rate schedules. Based on discussions with Roseville Electric, there are no immediate plans to adjust the 500KW demand threshold between the GS-2 and GS-3 rate schedules. Willdan assumed all the depot chargers will be consolidated under one meter, separate from any existing facility meters (having an isolated meter for all BEB charging is also important for LCFS reporting). Throughout the 20-year timeline, depot charging energy costs use the GS-2 rate until the BEB charging load grows to over 500kW, triggering a switch to GS-3. Each on-route charger for the fixed local routes would be on their own meter and fall under the GS-2 rate because the maximum load is less than 500KW. We assumed electricity rates would increase 3% per year, in-line with the long term trend Willdan has observed from multiple utilities.

As previously mentioned, EV energy costs are calculated by route, not by bus. This approach better portrays the incremental cost Roseville will incur as it expands the EV bus fleet and electrifies more routes over time. The electrification schedule is shown in **Table 10**. The AM and PM commuter routes are grouped together in the same way route energy requirements were determined in **Table 3**.

Table 10 – Route Electrification Schedule

Route Name	Route Type	Year Electrified
1/7AM+1PM	Commuter	2021
2/10AM + 7PM	Commuter	2021
3AM+3/10PM	Commuter	2021
4AM+4PM	Commuter	2023
5AM+5PM	Commuter	2023
6AM+6PM	Commuter	2023
8AM+8PM	Commuter	2023
9AM+2/9PM	Commuter	2021
11AM+11PM (new commuter line)	Commuter	2022
A1	Fixed Local	2029
A2	Fixed Local	2029
B1	Fixed Local	2029
B2	Fixed Local	2029
CGFE	Fixed Local	2033
D	Fixed Local	2033
L	Fixed Local	2026
M	Fixed Local	2033
R	Fixed Local	2026
S	Fixed Local	2026

The schedule for electrifying the commuter routes is flexible because the proposed bus specifications can meet any route needs. This is in alignment with Roseville's stated desire to rotate commuter BEBs throughout all the commuter routes. To be conservative, the analysis first electrified all four interlined routes and the expanded service routes with the first five bus purchases. Energy consumption from the expanded service route is conservatively estimated to be the highest of the existing AM and PM non-interlined routes. The remaining commuter routes can be electrified as additional EV commuter buses are purchased.

The fixed local routes electrification schedule is more intentional given the energy consumption needs of the FLR BEBs and current limitations of BEB technology. For this reason, we propose to electrify the shortest FLRs (R, S, and L) with the first four FLR BEBs purchases in 2026. This leaves one EV bus available as a backup for these routes. Based on currently available technology L, R and S are the only routes that can be reliably operated with a representative 35' BEB. The EBCA analysis suggests that A2 or B1 could meet service requirements but would fall below 20% SOC during certain times of the year. If Roseville decides to operate one of these routes with the fourth EV bus purchase, it could be charged at the depot, using the charging port set aside for the 4AM/PM route due to be electrified in 2033, but the proposed charging solution, load profile, and cost analysis does not account for this. We then electrified the mid-length routes (A1, A2, B1, B2) with the next four EV purchases in 2029. The first on-route charger would be needed to support these routes. The three remaining FLRs are electrified with the next four EV purchases on 2033. The second and third on-route chargers would be needed to support these routes.

Annual energy costs for each route (exclusive of demand charges) are summarized in **Table 11** and **Table 12**. Depot charging costs shown in **Table 11** are for both rate schedules to account for the different charger scenarios – they are not additive. Energy costs for FLR include applicable weekend energy usages. For the A route, Saturday service is applied to A2 energy costs. For the B route, Saturday service is applied to the B1 energy costs. Game Day Service routes are not included in the cost analysis; however, given the relative infrequency of this service compared to the regular commuter service the incremental cost increase is expected to be minimal. The 20-year cost analysis applies the annual energy cost based on the expected load and rate schedule each year. Annual energy costs are determined from month-by-month energy consumption based on the EBCA seasonal energy usage results and the seasonal rate schedules. Energy costs also account for a 10% charger loss factor. For example, the cost to recharge 200 kWh on a bus is calculated using 220 kWh. We applied the seasonal EBCA energy usages to the following months, which are then applied to the respective winter and summer utility rates.

- Winter: December, January, February
- Spring: March, April, May
- Summer: June, July August
- Fall: September, October, November

Table 11 – Annual Route Energy Costs – Depot Charging

Route Type	Route	GS-2	GS-3
Commuter	1/7AM+1PM	$9,805	$8,055
	4AM+4PM	$7,404	$5,225
	2/10AM + 7PM	$11,052	$9,070
	5AM+5PM	$7,432	$5,243
	3AM+3/10PM	$12,063	$9,196
	6AM+6PM	$6,919	$4,882
	9AM+2/9PM	$11,167	$8,497
	8AM+8PM	$6,646	$4,688
	11AM+11PM	$7,744	$5,463
Fixed Local	Route R	$4,622	$3,261
	Route S	$7,052	$4,978
	Route L	$10,226	$7,221
	Annual Total	**$91,905**	**$75,779**

Table 12 – Annual Route Energy Costs – On-Route Charging

Route	Annual Energy Cost
A1	$12,855
A2	$11,445
B1	$11,764
B2	$12,193
CGFE	$15,424
D	$15,431
M	$19,783
Annual Total	**$98,894**

Demand charges are calculated separately because it is based on the total meter load and not necessarily attributed to a specific bus or route. Demand charges account for a 10% loss factor in the chargers, as previously mentioned. Demand charges throughout the 20-year cost analysis are based on the number of active depot chargers that year. Since demand charges are based on the largest 15-minute load in a given month, it is reasonable to assume that at some point all the active chargers will draw their maximum capacity at the same time without a dedicated charge management software. Using a set of six 60 kW chargers, the peak demand is 396 kW and the depot chargers would stay on the GS-2 rate through 2040, assuming no other light duty vehicle chargers or loads are added to the meter. The higher power depot chargers will fall under the GS-3 rate in 2026, once the load from the FLRs is added. Using a set of five 100kW chargers, the peak demand is 550 kW; using a set of four 125KW chargers, the peak demand is 552 kW; and using a set of four 150KW chargers, the peak demand is 660 kW. **Table 13** summarizes the annual depot and on-route demand charges once the peak demand is reached for each charger scenario. Costs in **Table 13** are based on current (2019) Roseville Electric rates. Demand charges do not account for any extra chargers Roseville may purchase and use during the same hours we have set in the charging schedules. Roseville should consider working with charge management vendors to further optimize the charging schedules and reduce demand charges beyond what we have estimated and potentially keep the peak demand of the higher power chargers below 500 KW and on the GS-2 rate schedule.

Table 13 – Annual Depot and On-Route Peak Demand Charges (2019 Rates)

Charger Scenario	Depot Peak Demand (KW)	Annual Depot Demand Charge ($)	On-Route Peak Demand (KW)	Annual On-Route Demand Charge ($)	Total Annual Demand Charges ($)
60 KW	396	$29,272	990	$73,181	$102,453
100KW	550	$54,494	990	$73,181	$127,675
125KW	552	$54,692	990	$73,181	$127,873
150 KW	660	$65,393	990	$73,181	$138,574

Maintenance Costs

Maintenance costs for electric buses are typically lower than comparable diesel buses, primarily because BEBs do not require oil and filter replacements every 6,000 miles. BEBs also do not contain an engine, so any maintenance costs fixing or replacing engines are eliminated. Typically, Willdan estimates EV maintenance costs by eliminating diesel-specific maintenance costs (fluid changes, diesel particulate filter replacements, engine work, etc.) and assumes the remaining maintenance costs would be the same. Roseville provided maintenance costs as a lump sum per bus, without a specific breakdown of oil changes, diesel particulate filter replacements, gearbox work and other maintenance activities. Without this level of specificity, we assumed that maintenance costs for EV buses would be roughly half that of diesel buses. As a reference, based another EV transit analysis Willdan has completed, we found that maintenance costs of BEB's were expected to be 54% of a CNG bus. Other feedback from actual BEB deployments have found overall significant powertrain maintenance savings. Given BEB technology is still developing, there may be unexpected issues with electric motors or battery management systems. We recommend Roseville closely evaluate warranties on major BEB and charger components from vendor proposals to minimize the risk of incurring expensive repairs or replacements.

Incentives

The cost analysis accounts for existing and estimated future incentives for EV bus purchases and chargers. More detailed descriptions of available funding sources are included in the funding section of this report.

EV bus purchase costs account for existing rebates available through California's Hybrid and Zero-Emissions Truck and Bus Voucher Incentive Project (HVIP) program. Currently, 40' electric buses are eligible for a $150,000 rebate and 35' electric buses are eligible for a $120,000 rebate. EV chargers are currently eligible for a $30,000 rebate. As EV bus and charger technology improves becomes more accepted in the market over time, we expect this program to decrease and phase out the incentives. We assumed that the HVIP incentive for buses and chargers will decrease by 5% per year and be completely phased out by 2040; though this could vary substantially depending on future funding availability and the status of the technology. As of July 23, 2019, all the FY18-19 funds have been allocated and future requests will be placed on a waitlist. Funding is expected to be renewed in January 2020. Actual future incentive amounts may differ depending on the demand and funding allocated to the program. For example, CARB is considering decreasing the HVIP incentive for buses by 20% and removing the EV charger incentive entirely from the HVIP program in is latest draft FY19-20 budget proposal[7]

Willdan also accounts for potential Low Carbon Fuel Standard (LCFS) credits that may be generated from operating BEBs. Electricity is currently exempted from LCFS, but transit operates can "opt-in" to the program. The program is currently extended up to 2030; however, given California's GHG reduction goals and the state's tendency to favor decarbonization regulations we assume that this program will continue through 2040.

Based on data from other BEB deployments in PG&E territory, transit agencies accrue one credit for every 900 kWh supplied to the buses, as determined from utility bills. Credit prices have fluctuated between $170-$200 per credit over the past year and prices have generally trended upward over time. There are several factors, all changing differently over time, that will impact the actual revenue Roseville may receive throughout the duration of the program.

1. Value of a credit over time. Currently prices have trended upward but depending on how easily or quickly fuel supplier come into compliance these trends may change.
2. Energy needed to generate a single credit, which is driven by two main factors
    a. CA requirements on maximum carbon intensity allowed in fuels, which will be more stringent over time and require more kWh to generate a credit.
    b. The carbon intensity of the electricity in a given year, which is expected to decline over time and require fewer kWh to generate a credit. This factor may further incentive on-site solar PV if it directly powers the buses, to increase potential LCFS credit generation.

Given the uncertainty of the potential revenue generation we assumed the following throughout the 20-year analysis:

1. Roseville will accrue one LCFS credit every 900 kWh. We assume that the two factors determining the kWh/credit cancel themselves out.
2. We assumed three different average credit prices: $150, $175, and $200.

[7] https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan.pdf

20-Year Cost Analysis

The final cost analysis estimates costs for new bus purchases starting in 2020 for a Business-as-Usual (BaU) scenario and four EV scenarios, one for each different charger scenario. The BaU case assumes that ICT mandate does not exist, and Roseville would continue to purchase and operate only diesel buses through 2040. While Roseville does not have the option to use only diesel buses over the next 20 years, it is included as a reference so Roseville can start budgeting for future expenditures accordingly. The EV scenarios are based on the bus procurement and route electrification schedules previously described and are shown with varying levels of incentives. Costs may change depending on actual procurement schedule, future fleet size, or future route modifications. The differences in the EV scenario costs are due to the different charger purchase costs, different demand charges, and rate schedules from the different charger power levels. Total cumulative costs over time for the EV scenarios are calculated using the inputs and assumptions described in the previous sections. Both the BaU and proposed phase in schedule include at least some diesel bus purchases as shown in **Table 8**. We estimated fuel and maintenance costs for these buses based on the average existing fuel and maintenance costs Roseville provided.

The financial analysis accounts for the costs associated with any newly purchased vehicles (after 2020), whether they are diesel or EV each year. Chargers are purchased at the same time EVs are purchased as needed to support the fleet size at the time. Operation and maintenance costs are cumulative year over year for all the buses purchased starting in 2020. In the BaU scenario, annual fuel and maintenance costs increase each time a new diesel bus is purchased until all existing (Pre 2020) diesel buses have been replaced. This occurs in 2029, when Roseville will have completely turned over its existing fleet. After 2029, the annual fuel and maintenance cost is constant through 2040. In the EV scenarios, annual fuel and maintenance costs are based on the number of EV buses and diesel buses in operation that are purchased after 2020. EV bus purchases that replace previous EV bus purchases do not affect the annual energy and operation costs in that year, less the estimated increase in electricity costs.

Willdan has presented multiple iterations of the cost analysis in order for Roseville to better understand the implications of different charger scenarios and the financial savings of incentive programs. The financial analysis does not account for any direct site upgrade costs, solar PV installation costs, or stationary storage costs. Willdan used a very conservative installation cost per charger, $40,000. This conservative estimate across all the chargers is reasonably expected to account for site upgrade costs such as a new transformer, trenching, and conduit. **Figure 12** shows the cumulative incremental cost comparison from 2020 to 2040 for operating a diesel fleet versus converting to EV buses for each charger power level, without any incentives. Willdan estimates that Roseville will spend approximately $41 million in a BaU scenario of only diesel buses over 20 years. Without incentives, purchasing and operating BEBs will cost about $10 million more over 20 years as compared to continuing purchasing and operating only diesel buses. The type of charger however, does not significantly affect the overall cost analysis for the BEBs. While higher power chargers generally cost more than the lower power chargers, the total cost difference between them is less than $1 million over 20 years. **Figure 13** shows the same scenario and includes HVIP incentives for both buses and chargers. As previously mentioned, the analysis assumes a 5% decrease in available incentives from current levels for the 40’ BEBs, 35’ BEBs, and chargers. Actual future incentives may vary depending on future funding and design of this program. Incorporating HVIP incentives decreases the cost of the BEB scenarios by approximately $2 million over 20 years, by reducing capital costs of buses and chargers. **Figure 14** shows the best case scenario and incorporates HVIP incentives as described and a high LCFS credit value of $200 per credit. In this set of scenarios, BEBs will cost approximately $2-3 million more than diesel buses over 20 years. In each of these cases, the power level of the charger only alters the final BEB costs by a maximum of 3% over 20 years. To better understand the impact of HVIP and various LCFC credit values, Willdan conducted a sensitivity analysis on the incentives for just the 150KW charger scenario, see **Figure 15.** Willdan selected the 150KW charger as the base case because we recommend Roseville pursue higher power chargers to have the most flexible charging schedules. The sensitivity analysis shows that LCFS, in all cases we analyzed, significantly reduce the total cost of operating a BEB fleet.

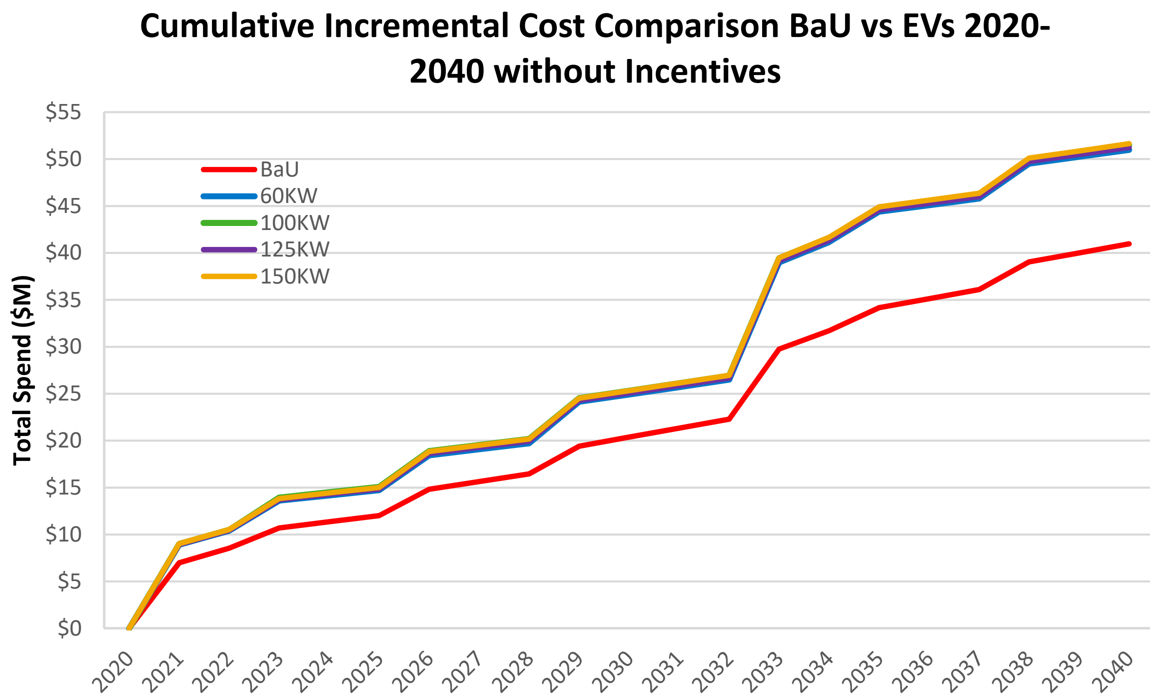


Figure 12. 20-year transit fleet electrification cost analysis without incentives versus BaU

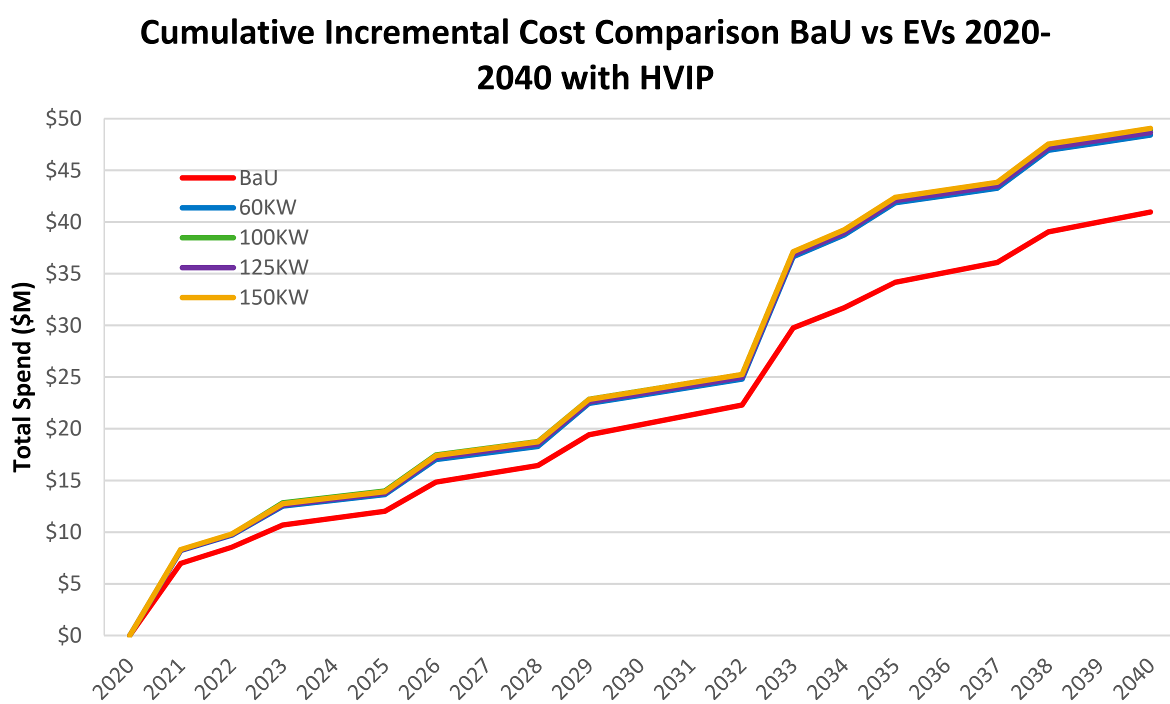


Figure 13 20-year transit fleet electrification cost analysis with HVIP incentives versus BaU

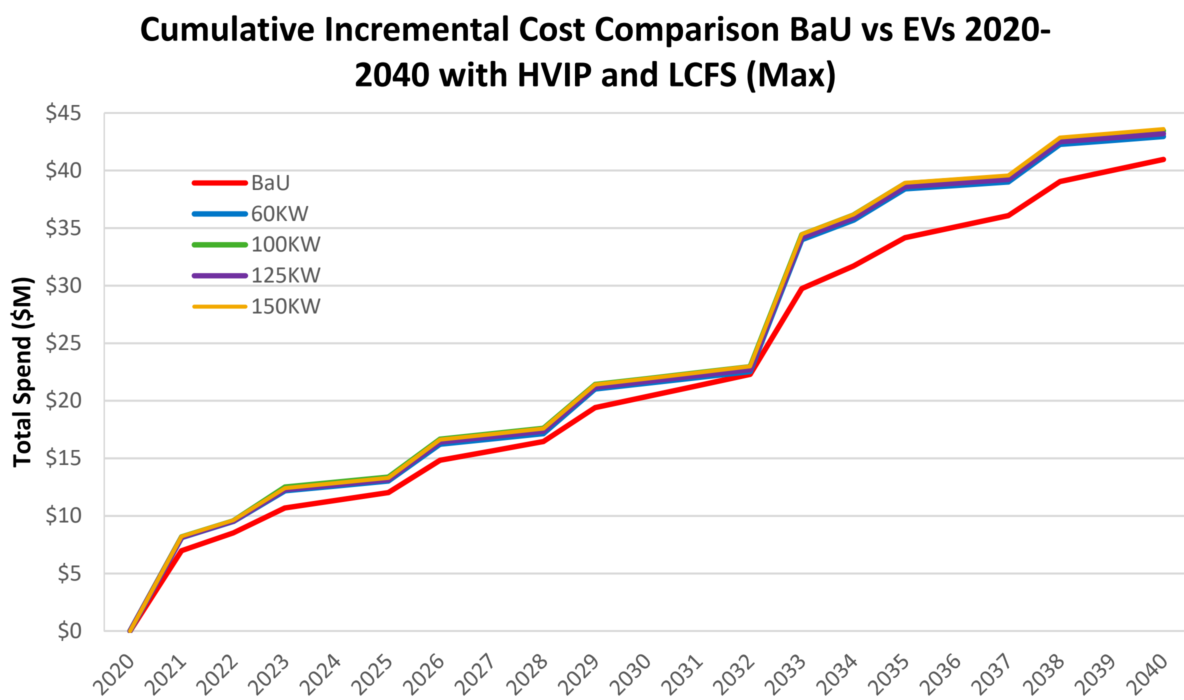


Figure 14 20-year transit fleet electrification cost analysis with HVIP and $200 per LCFS credit versus BaU

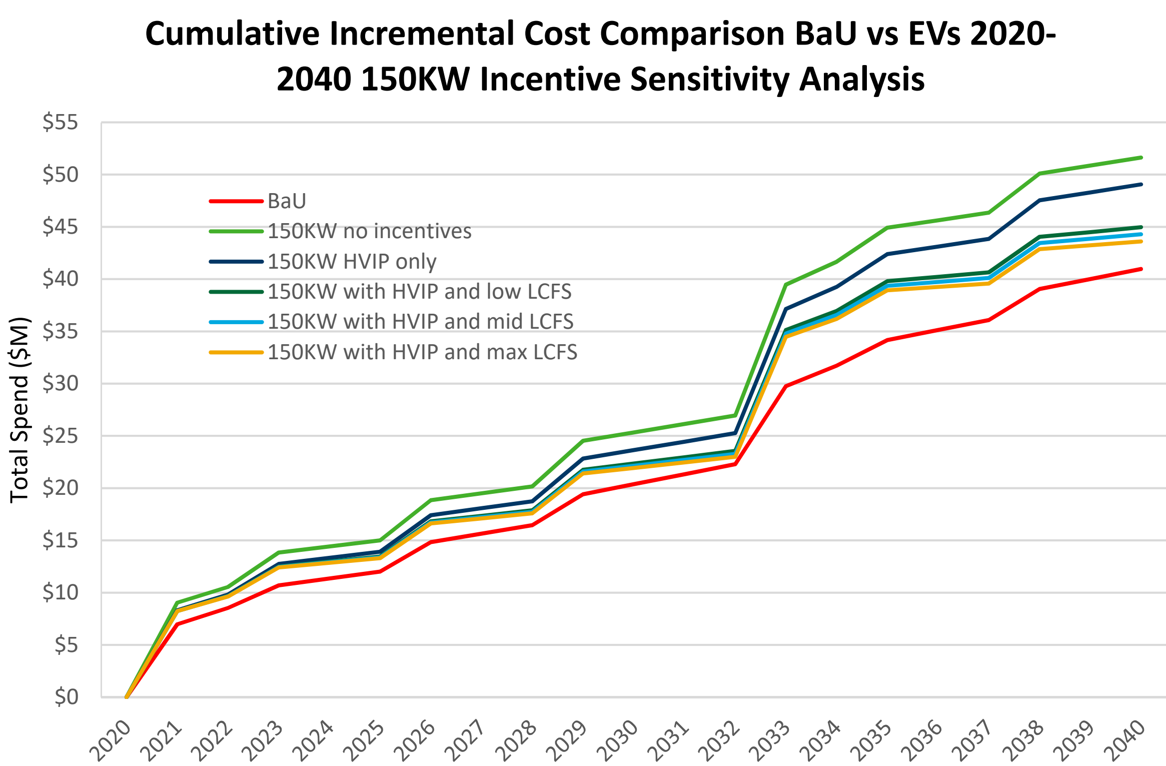


Figure 15 Sensitivity Analysis of different LCFS credit values on 20-year transit fleet electrification cost analysis

Overall, electrifying Roseville's transit fleet is expected to cost more over time than continuing to purchase and operate diesel buses. A summary of the total spend between 2020 and 2040 for the BaU and all the charger scenarios is shown in **Table 14**. As previously mentioned, the variation between the different charger scenarios accounts for less than 3% of the total spend over 20 years. This suggests that the higher power chargers (>100KW) are probably a better long-term investment than 60KW chargers since they will provide greater overall flexibility and potentially charge other heavy-duty electric vehicles without significantly increasing the total costs of fleet procurement and operation. A summary of the key cost factors for the diesel and 150KW charger EV scenario is shown in **Table 15**. The most significant factor for the increased cost of BEB scenarios is the additional capital cost associated with purchasing electric buses and chargers. Together, these two line-items cost nearly $12 million more than the BaU case over 20 years. Even though overall operating and maintenances costs for electric buses are less overall compared to the diesel buses, the operational savings are not enough to overcome the upfront cost differential. Roseville should note that Willdan used several conservative assumptions in the analysis that, if changed, could alter the results:

Willdan's financial analysis suggests BEBs will cost more over time as compared to diesel, even with available incentives. However, higher power chargers (>100KW) are not substantially more expensive than 60KW chargers.

- Diesel fuel costs were assumed to be 2019 prices and held constant over time. Fuel prices can be volatile and could increase over time.
- Bus and charger prices were held constant over time. Historical trends show that as new technology develops, prices are expected to decrease.
- Roseville Electric does not currently offer EV specific rates and we assumed they will not develop EV specific rates in the future. If they do, Roseville Transit may see a decrease energy costs and demand charges.
- Costs are projected without the integration of solar PV or battery storage. A thorough analysis about optimal sizing and operation of these systems may reduce energy costs and limit demand charges.

Table 14 – Summary of Final Costs through 2040

Scenario	Total Spend Without Incentives ($M)	Total Spend with HVIP ($M)	Total Spend with HVIP and low LCFS ($M)	Total Spend with HVIP and mid LCFS ($M)	Total Spend with HVIP and max LCFS ($M)
Diesel (BaU)	$40.97	$40.97	$40.97	$40.97	$40.97
60KW Chargers	$50.98	$48.41	$44.32	$43.64	$42.95
100KW Chargers	$51.49	$48.92	$44.82	$44.14	$43.46
125KW Chargers	$51.23	$48.66	$44.56	$43.88	$43.20
150 KW Chargers	$51.63	$49.07	$44.97	$44.29	$43.61

Table 15 – Summary of Key Cost Factors, 150KW Scenario

Cost Factor	Diesel	EVs (HVIP and LCFS)	EV Difference
20-year Purchase Price	$24M	$32.9M	+$8.9M
20-year Charger Cost	$0	$2.4M	+$2.4M
20-year Fuel/Energy costs (inc. demand charges)	$7.3M	$2.9M	-$4.4M
20-year Maintenance Costs	$9.7M	$6.1M	-$3.6M

Oversized Buses

We considered a scenario of buying oversized buses for the FLRs, specifically 40' transit BEBs with a 660 kWh battery. It should be noted that only a single manufacturer currently offers s a BEB that can accommodate that level of battery capacity, and it is only available for 40' buses, not 35' buses. This would eliminate the need to do on-route charging for the A and B routes, but on-route charging would likely still be required for routes CFGE, M and potentially D. Since there is not a shared stop between the three routes, at least two on-route chargers would still be required. The proposed fleet and charger selection assumes three on-route chargers so Roseville would save $565,000 on on-route charger costs but spend at least $1.4 million "over-buying" a fleet of larger buses, not accounting for when the oversized buses are inevitably replaced. Roseville could reduce some of this added cost by purchasing a mix of smaller capacity battery buses to handle just the shorter routes, but this reduces the overall flexibility of the fleet. Lastly, since the 660kWh buses are 40' long, they will not fit in the current FLR bus parking spaces and would need to be moved to another area of the corporation yard. For these reasons, Willdan does not suggest this option.

Expanding Total Fleet Size without On-Route Charging

We also considered a scenario that does not require any on-route charging and service could be met by buying seven additional 35' buses and switching them out midday on the longer FLR routes. This would reduce overall charger costs by about $1 million after accounting for the additional chargers and infrastructure needed at the depot. However, the additional bus purchases would cost $5.25 million using today's prices; far greater than the charger savings. This scenario would require additional energy costs to charge a larger set of buses at the depot and requires additional parking spaces for the larger fleet. For these reasons, Willdan does not suggest this option.

For the baseline cost analysis and both alternate scenarios Willdan did not evaluate how potential route modifications may reduce the need for on-route charging. Route planning is beyond the scope of this project and involves many factors beyond capital and operating costs. Roseville could consider adjusting its fixed local routes such that on-route charging is not required, but this would require a holistic review of transit operations to ensure that the community is being adequately served. Roseville should recognize that implementing new technologies can be enhanced when management policies and procedures are changed when necessary to take advantage of the benefits. Conversely, Roseville should recognize how policies and procedures can be changed to avoid a new technology's shortcomings.

Both options of buying 40' 660 kWh buses or extra 35' 440 kWh buses are more expensive than a fleet of 35' 440 kWh buses and three on-route chargers.

Funding

There are several options Roseville can use to help fund the purchase of electric buses. Options include direct funding (grants, rebates, and incentives), project financing (debt or equity), or combinations of both options. Willdan can provide additional information on any of the options outlined below that can be reviewed by Roseville Transit finance staff and outside Municipal Financial Advisors. **Table 16** summarizes different funding sources available for transit electrification.

Table 16 – Summary of Available Funding Sources

Program	Sponsor	Bus Eligible	EVSE Eligible	Annual Funding Amount*	Notes
Bus & Bus Facilities (5339)	USDOT	Yes	Yes	$366M	For all types of busses. EV portion growing ($36M to 12 EV awardees out of 107 total awards in 2018). Roseville has already secured this type of funding for the first five bus procurements.

Program	Sponsor	Bus Eligible	EVSE Eligible	Annual Funding Amount*	Notes
Urbanized Area Formula Grant (5307)	USDOT	Yes	Yes	$5B	Funding determined by population, population density, and transit operations for urbanized areas >200,000. Roseville has already secured this type of funding for the first five bus procurements.
Low-No (5339c)	USDOT	Yes	Yes	$84M	72% of awardees partnered with bus manufacturer. Lo-No often used to pay for incremental cost of EV over fossil fuel bus.
Low Carbon Transit Operations Program (LCTOP)	Caltrans	Yes	Yes	N/A	LCTOP funding can be banked over multiple (at least 4) years before it must be used on a project which starts within a year of final award. Project can last 2-3 years. Roseville has already secured this type of funding for initial chargers and infrastructure.
Transit and Intercity Rail Capital Program (TIRCP)	CalSTA	Yes	Yes	$450M	TIRCP funding can be used for large scale deployment of zero emission vehicles and associated infrastructure. Projects can last up to four fiscal years. Applications for FY 2020 funds are due January 16, 2020.
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)	CARB, CALSTART	Yes	Yes	$155M	Vouchers to reduce price of EV buses and EVSE at point of purchase. $150,000 for 40' bus, $120,000 for a 35" bus and $30,000 for EVSE. Currently awaiting new funds. Draft FY 19-20 budget proposes removing EVSE and reducing bus vouches by 20%. Roseville has already identified this as a funding source in FTA grant applications
Low Carbon Fuel Standard Program (LCFS)	CARB	Yes	Yes	11 Million Metric Tons of credits generated	Creates tradable credits based on carbon intensity of fuels used. They can be banked for future compliance or sold on the market. Credit prices fluctuate on market, currently ~$180/credit
VW Mitigation Trust	VW, CARB, SJVAPCD	Yes	No	$130M	Funding is available on a first-come first-serve basis. $180,000 max incentive per bus. Must replace buses with an engine year 2009 or older. Not combinable with HVIP, Carl Moyer, AB923, or AB617 funds.
Congestion Mitigation and Air Quality (CMAQ) Improvement Program	USDOT	Yes	Yes	$1.1M	For projects that improve air quality and traffic congestion. Funding amount listed is average annual allocation specifically for City of Roseville.
Sacramento Air Quality Management District SECAT Grant Program	SMAQMD	Yes	No	$85M	Provides funding for zero-emission vehicles within SACOG, Vehicles cannot be used to generate emission credits in any emissions averaging, banking, or trading program. Roseville has already secured this type of funding for the first five bus procurements.
Carl Moyer Grant Program	CARB	Yes	Yes	$60M	Provides grant funding for cleaner-than-required engines including zero emission buses and supporting infrastructure. Funding administered by local air districts,

*Based on most recent information available, funding cycles may vary between sources

Grants, Rebates, and Incentives

HVIP

CARB and CALSTART have partnered together to launch the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). This voucher program provides discounts to zero-emission bus purchasers at the point of sale. Purchasers do not need to wait for incentive or rebate checks. Only CARB approved vehicles are eligible for the discount. Eligible 40ft buses, potential replacements for Roseville's commuter buses, currently qualify for a $150,000 incentive. Eligible 35 ft buses, potential replacements for Roseville's fixed local routes, currently qualify for a $120,000 incentive. HVIP vouchers up to $30,000 are available for EVSE equipment, including hardware costs, load management software, and energy storage costs. EVSE vouchers must be applied for separately and within 60 days from vehicle voucher applications and approved before the EVSE equipment is ordered. All HVIP incentives are awarded on a first-come, first-served basis.

Roseville has already identified HVIP as a funding source in its USDOT 5339b grant applications. We encourage Roseville to continue using this funding source for future bus EV purchases. The program awarded its full allocation of $155 million for both bus and EVSE equipment in FY18-19 and FY19-20. Future voucher requests are currently on hold. Demand for this program remains high and funding is expected to be renewed in future years, though incentive levels may change based on program demand and the maturity of the technology. As previously mentioned, CARB is considering decreasing the HVIP incentive for buses by 20% in FY19-20 and removing the EVSE incentive entirely from the HVIP program in is latest draft budget proposal.

VW Mitigation Trust

The Volkswagen (VW) Environmental Mitigation Trust (Trust) provides about $423 million for California to mitigate the excess nitrogen oxide (NOx) emissions caused by VW's use of illegal emissions testing defeat devices in certain VW diesel vehicles. The Trust provides funding opportunities for specified eligible actions that are focused mostly on "scrap and replace" projects for the heavy-duty sector, including on-road freight trucks, transit and shuttle buses, school buses, forklifts and port cargo handling equipment, commercial marine vessels, and freight switcher locomotives. $130 million of this funding is allocated for replacing school, transit, and shuttle buses. This portion of funding is administered by San Joaquin Valley Air Pollution Control District. Applications are currently open, and funding is awarded on a first-come first-serve basis. The maximum incentive for eligible battery electric transit buses (must be HVIP listed) is $180,000 and the BEB must replace a conventionally powered transit bus with an engine year 2009 or older. Funding requests for multiple buses must be submitted individually and the maximum funding per entity, determined by Tax ID, is $3.25M. This funding cannot be combined with other funding sources designated to reduce NOx emissions including HVIP, Carl Moyer, AB923, or AB617 funds.

FTA

Several federal grants are available for bus-related public transportation network and infrastructure improvements. Grants may either be competitive, or formula based, and each come with specific local cost share requirements. Roseville has successfully applied for and been awarded federal grants to fund the first five EV buses and charging equipment. Willdan can support Roseville in formulating future FTA grant applications including building strategic partnerships with other local, regional and State funding sources. Willdan's experience in supporting FTA proposals is that FTA awards often require more than one cycle of application. Once the first application is received, FTA often engages transit agencies in a dialogue that helps to inform subsequent winning proposals.

Bus and transit-related facilities 5339 grants are competitive and can cover up to 80% of the net capital project cost. Eligible projects include replacement, overhaul and rebuilding of buses, related equipment, and constructing bus-related facilities including transitioning to zero-emission vehicles. The Federal cost share may exceed 80% of project costs if the projects are related to Clean Air Act or ADA compliance. Approximately $423.3 million was available in FY 2019, but the most recent application deadline was June 21, 2019, with the next grant funding application opportunity expected to be in June 2020. Willdan can support Roseville in applying for these grants during the next funding cycle including researching potential funding partners, drafting project profiles, and conducting Benefit-Cost Analysis of the proposed infrastructure improvements. Funds are available for a total of four fiscal years – the fiscal year awarded and up to three following fiscal years.

Low-No 5339c grants are competitive and can cover up to 85% of total transit bus cost and 90% of bus related equipment and facilities cost. All eligible expenses under the Low-No program are attributable to Clean Air Act (CAA) and Americans with Disabilities Act (ADA) compliance. $55 million will be available each fiscal year through FY 2020. The FY 2019 deadline was May 14, 2019. Willdan can support Roseville in applying for these grants during the next funding cycle. Similar to 5339 funds, Low-No funds are available for up to three fiscal years after the year appropriated.

Urbanized Formula Area 5307 grants are formula based and can cover up to 80% of the project cost for capital expenditures, 90% for vehicle-related equipment for compliance with ADA and CAA, 50% of the net project cost for operating assistance. Funding is available for the year appropriated plus five years. Capital investments including bus replacement and bus-related activities are eligible project costs for this grant. All preventive maintenance and some ADA complementary paratransit service costs are considered eligible capital costs for this grant.

Transit and Intercity Rail Capital Program (TIRCP)

The Transit and Intercity Rail Capital Program (TIRCP) provides competitive grants from the Greenhouse Gas Reduction Fund (GGRF) to fund transformative capital improvements that will modernize California's intercity, commuter, and urban rail systems, and bus and ferry transit systems, to significantly reduce emissions of greenhouse gases, vehicle miles traveled, and congestion. The TIRCP was created to fund transformative capital improvements that modernize California's intercity rail, bus (including feeder buses to intercity rail services), vanpool services, ferry, and rail transit systems to reduce GHG emissions, expand and improve transit service to increase ridership, integrating statewide rail systems including e the integration with the high-speed rail system, and improve safety.

A project must demonstrate that it will achieve a reduction in greenhouse gas emissions using the CARB quantification methodology to be eligible for funding. Eligible projects include large scale deployment of zero emission vehicles and the technologies to support them. While this funding source does not require local matches, leveraging other funding sources, including other GGRFs, is desirable will be considered in the evaluation of expected project benefits.

Applications for the upcoming funding cycle must be submitted in accordance with the Call for Projects and by January 16, 2020. Funding is competitive and projects will be evaluated on multiple factors including, but not limited to, the following:

- Cost effectiveness of reducing GHG emissions
- Increased ridership through expanded and improved rail and transit service including connecting to rail services
- Integration of services such as regional connectivity and connecting to various state-wide rail and transit operations including high-speed rail
- Improved safety
- Reducing automobile vehicles miles travelled
- Coordinating additional housing and employment opportunities near transit stops
- Investing in clean vehicle technology,
- Benefiting low-income and/or disadvantaged communities

Congestion Mitigation and Air Quality Improvement Program - CMAQ

Congestion Mitigation and Air Quality (CMAQ) are federal funds issued to states and counties that do not meet federal air quality requirements. In Placer County, CMAQ funds are managed by the Placer County Transportation Planning Agency (PCTPA) and are disbursed to local agencies on a formula basis. The City of Roseville is allocated approximately $3.2 million per three-year cycle to fund projects that improve air quality or traffic congestion. These funds can be used to subsidize BEBs or chargers; however, given the relatively small allocation and other local projects competing for these funds they may not be a viable source.

Sacramento Emergency Clean Air Transportation (SECAT)

The Sacramento Emergency Clean Air Transportation (SECAT) Program is a partnership between the Sacramento Metropolitan Air Quality Management District (SMAQMD) and the Sacramento Area Council of Governments (SACOG) with the goal to reduce emissions from heavy-duty vehicles operating within the SACOG region including transit fleet vehicles. Since 2000, SECAT receives approximately $70 million in total annual funding from the state traffic congestion relief fund and CMAQ funds (separate from CMAQ previously identified). An additional $15 million in annual CMAQ funds has been allocated to this program for 2018-2020. Zero-emission heavy duty vehicles, including battery electric buses, are eligible. However, vehicles purchased from SECAT funds cannot then be used to generate emission credits for emissions averaging, banking or trading programs. Program participates must commit to using the vehicle for three years and submit annual usage reports.

Most participates use the fleet modernization option to access SECAT funds. This option provides incentives up to $100,000 to replace older diesel engines that have a 2009 or older model year engine with cleaner options. Zero-emission vehicles qualify for the full $100,000 incentive and do not require the old vehicle to be removed or destroyed in the event that the new vehicle experiences prolonged downtime or cannot meet long range requirements. Roseville has already secured SECAT funding for the first five bus purchases.

Carl Moyer Memorial Air Quality Standards Attainment Program

The Carl Moyer Program provides over $60 million grant funding annual for cleaner-than-required engines, equipment, and other sources of air pollution to reduce smog-forming and other toxic emissions. The program has been revised to include zero-emission technology including transit vehicles subject to ICT and supporting infrastructure as eligible projects. The program is administered by CARB and the local air districts. For Roseville, Carl Moyer is administered by Placer County Air Pollution Control District. Grants are competitive and may be based on cost effectiveness of emission reductions. Placer County APCD Carl Moyer grant applications are currently closed.

Carbon Credits

Low carbon credits may be used to offset future operating costs or as insurance against future compliance requirements if bus replacements are delayed. Willdan can assist Roseville in applying for and optimizing the generation and sale of credits.

Low Carbon Transportation Operations Program (LCTOP)

Funded by GHG cap and trade funds, LCTOP is designed to provide operating and capital assistance for transit agencies to reduce their GHG emissions. The program prioritizes serving disadvantaged communities (DACs). Funds can be used to purchase zero-emission buses and the infrastructure to support them, but not for existing expenditures. As of 2016, legislation allows funding to be rolled over for a maximum of 4 years. Roseville has already banked 2 years of funds with the intention of banking another year to fund the initial charger purchases and installation.

The State Controller's Office (SCO) provides an annual list of eligible recipients and awards here. The portion of funds available to transit operators is distributed based on the ratio of total revenue of each operator during the prior fiscal year to the total revenue (fare) of all operators of the state.

Low Carbon Fuel Standard (LCFS)

The Low Carbon Fuel Standard program generates carbon credits that EV users can sell to industrial polluters to help the polluters comply with carbon pollution regulations. Electricity is currently exempted from the LCFS program because it meets current carbon intensity targets, however transit agencies operating electric buses can "opt-in" beforehand to generate credits. Roseville Electric is currently claiming these credits for supplying "fuel" to residential EVs. Based on initial discussions with Roseville Electric, Roseville Electric is willing to claim LCFS credits and transferring them to Roseville Transit or letting Roseville Transit claim the credits directly. Roseville Transit will need to work with Roseville Electric on determining who will claim the credits once the EV buses are in operation.

Accrued credits can then be sold to other agencies that have not met carbon intensity targets to subsidize BEB operation and maintenance costs. Approximately 11 million credits were generated throughout the program in 2018. This past year the value of a single credit has fluctuated between $170 and $200 and generally trended upward over time. As shown in the financial analysis, utilizing LCFS credits can significantly reduce the total cost of ownership of a BEB fleet. Data from other BEB deployments in northern California suggest that current LCFS credit generation rates and value can reduce operating costs by $0.50 to $0.60 per mile which in many cases can make the fuel operating costs less than diesel.

Third Party Financing

Most transit agencies use a combination of grant funding and traditional municipal funding mechanisms (such as debt or capital budgeting) to fund their conversion to EVs. Some bus and EVSE vendors offer their own financing programs to assist transit agencies convert to electric fleets including lease programs and charging as a service.

Municipal Debt

One of the most commonly utilized financing for transit infrastructure projects is municipal debt. Whether through bonds, leases, or loans, the municipal market offers several cost-effective options. Interest rates and terms vary, depending on the equipment being financed, type of municipal debt being utilized, and the public agency's underlying creditworthiness. Usually, a public agency will make decisions about using municipal debt in concert with its finance group, often utilizing its Independent Registered Municipal Advisor.

Vendor Sponsored Battery Leases

Certain bus manufacturers offer their own financing programs to facilitate the purchase of EV buses. Proterra offers a leasing program where a transit agency can purchase an electric bus for $553,000 and lease the associated batteries over a 12-year period instead of purchasing both together. This offering is designed to bring the upfront capital cost of electric buses in line with diesel buses. Proterra's lease agreement includes one battery replacement after year 6, halfway through the bus's lifetime.

Charging as a Service

There are companies that offer charging as a service (Caas) for municipal fleets, structured similarly to a solar power purchase agreement (PPA). In this scenario the CaaS provider would own and maintain all the charging equipment, removing liability and risk from Roseville. The provider also funds initial startup EV Fleet conversion costs such as infrastructure upgrades, EV Charger installation, and utility interconnections. They are also responsible for working with the utility and managing the meters and invoices. CaaS providers usually offer a product "up-time guarantee" which ensures that each vehicle is charged at least 90% every day so it can run its route. Pricing models for this type of service are flexible and can be billed on a per-electric-mile driven basis, giving pricing certainty to Roseville. These types of services can provide low upfront cost charging solutions to Roseville and allow Roseville to focus on its transit services.

Maintenance Facility Considerations

Maintenance facility requirements are generally similar for BEBs and conventional transit vehicles. While tooling and techniques may be different, facility envelopes and major equipment are largely compatible between technologies. Changes in the layout of maintenance bays, utilization of building roof space to support electrical equipment, and configuration of parking areas to allow operational flexibility are possible areas of marginal impacts. Charging and electrical power infrastructure are recognized as the main differentiator as large-scale deployments of BEBs are considered.

The bulk of tools required to maintain BEBs is very similar to those required to maintain conventionally fueled buses. However, there are some unique tools and testing equipment that will be required to maintain BEBs as they have battery packs, inverters and electric drive systems. A non-exhaustive list of these specialist tools is as follows:

- Propulsion service kit which will include diagnostic interface/cables, high impedance multi-meter, battery protection tools, high voltage gloves, and motor bearing tools
- Special tools for electric accessories which include HVAC, air compressor, steering, and cooling
- Battery pack and Inverter lifting jigs
- An overhead crane, or jib crane for lifting rooftop battery packs or other components will be required if not available at the current facility.
- Battery packs can be made to last a long time with proper heat/voltage monitoring, and selected cell replacement later in life. A forklift should be able to remove smaller roof components such as inverters, and HVAC units.
- Gantry platforms or rolling scaffold platforms will be required for roof access. Fall protection anchors will also be required for maintenance personnel working on the roofs of the electric buses.
- Depending on the agency maintenance model – an electrical “lab” may be needed for electronic component repair/troubleshooting (if this function is not outsourced)
- Specific BEB OEMs may require specific tools depending on the bus’s axles, brakes, PLC, body, or other components

Figure 16 Roseville's existing maintenance facility and bus lifts

Training Considerations

Training is an essential part of the process for introducing new bus technologies into revenue service, and DHS has worked with several transit managers and mechanics to identify critical skills and knowledge gaps that need to be addressed before operating a BEB fleet. Training ensures staff buy-in and a smoother integration of the new technology, especially when staff are required to take over all maintenance responsibilities after the manufacturer warranty period ends. Although there are many similarities between conventionally fueled buses and BEBs, understanding the modern bus electrical systems is critical to filling the technician job skills gap for BEBs. Maintenance technicians need foundational training on working with high voltage systems that they likely have never used before. Such training should include:

- Knowing the preparations that are necessary prior to working on or near high-voltage systems such as charging infrastructure or batteries. This includes how to protect against shock and arc flash, PPE requirements, permits and creating an electrically safe work condition. Roseville's maintenance staff and fleet managers should consider acquiring the following certifications:
  - NFPA 70E: Standards for Electrical Safety in the Workplace
  - High Voltage OSHA 1910.269 8 Hour Qualified Training Course
- Training on cable management processes, a challenge which plug-in charging presents, is essential to effective operations.
- Handling batteries in the maintenance garage or in the context of accidents requires that operators, first responders and maintenance staff know the risks associated with the battery chemistry selected when the BEBs are purchased, and that all personnel be trained accordingly to mitigate such risks. BEB battery chemistries at this time are typically lithium-ion based though exact chemistries are often proprietary and constantly revised to increase safety, optimize performance, and minimize use of heavy and precious metals. Roseville should refer to manufactures specifications and recommendations with each new BEB purchase as battery chemistry and associated training may change over time.
- Familiarity training should be provided for Roseville's emergency first responders. In case of an accident involving an electric bus, responders will need to know where the emergency high voltage power shut-off

switch is located. If there is a fire, they will need to know that respirators will be needed because if batteries are ruptured, there may be noxious flames.

  - Roseville should consider expanding this training or coordinating a group training with neighboring agencies and first responders since commuter routes travel beyond the city limits.

Mechanics, maintenance supervisors, bus operators, finance and human resources departments need to be thoroughly trained before a new electric fleet is placed in service. The training can be provided either by the selected bus OEM or through a third-party technical training institution. Mechanics, maintenance supervisors, and bus operators will need more technical training related to daily bus operations. Finance and human resource staff will not require the same technical training but should be generally knowledgeable about the technology. Human resource staff may hire maintenance staff or fleet operators and should be aware of the skills needed to fulfil the position. Finance staff may be responsible for tracking and managing costs specific to BEBs such as electricity as a fuel source, BEB spare parts, or battery lease payments.

For trainings completed by OEM's, generally, the price of training is included in the cost of the bus and it would be subject to the terms negotiated during the procurement process. Some agreements between manufacturers and transit agencies include presence of maintenance staff from the bus manufacturer onsite for at least the first few months of the implementation to address maintenance issues on site. The length of training would depend on the scope of training and since most of the non-electric components on electric buses are very similar to those found on standard diesel buses, it is estimated training designed for mechanics would take 40 to 60 hours. Operator familiarization with electric buses could take about 16 hours. Bus manufacturers also provide operating and maintenance manuals, usually provided as part of the contract, to support training needs. Examples of the types training programs offered by various BEB OEMs include:

- Operator training, vehicle maintenance training, charger maintenance training and new bus launch support.
- Training on the electric propulsion system and batteries.
- FAAC, a simulation for training and research organization, has partnered with some BEB OEMs to provide a BEB vehicle simulator at their Advanced Vehicle Innovation Center (VIC). The simulator's main objective is to support driver training specific to regenerative braking, an energy-saving technique which drivers can employ to conserve energy.
- Training packages that cater to operators, mechanics and trainers.

Technical colleges and institutes also provide BEB focused training and maintenance programs. Examples of such institutes include:

1. **Southern California Regional Transit Training Consortium (SCRTTC)**: **Introduction and Troubleshooting Zero Emission Propulsion (ZEPS):** Offers a course to orient participants in bus electrical-systems and their safe operation. Participants will learn essential aspects of high-voltage drive systems and low voltage accessories systems, including safety protection and safe operation.
2. **West Coast Center of Excellence in Zero Emission Technology:** Launched by SunLine Transit Agency and funded by the FTA, this is a collaboration between public and private organizations, including transit agencies, colleges, private industry, and government agencies, that ensures the development of excellence in the maintenance of zero emission buses. Currently, SunLine Transit Agency has partnered with College of the Desert, Rio Hondo College, California Community College-Doing What Matters, BAE Systems, Ballard Power Systems, BYD Coach and Bus, Hydrogenics, and Proterra to develop this center.
3. **American Public Transportation Association (APTA), Bus Maintenance Training Committee (BMTC)**: Offers various Technical Services and Innovation Webinars

4. **International Association of Public Transportation (UITP):** UITP, APTA and the Canadian Urban Transit Association (CUTA) have partnered to provide UITP's Electric Bus Training Program.

Willdan recommends Roseville implement an ongoing training program as it relates to safety and public service. Specialized training related to operating and maintaining a BEB fleet should be done as recommended by manufacturer requirements. Additional training should be provided to comply with industry best management practices which may evolve over time.

Implementation and Next Steps

Roseville has several near and mid-term steps to take to successfully implement the pilot BEBs as illustrated in **Figure 17** and described in the following sections.

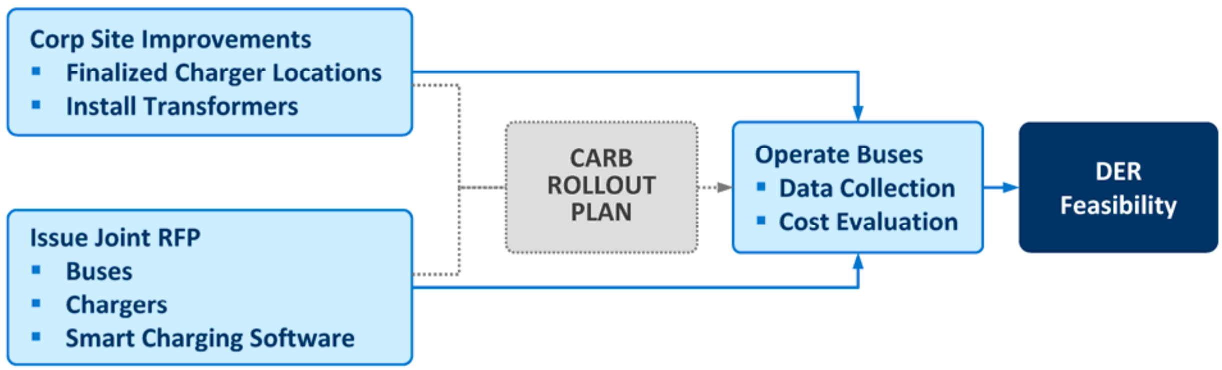


Figure 17.Near and mid-term BEB Implementation Steps

Corporation Yard Site Improvements

One of Roseville's immediate steps should be to work with Roseville Electric, Engineering and Public Works to identify where the chargers will be located and prepare the corporation yard for the upcoming equipment. Based on initial discussions with Roseville there are three potential areas under consideration: the ring road where commuter buses are currently parked, the Central Services lot, and the grassy knoll in the center of the corporation yard as illustrated in **Figure 18** and **Figure 19**. Roseville will develop conceptual plans for each of these sites to evaluate the benefits and drawbacks of each site.

Figure 18. Proposed charger locations

Roseville Electric has indicated that a new transformer will be installed to support the BEBs in the final charging location. Roseville Transit will also need to work with Roseville Electric to determine what size transformer should be installed as part of the pilot BEBs. According to Roseville Electric, Roseville Transit can consider two pathways for the new transformer. The first pathway is to install a large 1 MW transformer now to meet the anticipated depot charging needs for the next 20 years. The second pathway is to install a smaller transformer now and upgrade it to a larger one when the load is expected to exceed its capacity. A transformer of either size will cost between $30,000-$50,000 depending on its capacity, not counting for any trenching work to support the chargers. The labor cost of upgrading a small transformer to a larger transformer will cost about $10,000, but Roseville will receive the depreciated value of the old transformer as a credit towards the new one. Roseville Transit will need to review the expect load growth under various scenarios with Roseville Electric to determine what solution is ideal.

Other factors to consider for infrastructure improvements are how Dial-A-Ride buses may eventually be charged and if other departments may electrify their vehicles over time. If other departments choose to electrify their own fleet vehicles and want to operate of the transformer installed for Roseville Transit, submeters (either physical submeters or virtual submetering available through the EV charger management software) may be needed for accurate billing and LCFS reporting. Roseville should consider there may be negotiations with the selected charging vendors that require specific infrastructure improvements.

Any solicitation requirements for the design, construction, procurement and installation of the chargers should be considered to assure that the chargers are operational prior to the delivery of the first BEB. To take advantage of economies of scale and prevent additional disruption and demolition at the corporation yard, Roseville is encouraged to consider installing as much infrastructure as possible (larger transformers, laying conduit for future chargers, integration of supporting renewable energy sources and battery storage, etc.) to support the full build out during the first phase of depot charger installation.

Figure 19. Roseville's ring road and Central Services lot where chargers may be located

RFP for Buses, Chargers, and Charge Management Software

After Roseville reviews the route modelling results and proposed technical specifications for BEBs that can successfully complete Roseville's existing routes, Willdan recommends that Roseville develop an RFP to procure both chargers and buses. As a template to begin drafting the RFP, Center for Transportation and Environments (CTE) recently released an EV bus procurement template that includes language for many elements important to electric buses including but not limited to a pilot bus, battery degradation, and battery warranties. California Department of General Services has also released a statewide procurement which includes technical specifications for two BEB OEMs. The statewide procurement, however, does not include any provisions or technical specifications for chargers or smart charging software. Willdan suggests that Roseville start with these sources as a template and adapt them for Roseville's specific needs. Willdan also recommends that Roseville consider issuing a joint bus and charger RFP to ensure interoperability between buses and chargers and to allow vendors to provide a complete solution. Other advantages of a joint procurement include:

- Roseville will be able to request a performance guarantee to a vendor who offers an integrated bus and charger solution. Some vendors may not be willing to offer this, but by procuring both items together it increases the chances that one vendor will guarantee performance of the entire system.
- An integrated smart charging solution offered by OEMs and/or 3rd party vendors may also be available by a request to procure the entire BEB system, with available performance guarantees
- A procurement/delivery timeline for chargers to arrive and be installed before the BEBs arrive
- Ability to request pricing for an additional "backup" charger

Roseville should consider what factors are important when developing performance guarantee technical specifications, as leaving this vague in an RFP may result in less-than-ideal offerings from vendors. Some potential performance guarantee structures for consideration are minimum guaranteed SOC before AM deployment or overall guaranteed uptime.

Specific qualifications/minimum requirements for Roseville's existing routes:

- Five 40' buses that can reliably operate any AM route and a PM route, including interlined routes with a final SOC of at least 20%.
- A charging solution that provides for a full charge (>90%) each day that optimizes cost, load, demand charges and charging time.
- Request pricing for an additional "backup" charger

Roseville's FTA grants require that a contract for the pilot buses be issued by the end of February 2020; however according to Roseville this is flexible and assumed an 18 month lead time for electric buses. The grant identified a target revenue service date by June 2022. Based on discussions Willdan has had with various bus and charger OEMs, current charger lead times are 3-4 months and current EV bus lead times may be up to 14 months. Roseville is well within the timeline to operate the pilot BEBs by June 2022 and could operate them much sooner if any necessary corporation yard improvements are completed in time.

The technical specifications and specific language will be finalized in the RFP; however, Roseville should begin thinking about incorporating the following elements.

Initial Bus Specifications

- Five 40' transit buses to service primarily existing commuter routes
- Battery capacity to meet 150 miles of range on Roseville's existing commuter routes
- The specific make and model must currently qualify for HVIP vouchers
- Buses should meet 85% overall availability between being fully charged and maintenance.
- Battery warranty including degradation not to exceed 20% over the 12-year expected useful life
- Any additional typical bus specifications such as seating capacity, ADA compliance, HVAC, and other non-propulsion related specifications
- Battery Management system to accept over 100KW from plug-in chargers
- Battery Management system that follows industry standard Open Charge Point Protocols (OCPP) and can accept industry standard plug types
- Eligible for HVIP incentives

Initial Charger Specifications

- Two high power plug-in chargers (>100KW) with three charging dispensers each
- Chargers must use DC charging and follow industry standard charging protocols (OCPP) and use industry standard plug types to ensure interoperability between different manufacturers following the same charging protocol.

- Guaranteed interoperability between the charger and bus
- Pricing for one additional charger
- Data management system that allows Roseville to view and track key elements in real time – this may be included as part of a charge management system
    - SOC of all connected buses
    - Estimated remaining charge time

Suggested Charge Management Software Specifications

- Ability to throttle demand to minimize overall energy costs while still guaranteeing that buses are charged to at least 90% before they are sent out for service
- Ability to optimize charging with future solar PV and battery storage systems

Willdan recommends Roseville start the procurement process for the first five BEBs and chargers in tandem with identifying and starting corporation yard infrastructure improvements. After Roseville has selected and bus and charging vendor for the pilot BEBs, Roseville can discuss delivery timelines with the vendor that is in line with site improvements.

File CARB ICT Rollout Plan

With all the information presented in this study, Roseville has several key decisions to make, including conversion timeframes and ultimate project scope. As described earlier, Roseville is considered a small transit agency and has until July 1, 2023 to submit a ZEB Rollout plan to CARB. The Rollout Plan will demonstrate how Roseville has planned for ZEB purchases, infrastructure buildout, and associated financial planning and workforce training. It must include the following elements:

- A goal of full transition to zero-emission buses by 2040 with careful planning that avoids early retirement of conventional internal combustion engine buses
- Identification of the types of zero-emission bus technologies a transit agency is planning to deploy, such as battery electric or fuel cell electric bus
- A schedule for construction of facilities and infrastructure modifications or upgrades, including charging, fueling, and maintenance facilities, to deploy and maintain zero-emission buses. This schedule must specify the general location of each facility, type of infrastructure, service capacity of infrastructure, and a timeline for construction
- A schedule for zero-emission and conventional internal combustion engine bus purchases and lease options. This schedule for bus purchases must identify the bus types, fuel types, and number of buses
- A schedule for conversion of conventional internal combustion engine buses to zero-emission buses, if any. This schedule for bus conversion must identify number of buses, bus types, the propulsion systems being removed and converted to
- A description on how a transit agency plans to deploy zero-emission buses in disadvantaged communities as listed in the latest version of CalEnviroScreen (https://oehha.ca.gov/calenviroscreen)
- A training plan and schedule for zero-emission bus operators and maintenance and repair staff
- Identification of potential funding sources.

As a value-added service to Roseville, Willdan has developed this Business Plan to be a strong foundation for Roseville to develop a fully compliant CARB Rollout Plan. All of the CARB Rollout Plan required elements are touched on in this report, as shown in **Table 17**; however, certain elements may require deeper analysis and planning to meet CARB's requirements. Specifically, this report does not include a detailed analysis of Roseville's existing maintenance facility capacities and what upgrades, if any, are needed to support an EV fleet. If upgrades are required, a construction timeline will need to be developed. This report identifies several training options and considerations for Roseville's fleet operators, maintenance staff, and public safety personnel, but a schedule for implementing a training program still needs to be developed.

As the purpose of the Rollout Plan is to cause transit agencies thinking early about the steps they will need to take to operate and maintain a fully zero emission fleet over the next 20 years, Roseville should recognize that the bus procurement, infrastructure buildout, and training schedules do not need be followed exactly as indicated in final CARB Roll Out Plan; however, actual ZEB purchases must still meet ICT requirements.

Table 17 – CARB Rollout Plan Compliance

	CARB ICT Element	Extent Addressed in Business Plan
1	A goal of full transition to zero-emission buses by 2040 with careful planning that avoids early retirement of conventional internal combustion engine buses	This report outlines how Roseville will achieve a fully ZEB fleet by 2033 without any early diesel retirements, see Table 8
2	Identification of the types of zero-emission bus technologies a transit agency is planning to deploy, such as battery electric or fuel cell electric bus	This report outlines how Roseville can meet service requirements with current battery electric buses and charging technology.
3	A schedule for construction of facilities and infrastructure modifications or upgrades, including charging, fueling, and maintenance facilities, to deploy and maintain zero-emission buses. This schedule must specify the general location of each facility, type of infrastructure, service capacity of infrastructure, and a timeline for construction	The Project Plan presented in Appendix B illustrates a general timeline for installing infrastructure needed to support a BEB fleet, including on-route chargers, and when maintenance facility upgrades must be completed; however, more detailed timelines may need to be developed. Proposed depot and on-route charger locations are discussed in this report. The existing depot electrical capacity and potential transformer capacities needed to support the BEB fleet have been discussed in this report.
4	A schedule for zero-emission and conventional internal combustion engine bus purchases and lease options. This schedule for bus purchases must identify the bus types, fuel types, and number of buses	Table 8 describes the proposed procurement schedule for diesel buses and BEBs. All zero-emission buses are expected to be battery electric and are expected to be purchased outright as done in prior bus purchases. Roseville may consider lease options pending review and evaluation of vendor responses to RFPs.
5	A schedule for conversion of conventional internal combustion engine buses to zero-emission buses, if any. This schedule for bus conversion must identify number of buses, bus types, the propulsion systems being removed and converted to	No direct ICE to zero emission buses are proposed in this report. All zero emission buses will be new bus purchases as ICEs are retired.
6	A description on how a transit agency plans to deploy zero-emission buses in disadvantaged communities as listed in the latest version of CalEnviroScreen	There are no DACs in Roseville, therefore this does not explicitly apply. Commuter routes, which have very high ridership, do pass through DACs and those are the first routes to be electrified. This helps pass environmental benefits to the greatest number of riders and those near commuter routes quickly.
7	A training plan and schedule for zero-emission bus operators and maintenance and repair staff	Various training considerations have been identified for maintenance staff and fleet operators; however, a training schedule may need to be developed. Willdan recommends at minimum that maintenance training be completed per manufacturer recommendations and as industry best practices develop.
8	Identification of potential funding sources.	Potential funding sources are included in Table 16

Evaluate BEB Cost and Operational Data

After the first BEBs are procured and placed into revenue service, actual data regarding operational efficiencies and costs should be compared to the estimated values in this report to determine if the original assumptions are valid or if they need updating to obtain a better vision of the future needs. Roseville should use pricing received from vendors for the pilot buses and actual installation costs of the first few charging stations to revise future capital cost expenditures. Roseville intends to rotate the pilot BEBs throughout all the commuter routes which will provide more accurate operating efficiencies, average charging times, and costs. Willdan suggests that Roseville track how efficiency changes throughout the year to validate the seasonal efficiencies projected in the EBCA results. After Roseville has compiled sufficient operational cost data, Roseville can revise future ongoing cost estimates. We recommend Roseville procure a data management system that can easily track and present this information in a format this is easy for fleet managers and operators to understand.

Conduct DER Feasibility Study

Willdan recommends Roseville conduct a full solar PV and battery storage analysis after the first five BEBs have been in revenue service for at least 12 months to evaluate potential future cost savings. After a full year of operation, Roseville will have enough real-world data to conduct a detailed feasibility analysis. Solar PV may be able to lower overall energy costs by reducing the average $/kWh Roseville may pay. Based on Willdan's charging schedules, load profiles, and financial analysis, approximately one-third of the total energy costs are from demand charges; therefore, storing excess solar energy during the day in batteries may significantly reduce overnight peak demand and overall demand charges. The feasibility study should also consider the interplay between changing the charging schedule to better align with peak solar production. It may prove financially advantageous, for example, to recharge more of the commuter routes during the midday break when solar production is at its peak. Willdan suggests that Roseville procure a charge management system that has the ability to incorporation real-time on-site solar PV production and on-site batteries, even if that capability is not needed today.

Conclusion

Key elements and considerations for transiting to a zero-emission fleet have been included in this report including detailed route modelling and energy requirements, an assessment of commercially available viable solutions, a phase-in strategy that accounts for technology limitations, and a financial analysis.

Key conclusions for overall phase-in plan:

- Roseville's existing commuter routes can be reliably serviced with BEBs currently available on the market with depot-only charging
- Roseville's FLRs are significantly more difficult to electrify; therefore, Willdan recommends Roseville delay electrification until CARB mandated ZEB purchases begin in 2026 to allow technology to develop further.
- The financial analysis suggests that purchasing and operating a fully electric fleet will cost more than diesel buses over 20 years. Roseville should use this information, not to deter against electrification, but to take the steps now to budget capital and operating expenses accordingly.
- The power level of the charger does not substantially affect total cost of electrifying the transit fleet. As a result, Willdan suggest Roseville pursue chargers with a power level greater than >100KW to have more flexible charging schedules and future proof against larger battery capacities.

Given this information, Roseville should proceed with procuring the first five pilot BEBs and necessary chargers to ensure the buses can be placed in revenue service in line with FTA grant deadlines. Roseville needs to decide the power level of depot chargers to procure and where they will be located at the corporation yard. At the time of this report, Willdan is currently working with Roseville to develop conceptual plans for different potential charger locations.

Willdan recommends Roseville take the following near-term steps:

- Issue a joint RFP for the first five BEBs, chargers, and charge management system. Willdan recommends that Roseville purchase a backup charger with this initial procurement, available funding permitting. It is suggested Roseville indicate preferred locations for the chargers in the RFP to get more accurate installation cost estimates.

Develop and file the CARB Rollout Plan. Roseville is a small transit agency and has until July 1, 2023 to submit the Roll-out Plan to CARB. Large transit agencies; however, must submit their Rollout Plans by July 1, 2020. Willdan suggests Roseville review submitted and approved plans to help inform what a compliant Rollout Plan for Roseville must contain. It is possible that CARB revises the Rollout Plan requirements or provides additional guidance based on what the large transit agencies submit.

Willdan recommends Roseville take the following mid-term steps following the procurement and operation of the first five ZEBs:

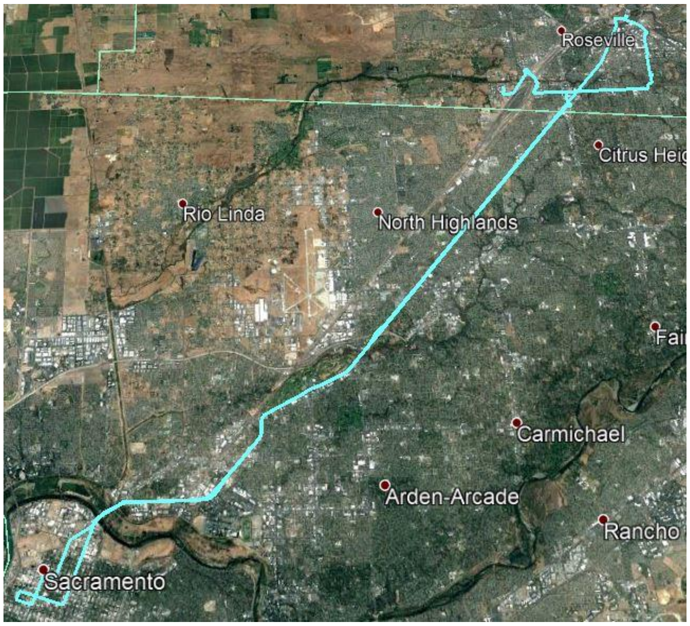
- Continue to evaluate and pursue funding opportunities for subsequent BEB and charger purchases.
- Evaluate the pilot BEB operational data including actual efficiency, energy usage, costs, range, and charge times. Compare actual operational data to modelled estimates and revise operational procedures and charging schedules as appropriate.
- Conduct a solar PV and battery energy storage feasibility analysis after operating the pilot buses for at least 12 months.

This plan uses a snapshot of current and imminent product offerings to create a roadmap for Roseville to continue to provide safe, reliable, and affordable transit service as they electrify their bus fleet by 2040, and to remain compliant with CARB ICT. Guidelines and recommendations presented here provide a starting point for Roseville on their zero-emission bus conversion journey, leveraging their existing fleet replacement schedule and using technology available today, where appropriate, and identifying gaps in current product offerings which will need to ultimately be addressed through future improvements in technology or other proposed solutions. The report also estimates the difference in financial impact of fleet over time to allow for Roseville to properly plan and budget for the increase in funding needed. As technology continues to develop and transit needs change over time Roseville, should continue to track the ZEB market to understand the available solutions to meet the City's needs and adjust the initial plan and recommendations outlined in this report accordingly. By planning for fleet electrification now, Roseville is taking the necessary action to proactively stay ahead of the CARB ICT regulation, help meet California meet its greenhouse gas emission and climate goals and be a regional leader in zero-emission transit.

APPENDICES

APPENDIX A – EBCA Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	5 AM
	8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

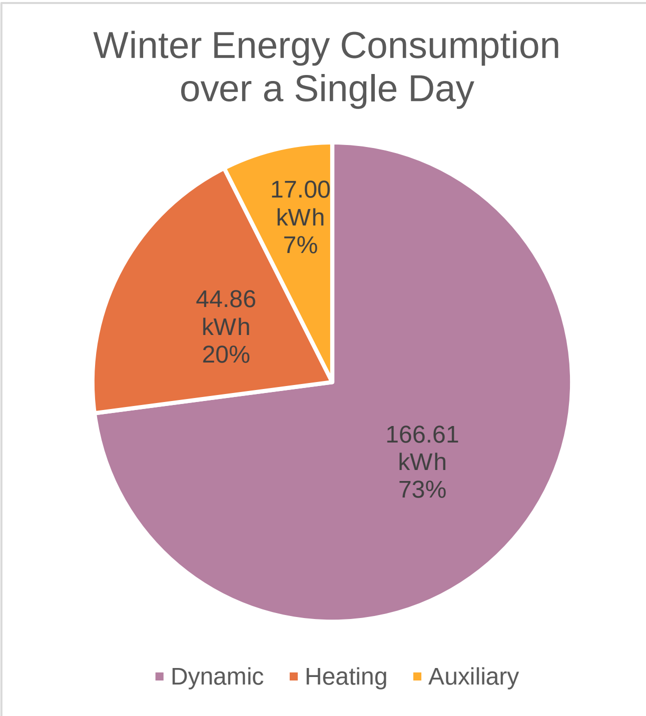
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.68 kWh/mi	2.16 kWh/mi	2.27 kWh/mi	2.28 kWh/mi

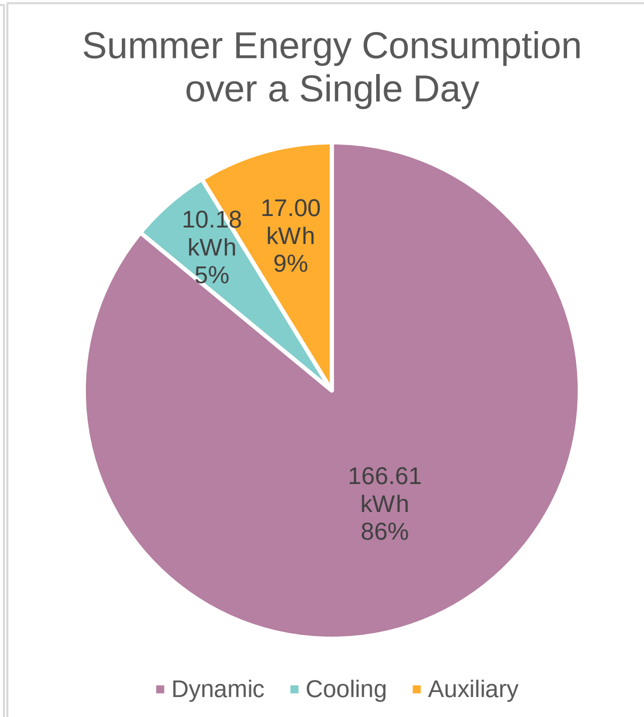
Route 1 and 7 AM Results

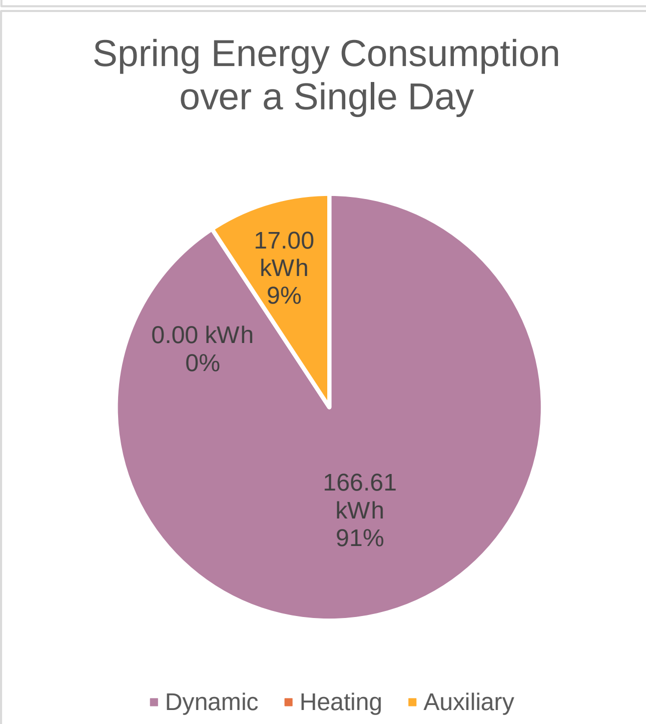
Daily Energy Consumption by Subsystem

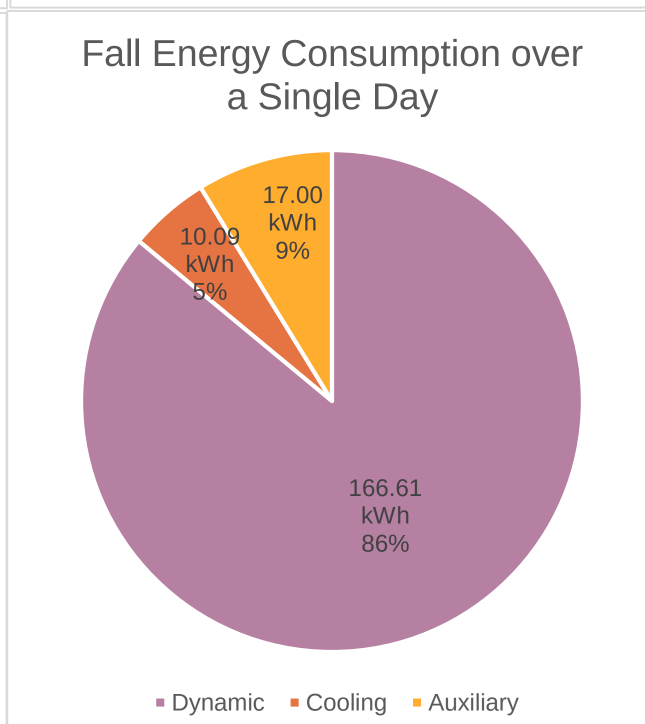
Total Daily Energy Consumption:

Summer:	193.79 KWH	Fall	193.70
Winter:	228.47 KWH	Spring	183.61









Route 1 and 7 AM Results

Daily State of Charge

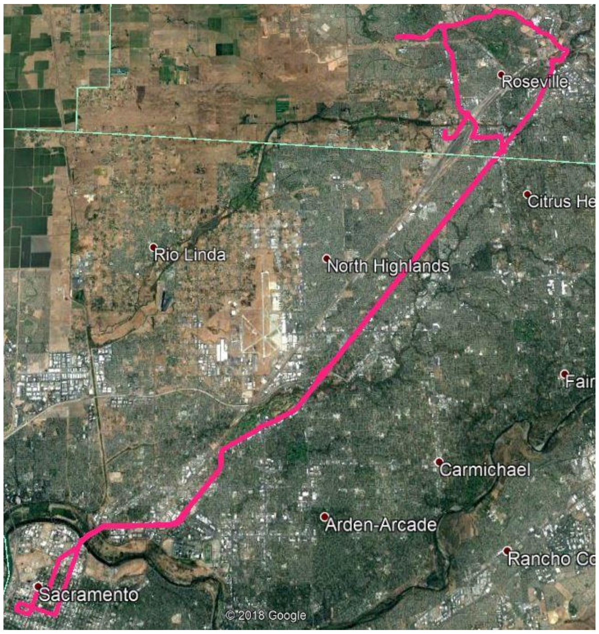
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**228.47**	0.00	**211.53**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**193.79**	0.00	**246.21**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	5 AM
	9 AM

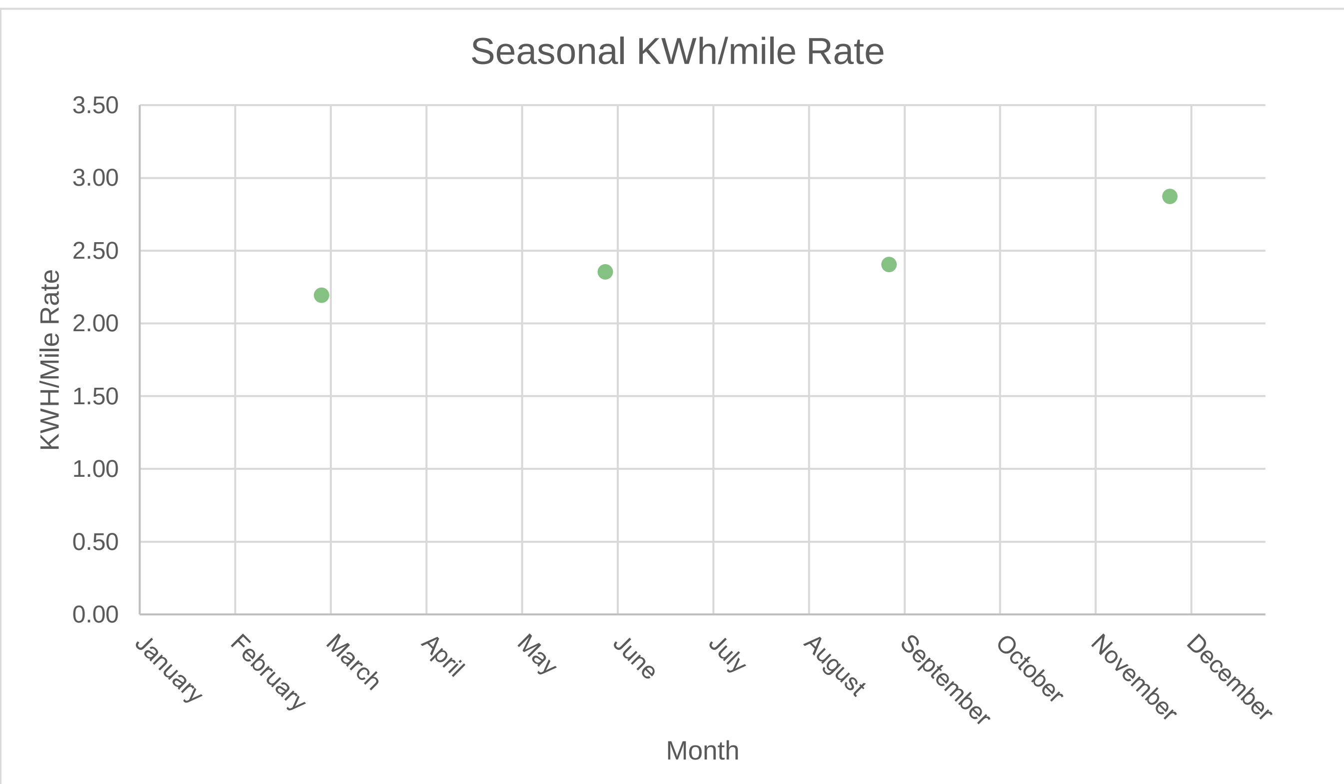
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.87 kWh/mi	2.19 kWh/mi	2.40 kWh/mi	2.35 kWh/mi

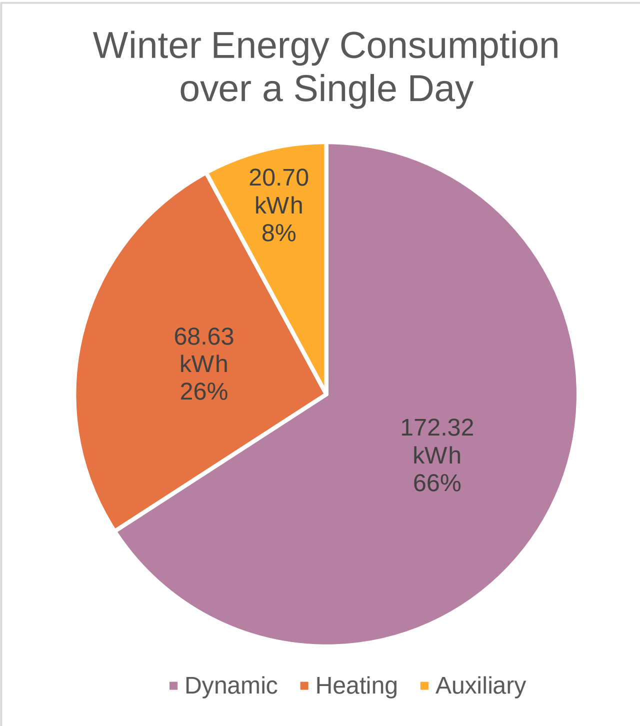


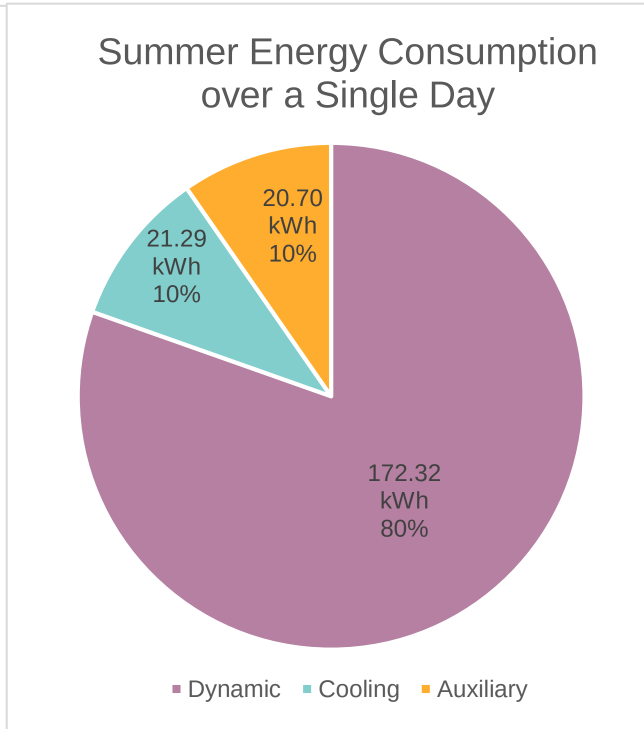
Route 2 and 10 AM Results

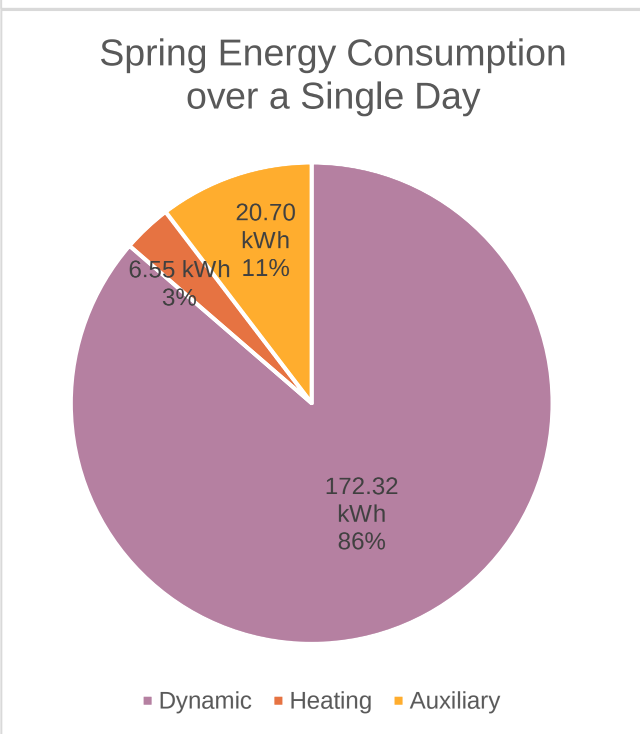
Daily Energy Consumption by Subsystem

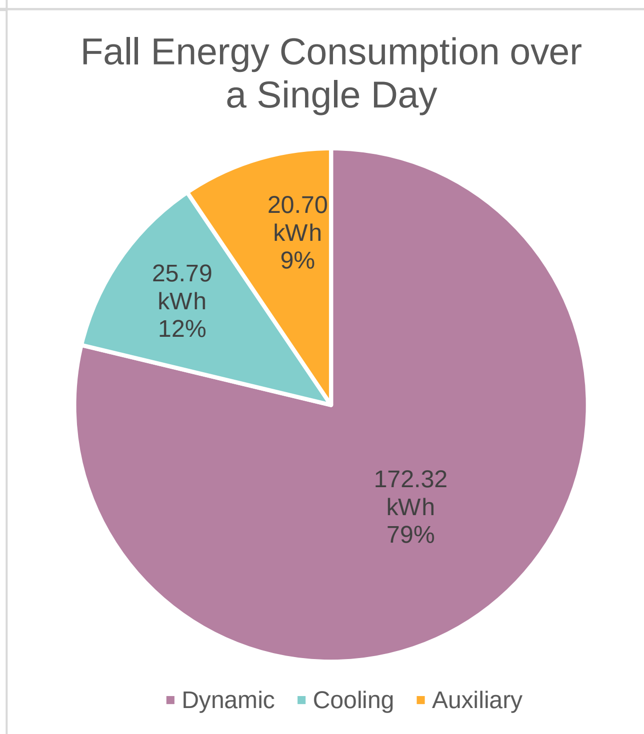
Total Daily Energy Consumption:

Summer:	214.31 KWH	Fall	218.81
Winter:	261.66 KWH	Spring	199.57









Route 2 and 10 AM Results

Daily State of Charge

Winter

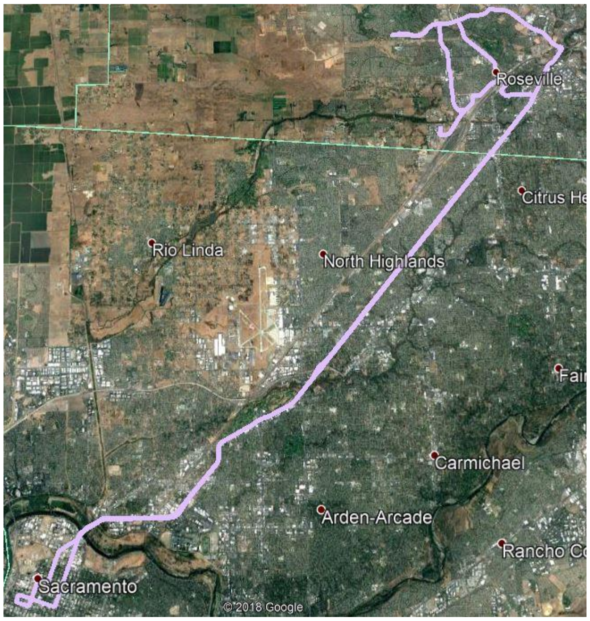
Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**261.66**	0.00	**178.34**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**214.31**	0.00	**225.69**

Route 3 AM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	5 AM
	8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

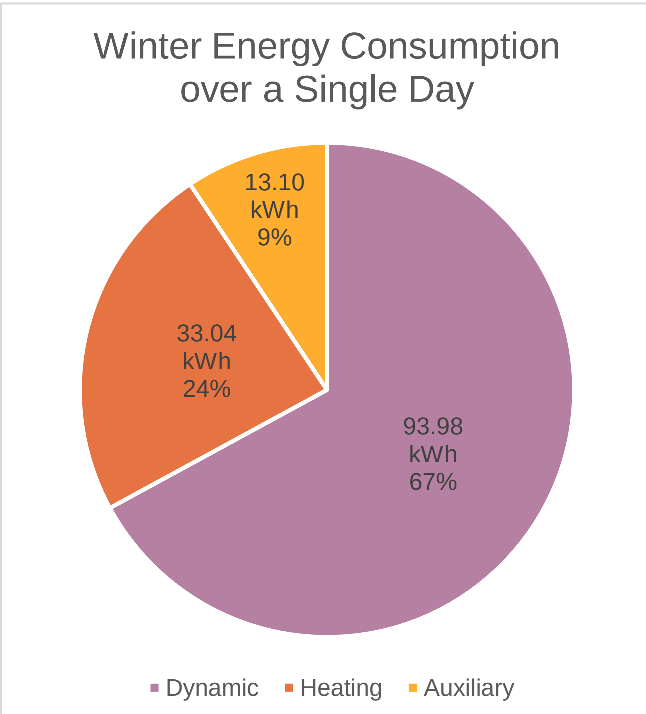
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.48 kWh/mi	1.90 kWh/mi	2.03 kWh/mi	2.03 kWh/mi

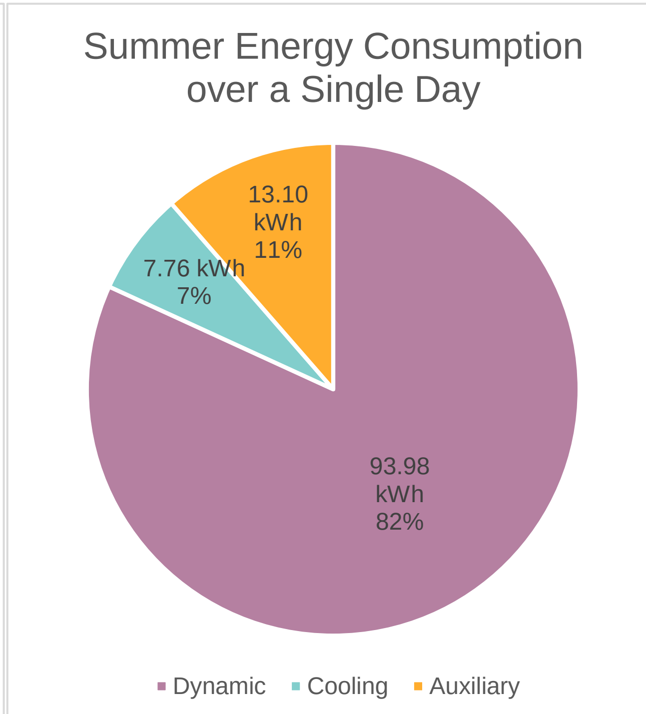
Route 3 AM Results

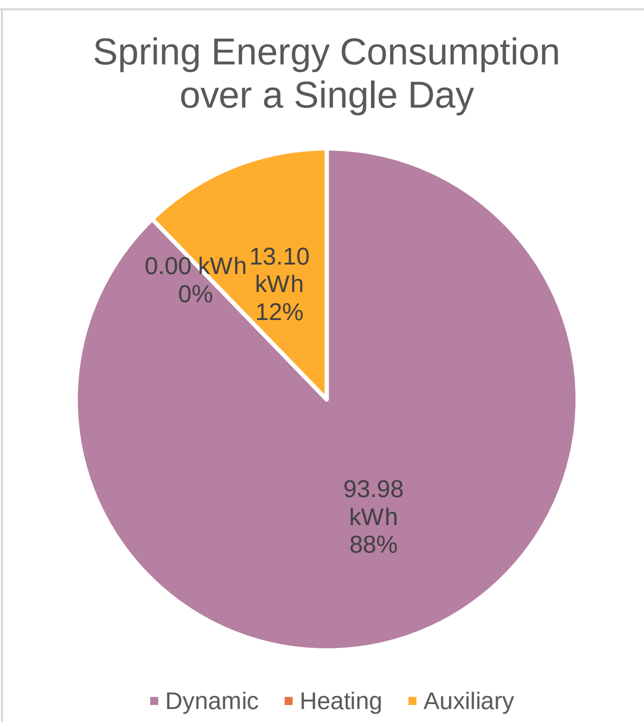
Daily Energy Consumption by Subsystem

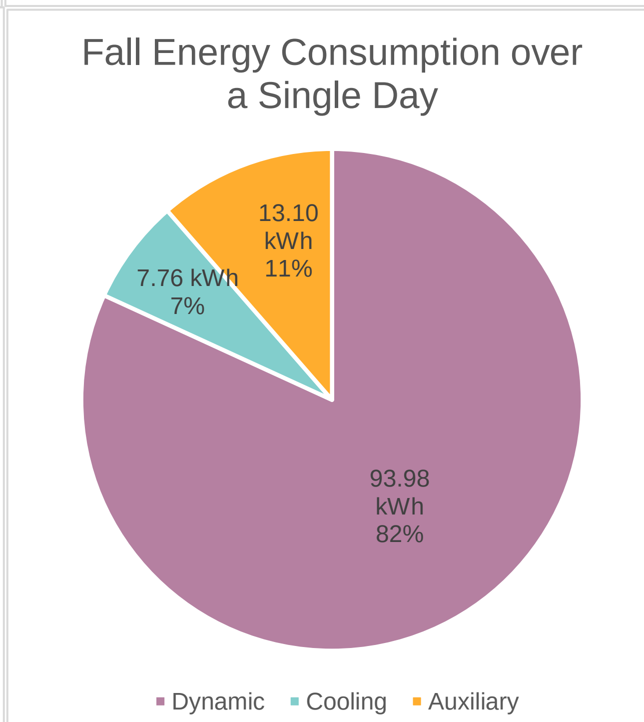
Total Daily Energy Consumption:

Summer:	114.84 KWH	Fall	114.84
Winter:	140.12 KWH	Spring	107.08









Route 3 AM Results

Daily State of Charge

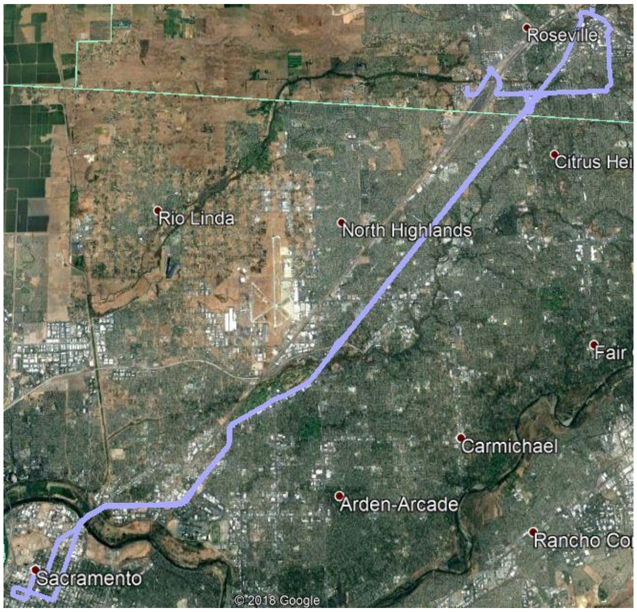
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**140.12**	0.00	**299.88**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**114.84**	0.00	**325.16**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	6 AM
	8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

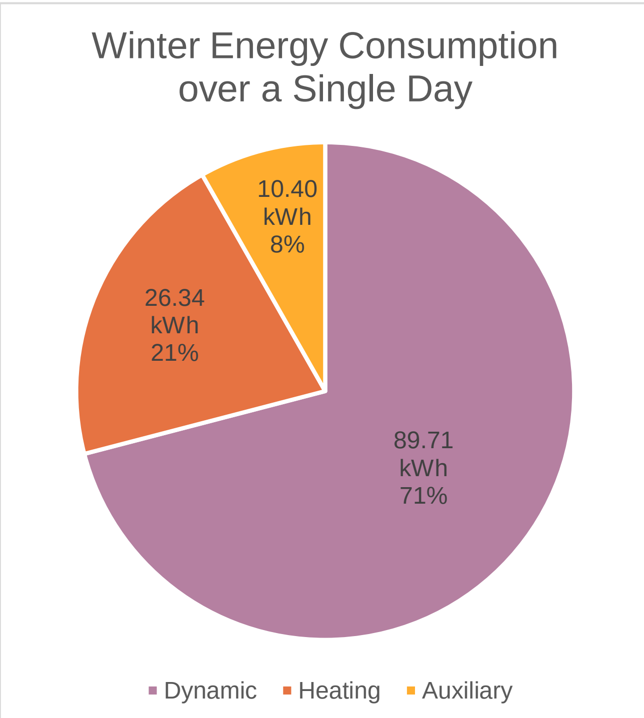
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.62 kWh/mi	2.07 kWh/mi	2.21 kWh/mi	2.21 kWh/mi

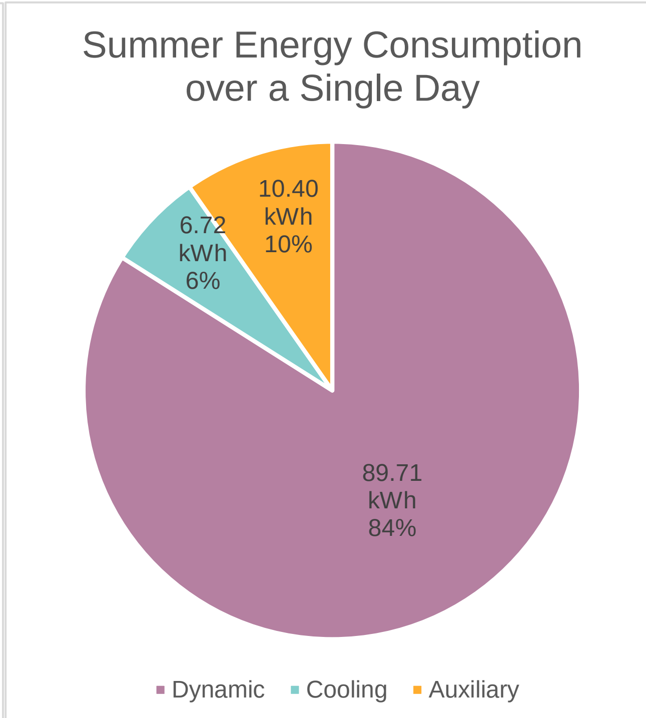
Route 4 AM Results

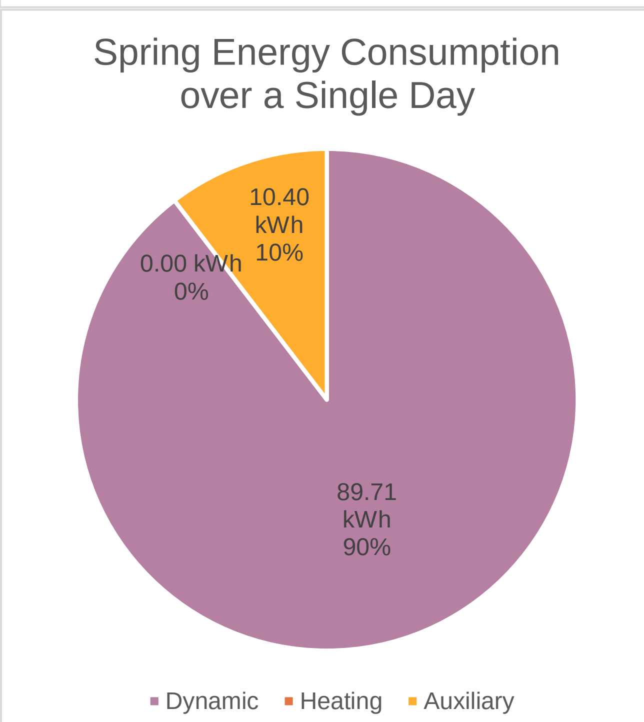
Daily Energy Consumption by Subsystem

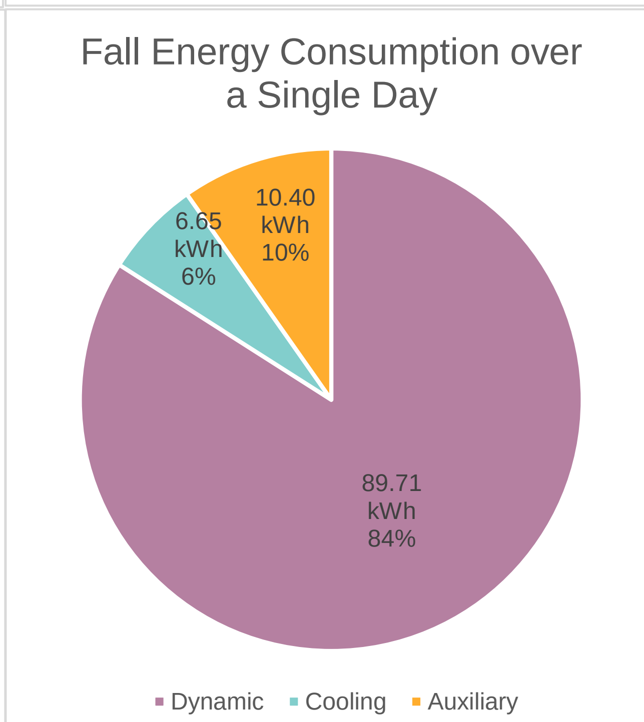
Total Daily Energy Consumption:

Summer:	106.82 KWH	Fall	106.76
Winter:	126.45 KWH	Spring	100.11









Route 4 AM Results

Daily State of Charge

Winter

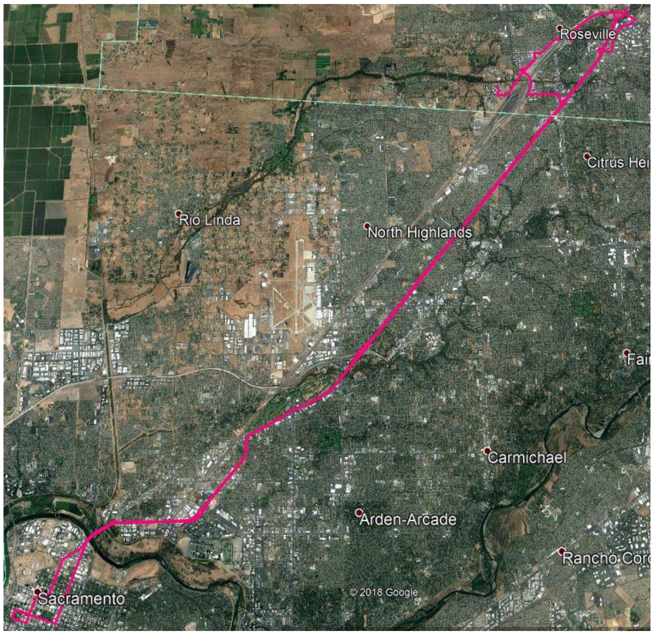
Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**126.45**	0.00	**313.55**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**106.82**	0.00	**333.18**

Route 5 AM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	6 AM
	8 AM

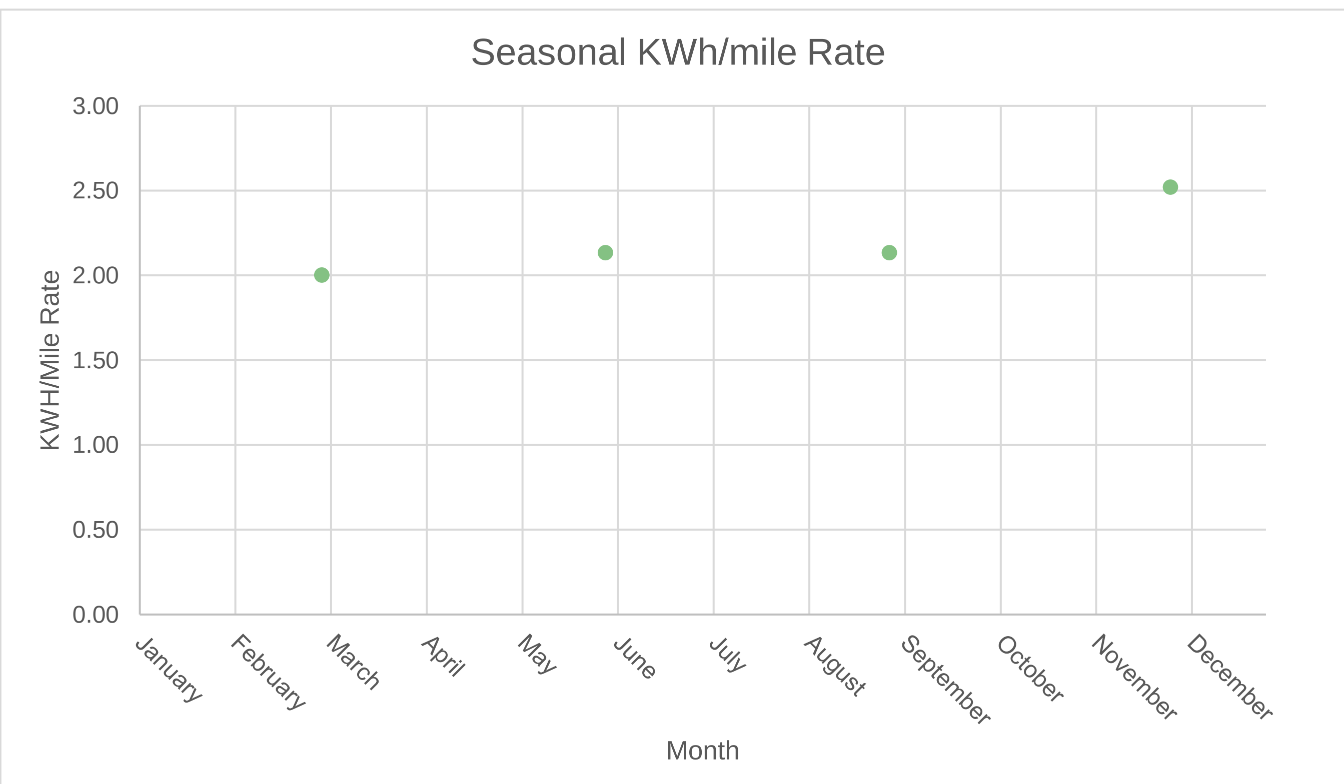
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.52 kWh/mi	2.00 kWh/mi	2.13 kWh/mi	2.13 kWh/mi

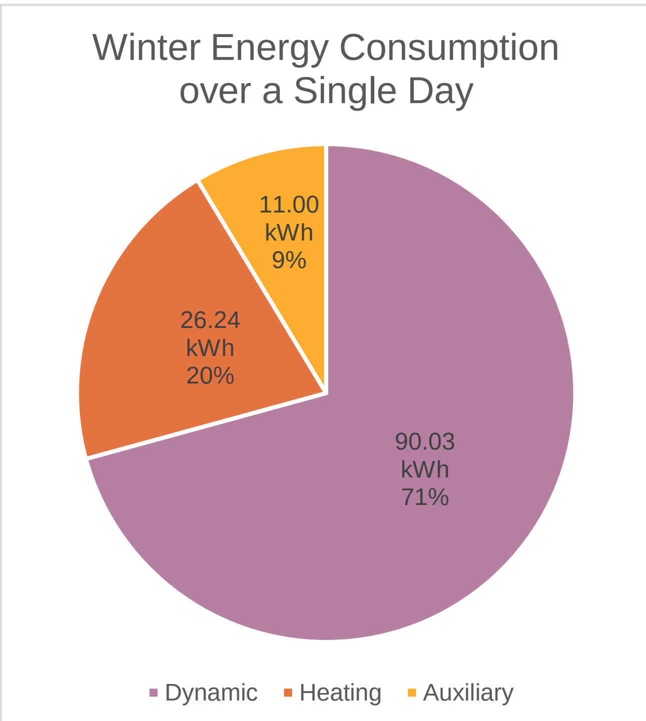


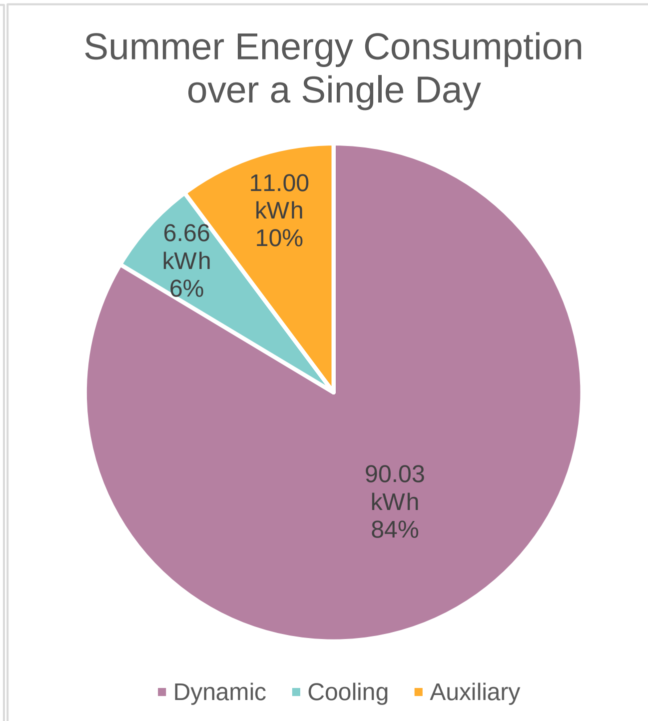
Route 5 AM Results

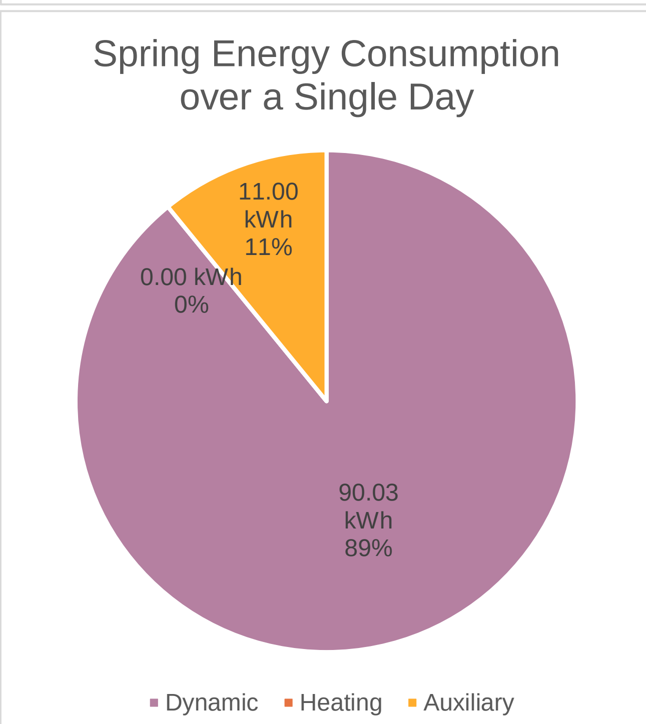
Daily Energy Consumption by Subsystem

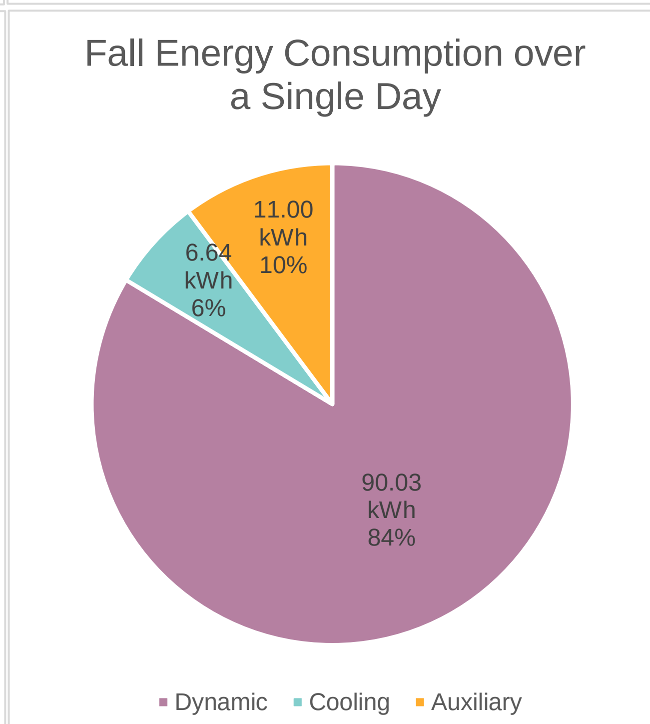
Total Daily Energy Consumption:

Summer:	107.69 KWH	Fall	107.66
Winter:	127.27 KWH	Spring	101.03









Route 5 AM Results

Daily State of Charge

Winter

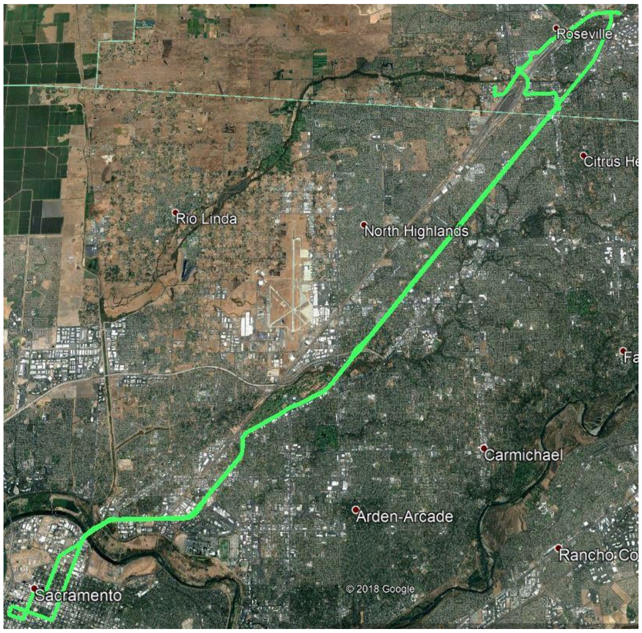
Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**127.27**	0.00	**312.73**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**107.69**	0.00	**332.31**

Route 6 AM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	6 AM 8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

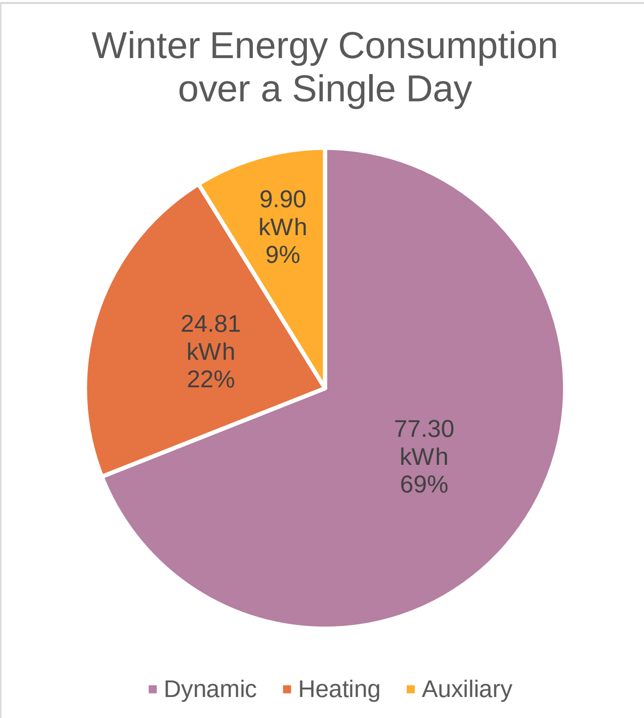
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.54 kWh/mi	1.98 kWh/mi	2.12 kWh/mi	2.12 kWh/mi

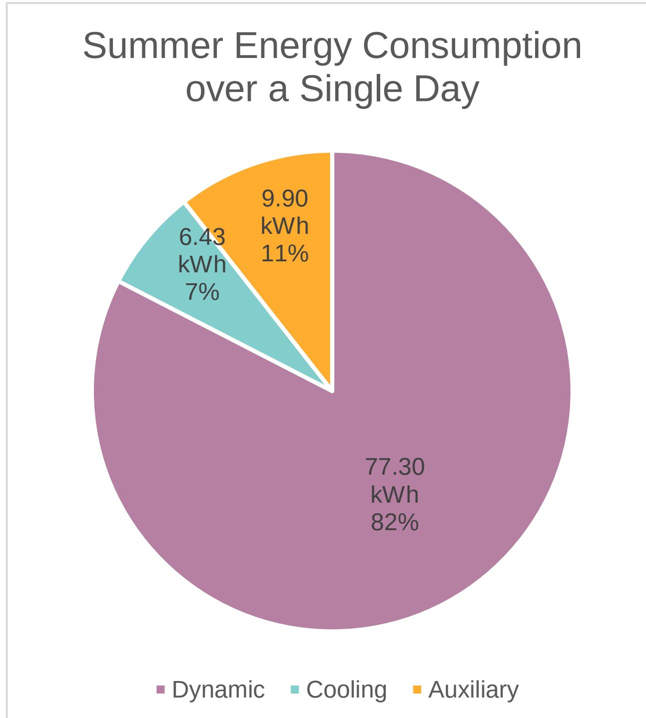
Route 6 AM Results

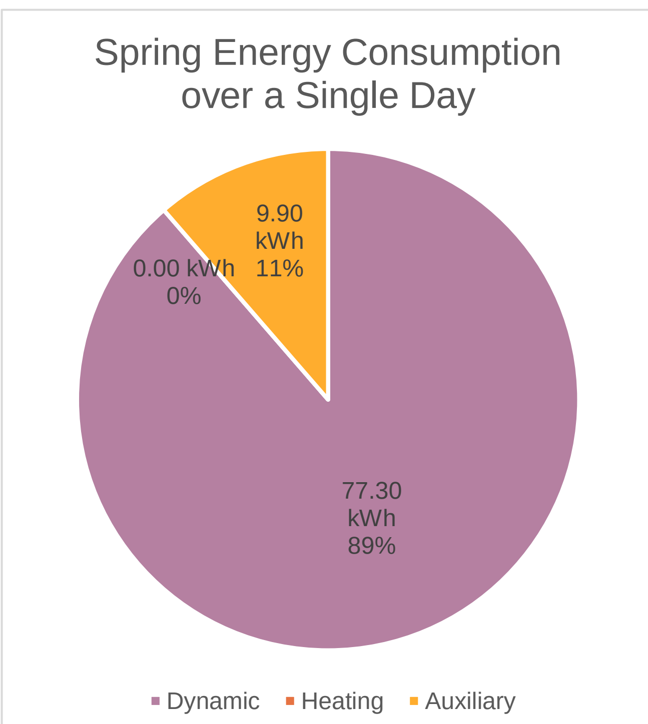
Daily Energy Consumption by Subsystem

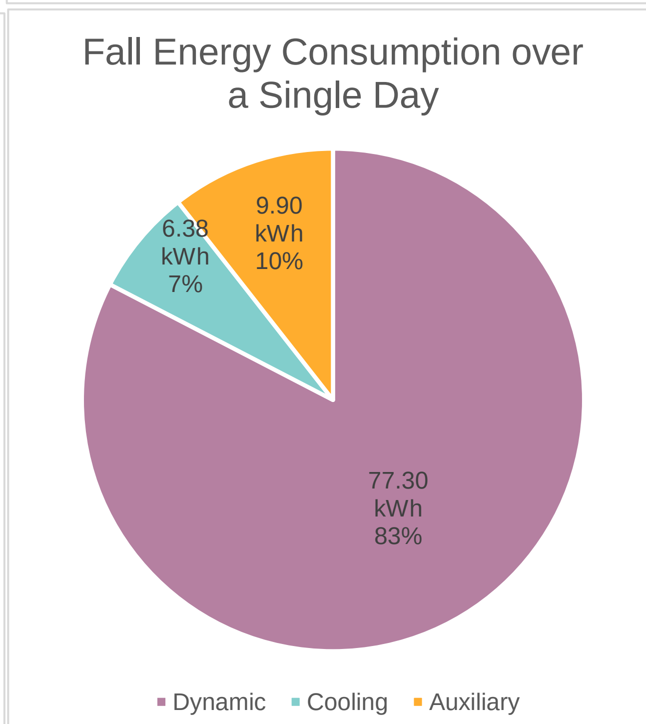
Total Daily Energy Consumption:

Summer:	93.63	KWH	Fall	93.58
Winter:	112.01	KWH	Spring	87.20









Route 6 AM Results

Daily State of Charge

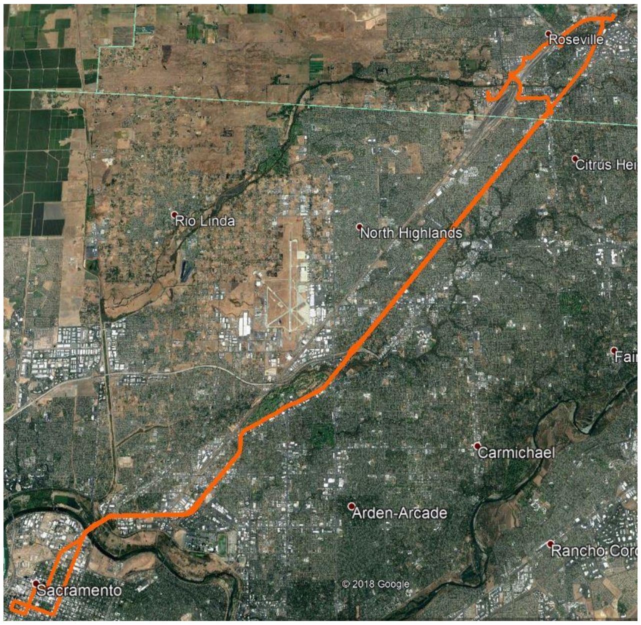
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**112.01**	0.00	**327.99**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**93.63**	0.00	**346.37**

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 40

Battery Size: 440 KWH

Hours of Service 6 AM
8 AM

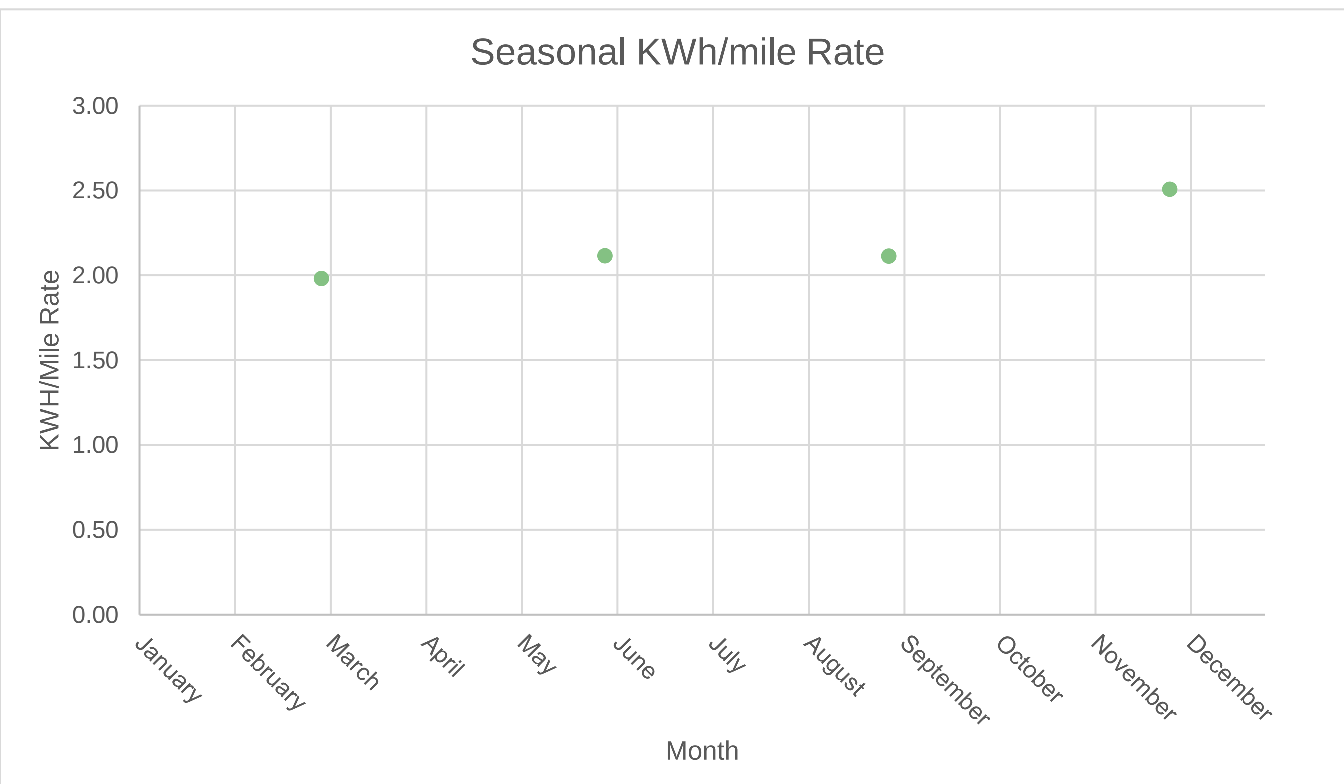
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.51 kWh/mi	1.98 kWh/mi	2.11 kWh/mi	2.11 kWh/mi

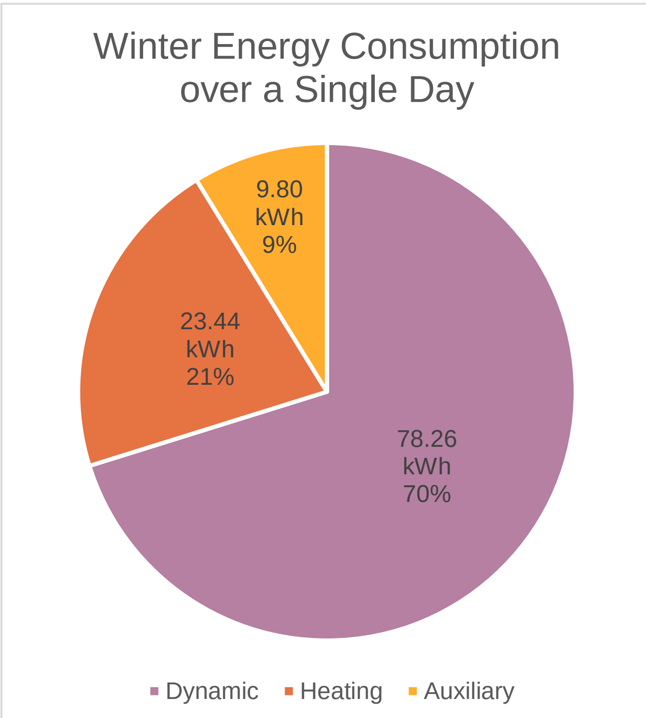


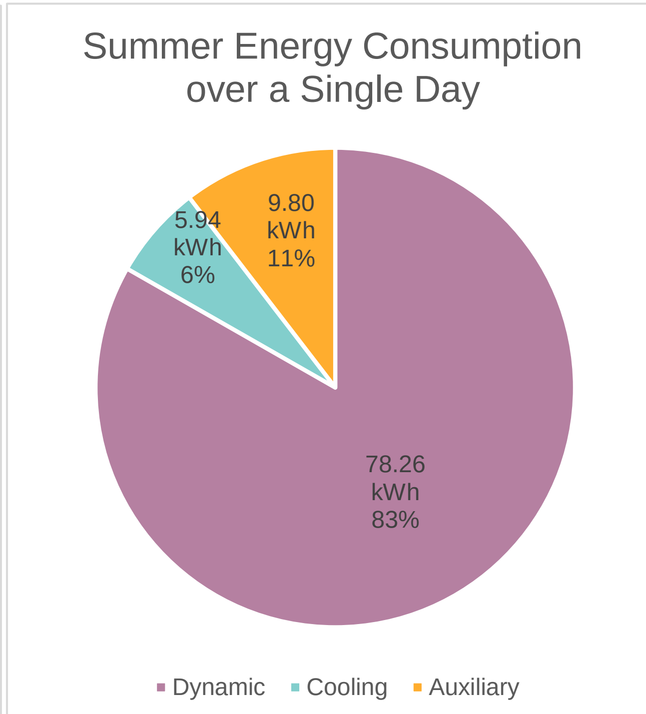
Route 8 AM Results

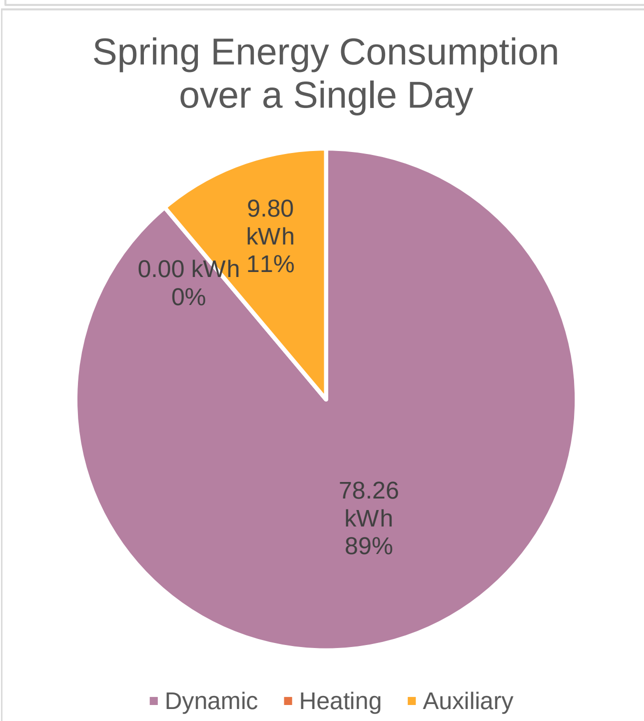
Daily Energy Consumption by Subsystem

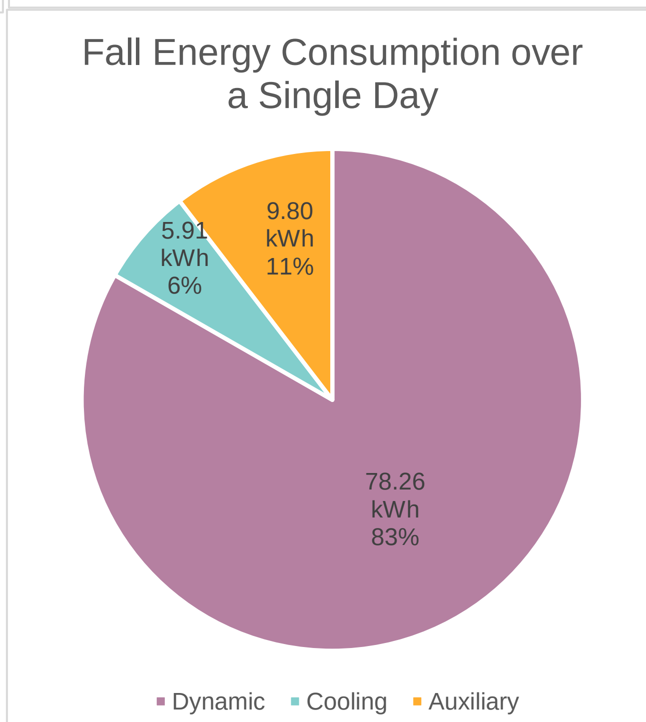
Total Daily Energy Consumption:

Summer:	94.00	KWH	Fall	93.98
Winter:	111.51	KWH	Spring	88.06









Route 8 AM Results

Daily State of Charge

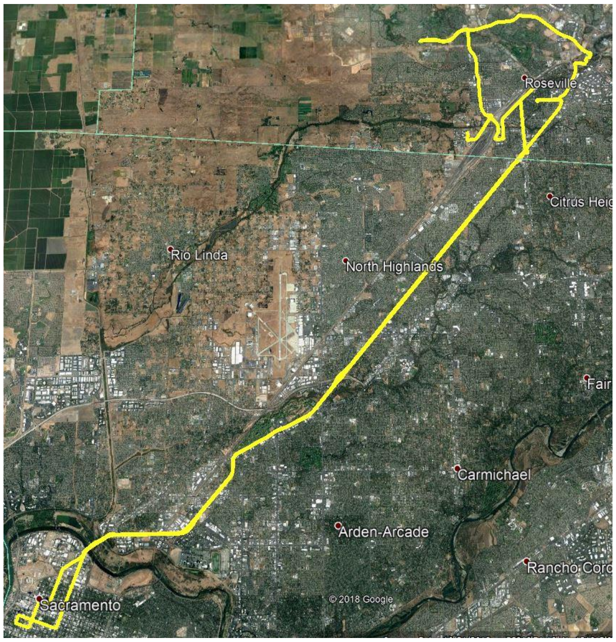
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**111.51**	0.00	**328.49**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**94.00**	0.00	**346.00**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	6 AM
	8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

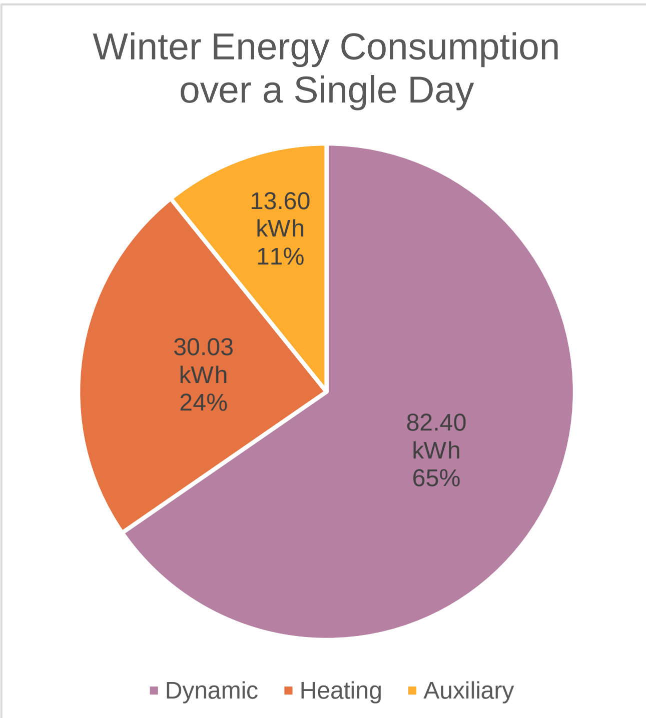
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.33 kWh/mi	1.78 kWh/mi	1.92 kWh/mi	1.92 kWh/mi

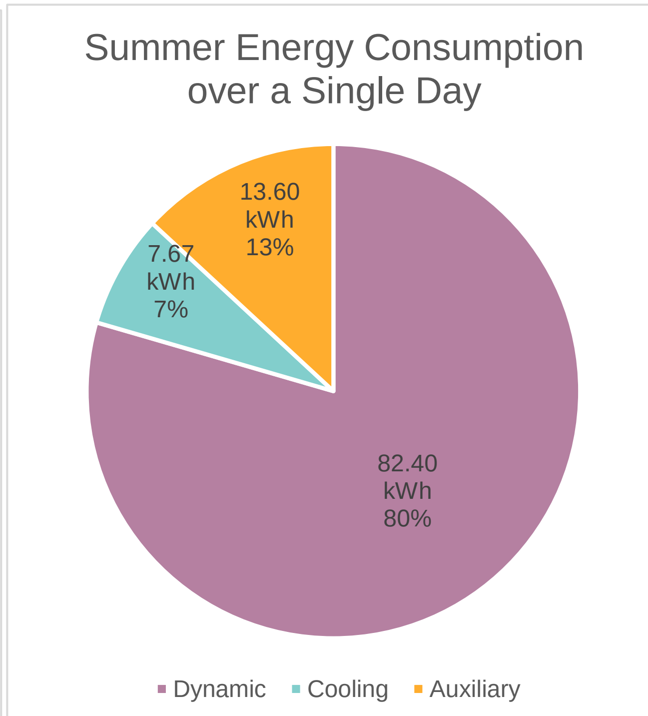
Route 9 AM Results

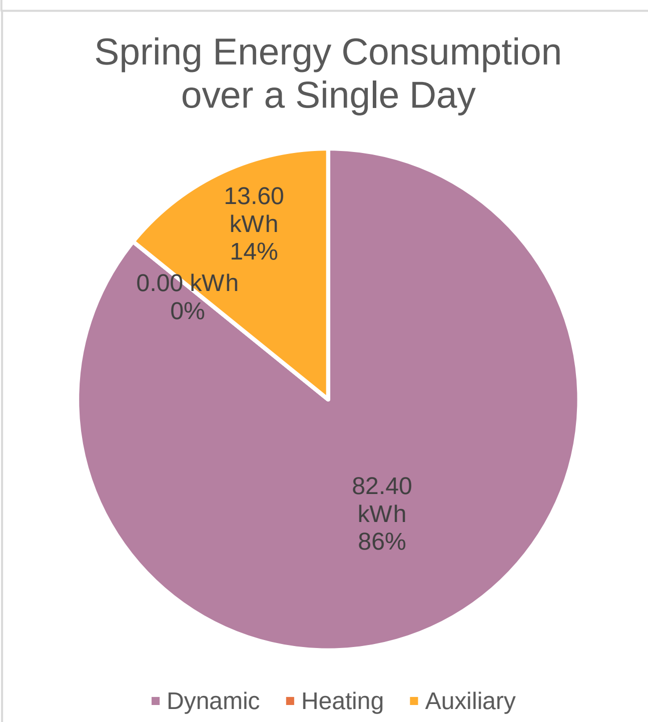
Daily Energy Consumption by Subsystem

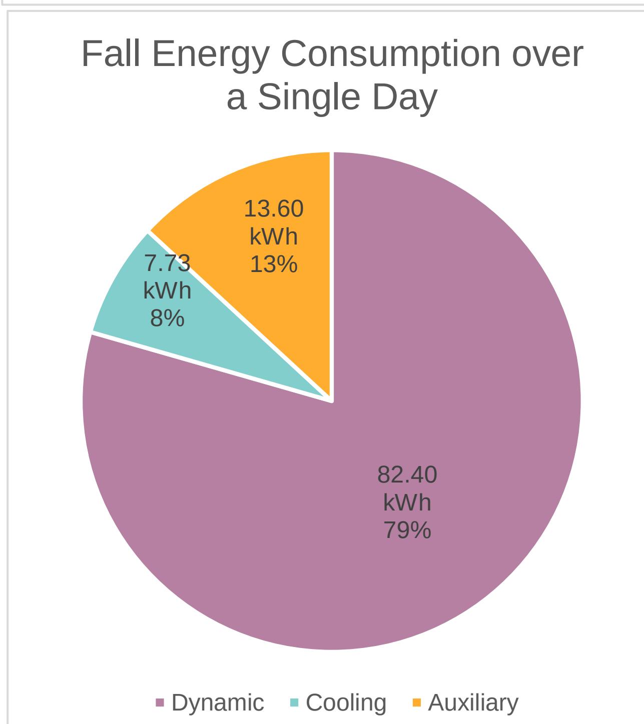
Total Daily Energy Consumption:

Summer:	103.67	KWH	Fall	103.73
Winter:	126.03	KWH	Spring	96.00









Route 9 AM Results

Daily State of Charge

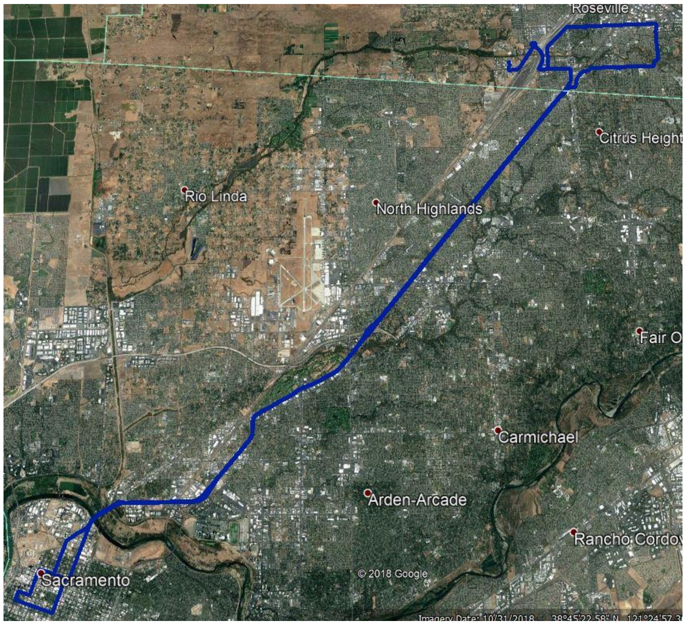
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**126.03**	0.00	**313.97**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**103.67**	0.00	**336.33**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM 5 PM

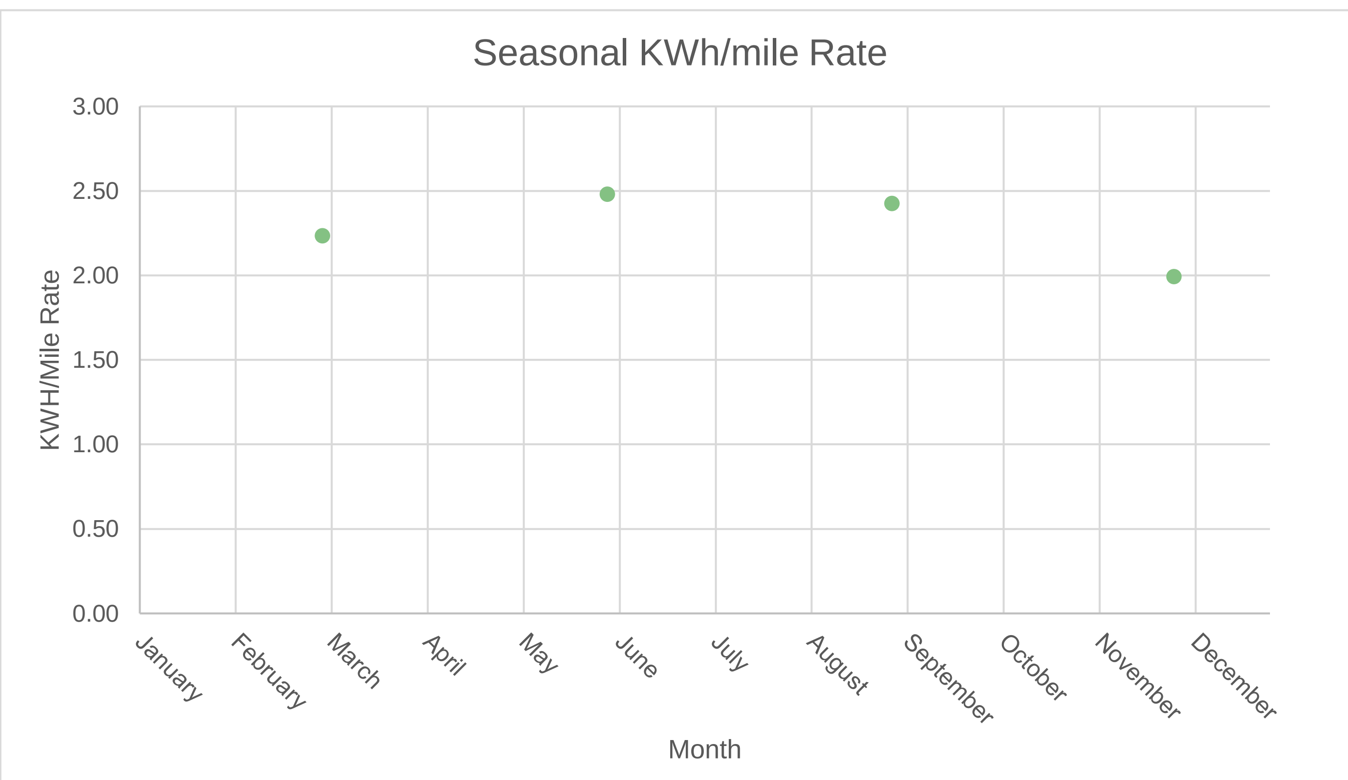
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
1.99 kWh/mi	2.23 kWh/mi	2.43 kWh/mi	2.48 kWh/mi

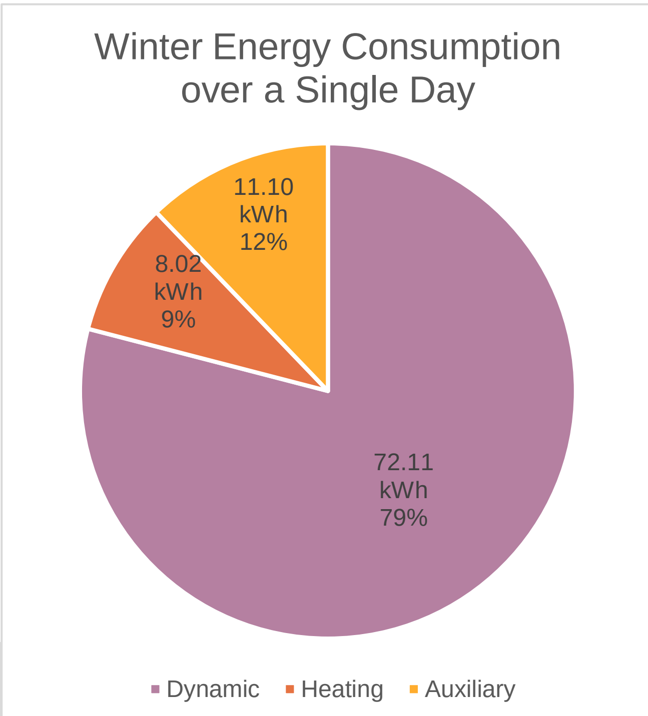


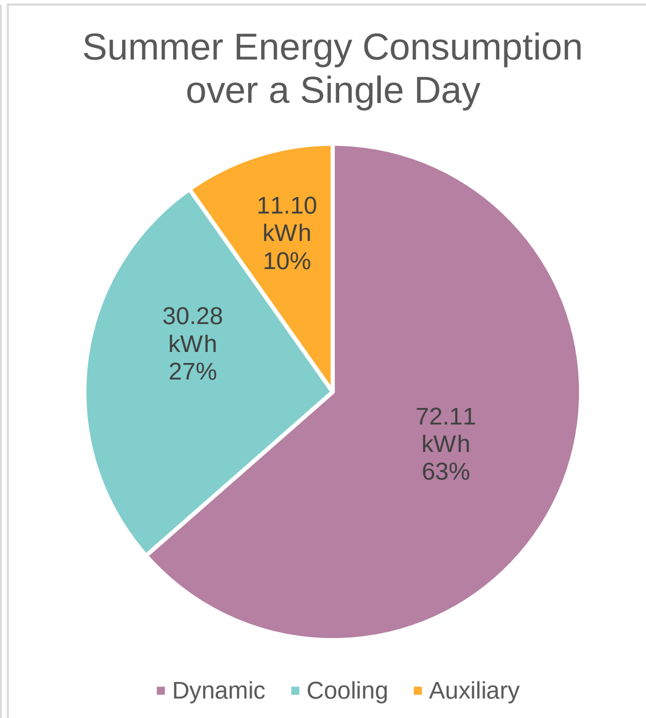
Route 1 PM Results

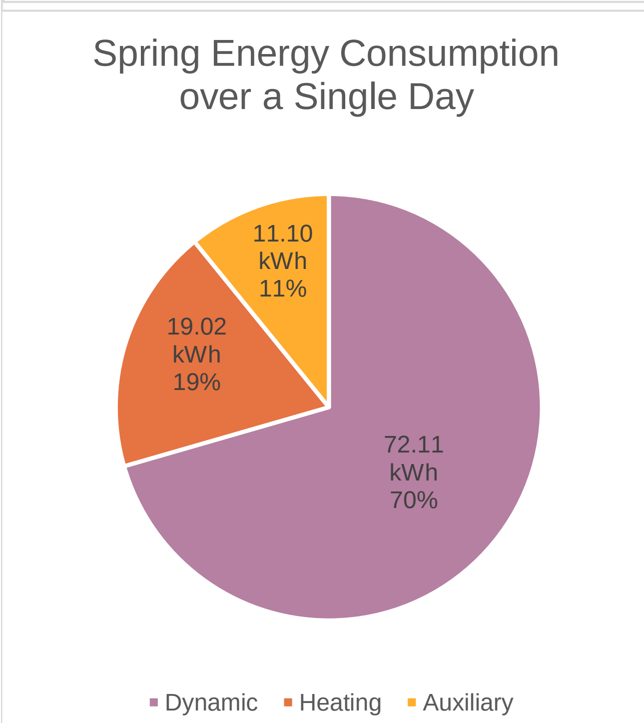
Daily Energy Consumption by Subsystem

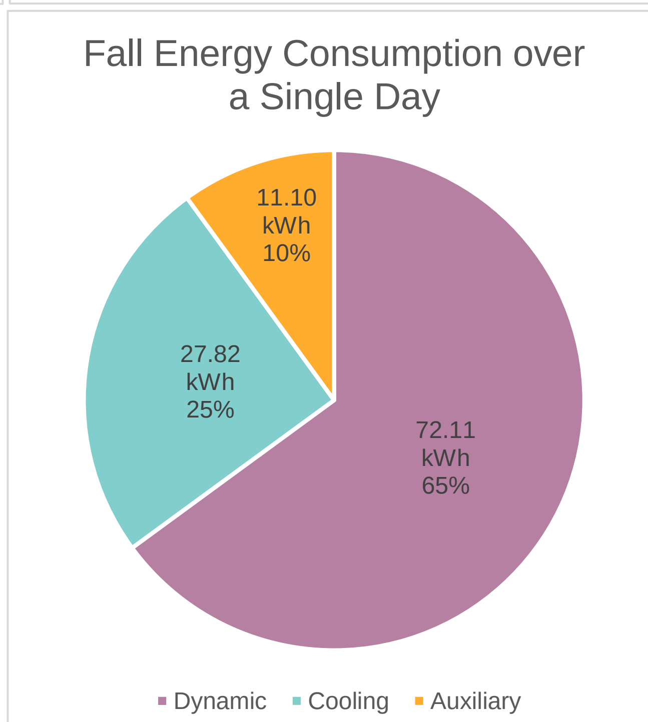
Total Daily Energy Consumption:

Summer:	113.49 KWH	Fall	111.03
Winter:	91.23 KWH	Spring	102.23









Route 1 PM Results

Daily State of Charge

Winter

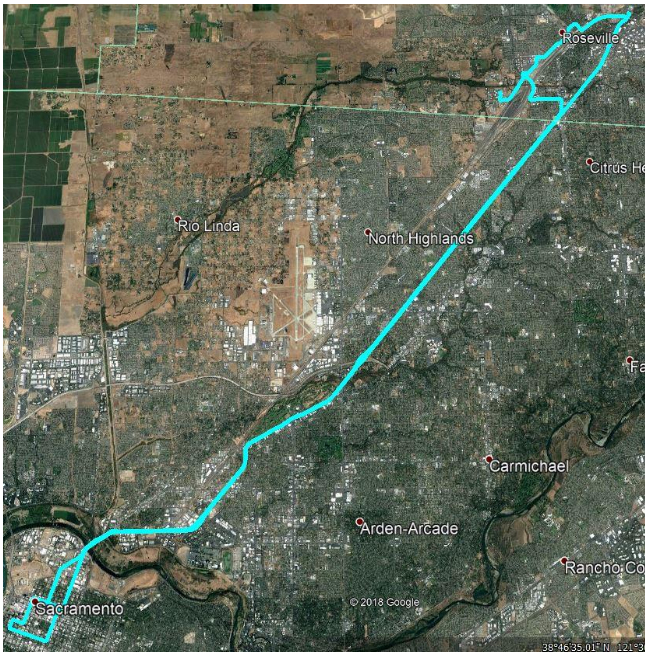
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**91.23**	0.00	**348.77**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**113.49**	0.00	**326.51**

Route 2 and 9 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM 7 PM

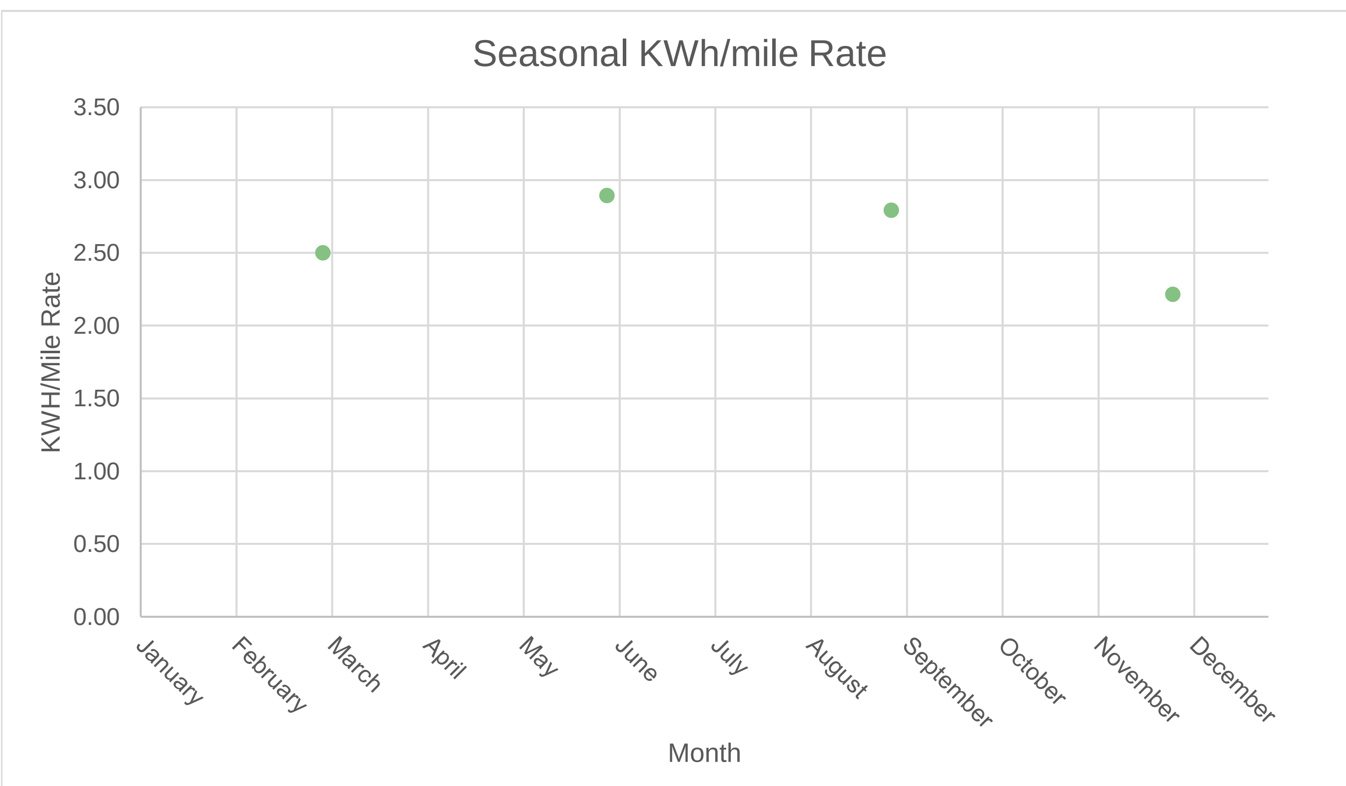
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.21 kWh/mi	2.50 kWh/mi	2.79 kWh/mi	2.89 kWh/mi

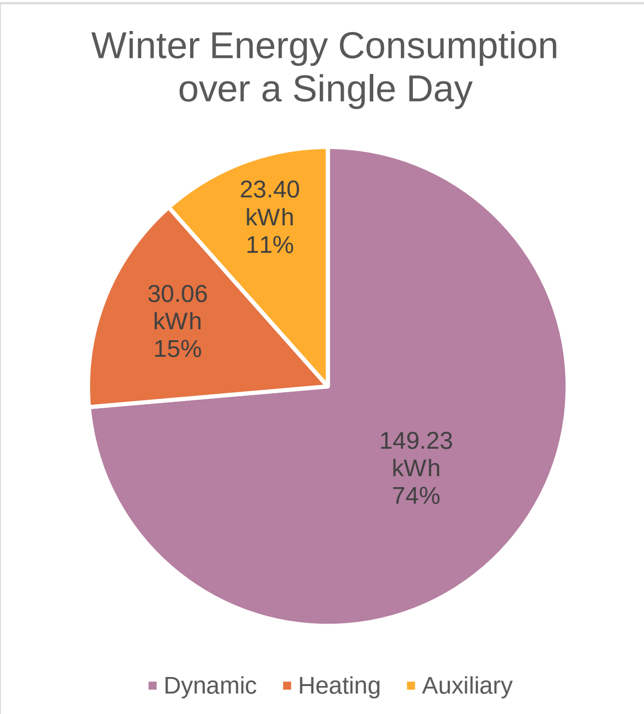


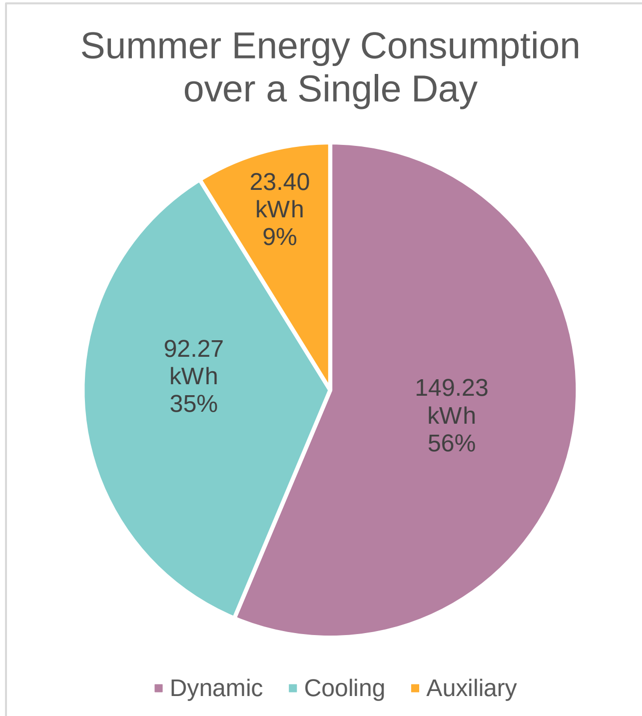
Route 2 and 9 PM Results

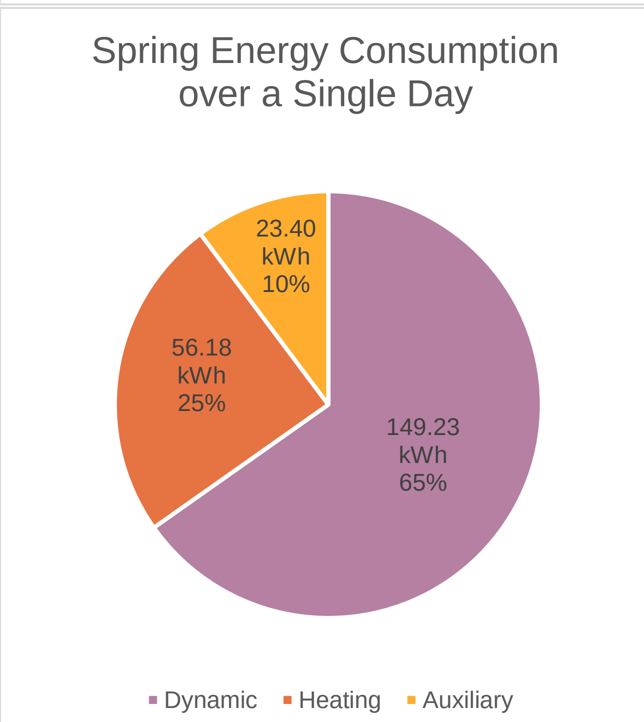
Daily Energy Consumption by Subsystem

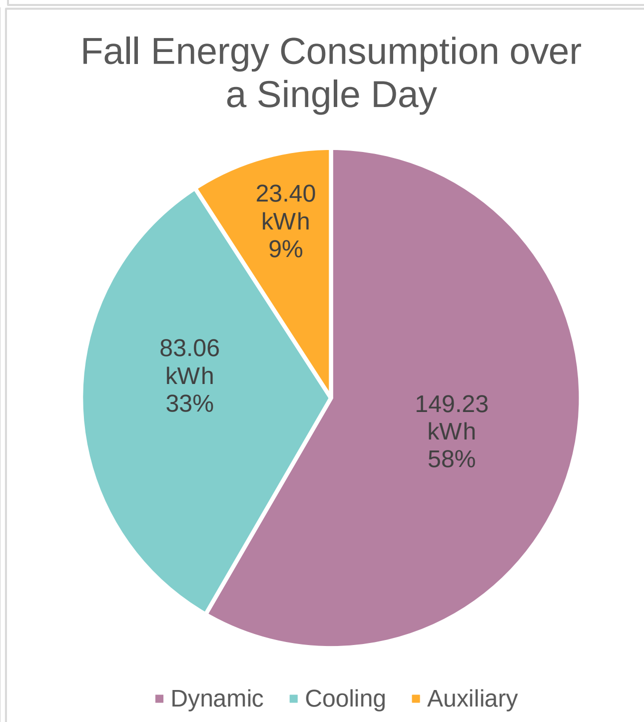
Total Daily Energy Consumption:

Summer:	264.89	KWH	Fall	255.68
Winter:	202.69	KWH	Spring	228.80









Route 2 and 9 PM Results

Daily State of Charge

Winter

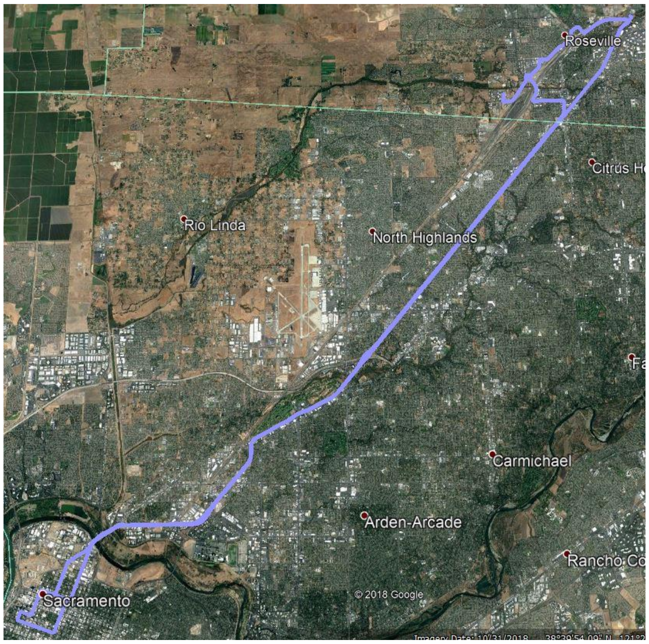
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**202.69**	0.00	**237.31**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**264.89**	0.00	**175.11**

Route 3 and 10 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM 7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

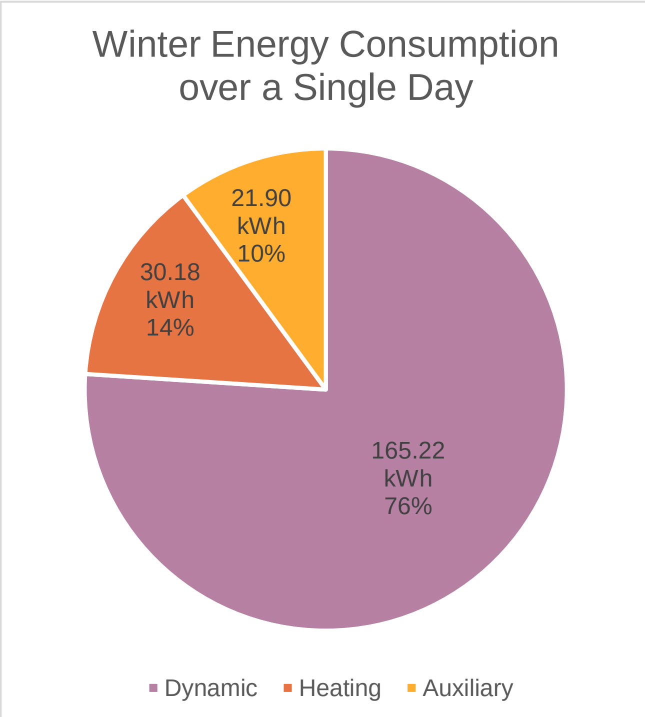
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.36 kWh/mi	2.65 kWh/mi	2.95 kWh/mi	3.06 kWh/mi

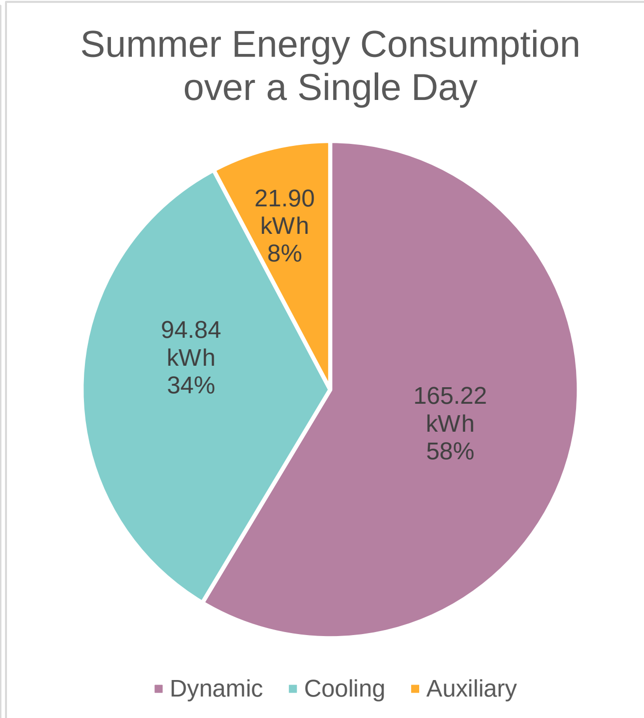
Route 3 and 10 PM Results

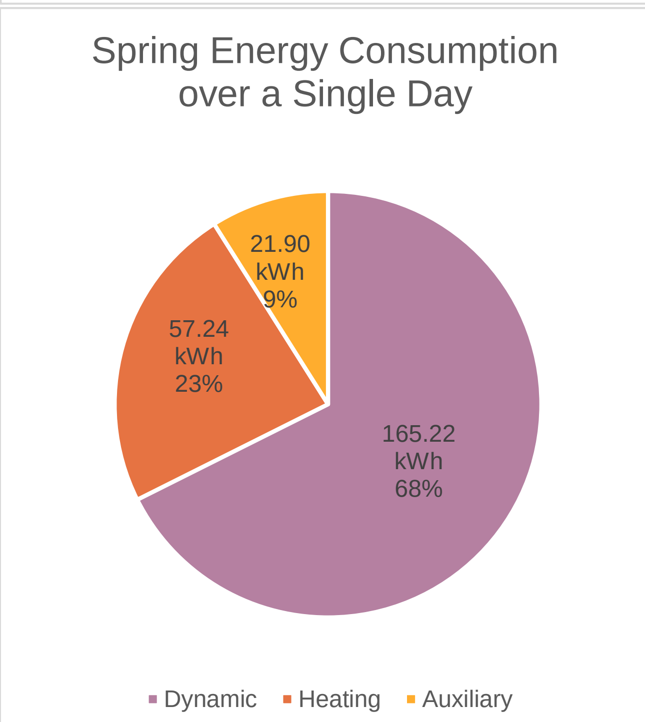
Daily Energy Consumption by Subsystem

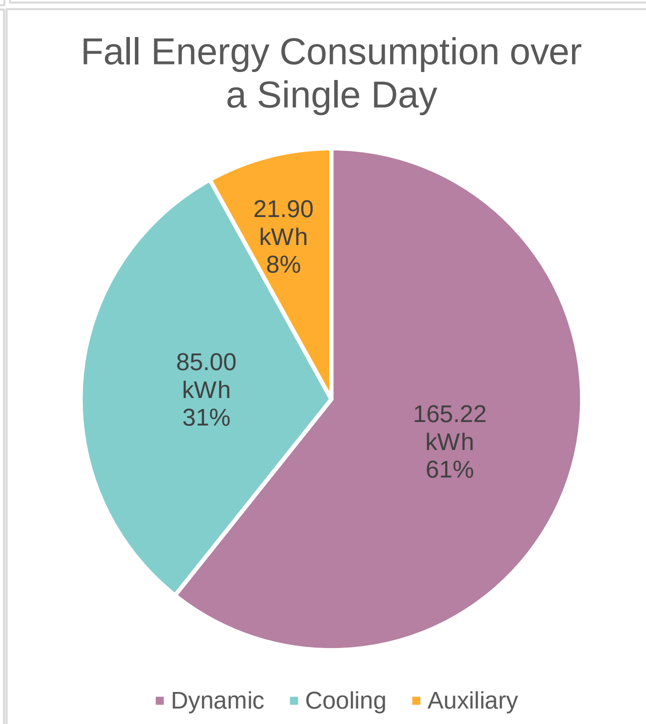
Total Daily Energy Consumption:

Summer:	281.95 KWH	Fall	272.12
Winter:	217.30 KWH	Spring	244.36









Route 3 and 10 PM Results

Daily State of Charge

Winter

		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**217.30**	0.00	**222.70**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**281.95**	0.00	**158.05**

Route 4 PM Results

Electric Bus Corridor Model Results

Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM
	5 PM

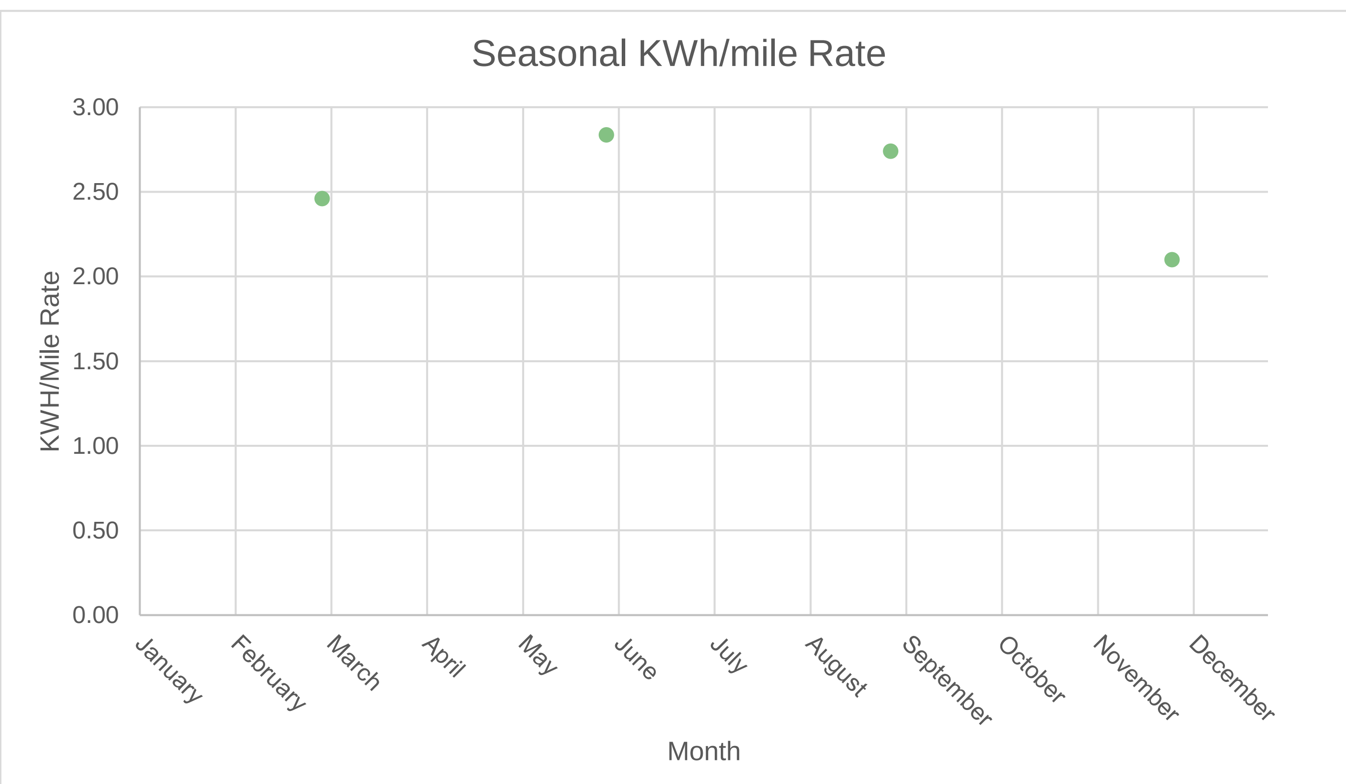
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.10 kWh/mi	2.46 kWh/mi	2.74 kWh/mi	2.84 kWh/mi

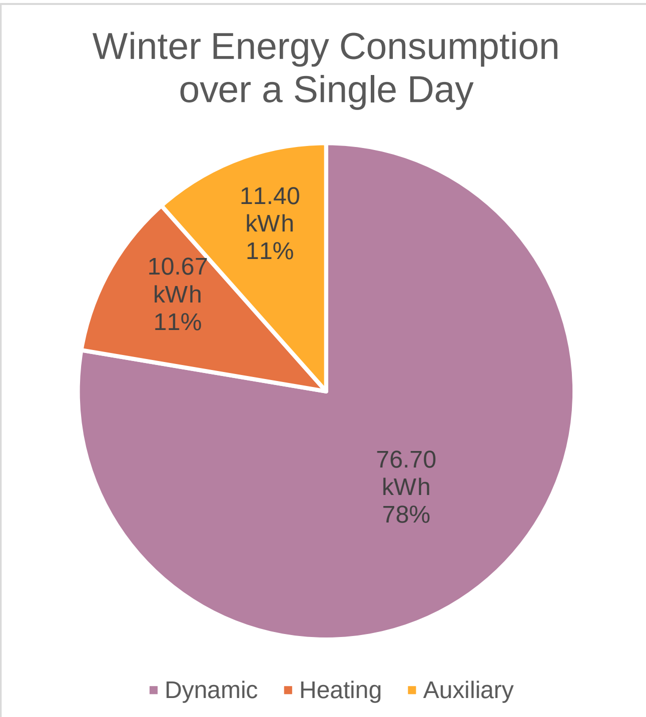


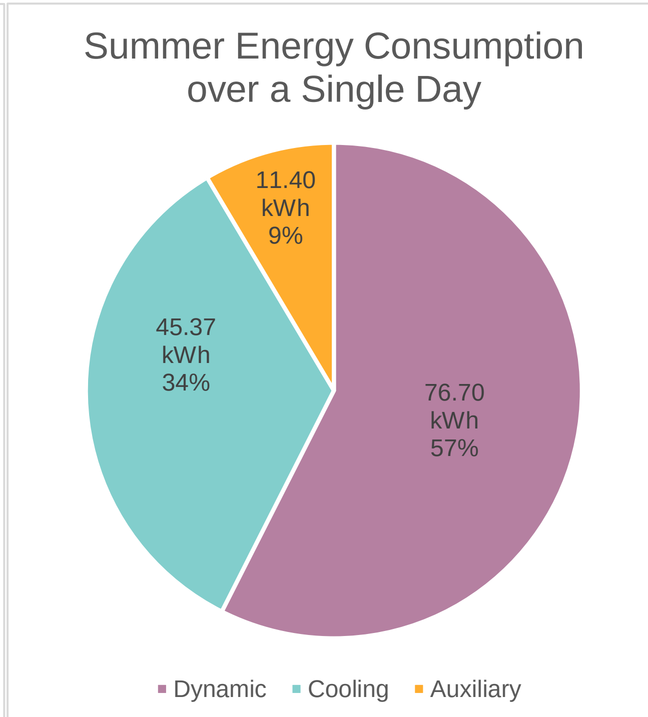
Route 4 PM Results

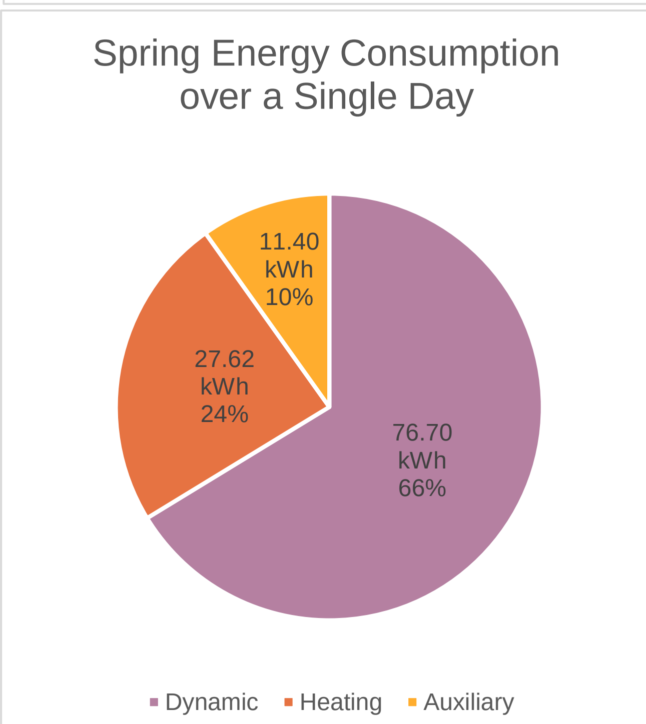
Daily Energy Consumption by Subsystem

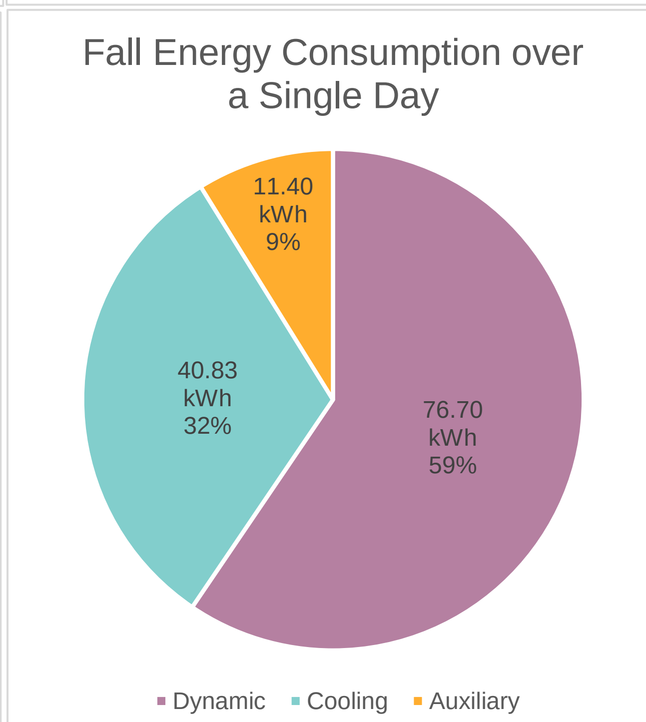
Total Daily Energy Consumption:

Summer:	133.47 KWH	Fall	128.93
Winter:	98.76 KWH	Spring	115.72









Route 4 PM Results

Daily State of Charge

Winter

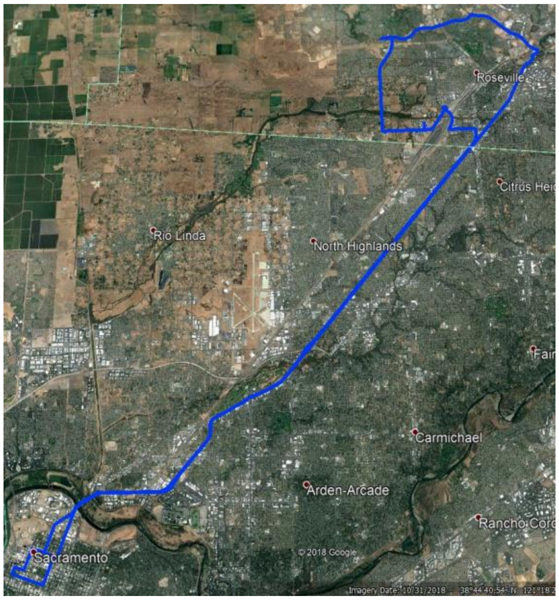
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**98.76**	0.00	**341.24**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**133.47**	0.00	**306.53**

Route 5 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM
	5 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.10 kWh/mi	2.36 kWh/mi	2.56 kWh/mi	2.62 kWh/mi

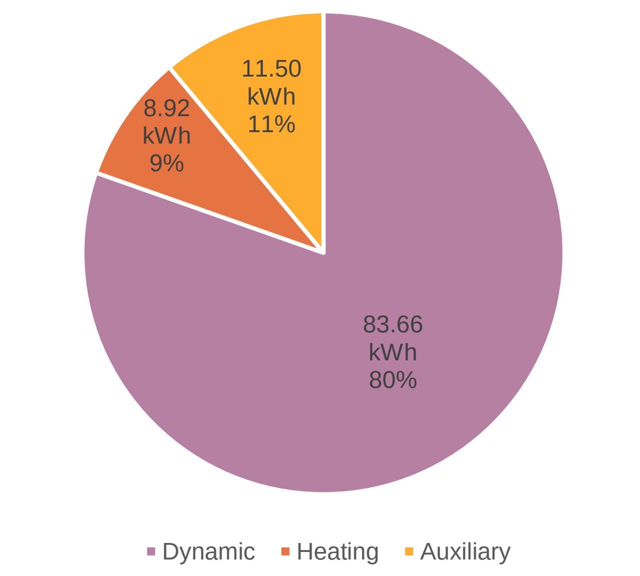
Route 5 PM Results

Daily Energy Consumption by Subsystem

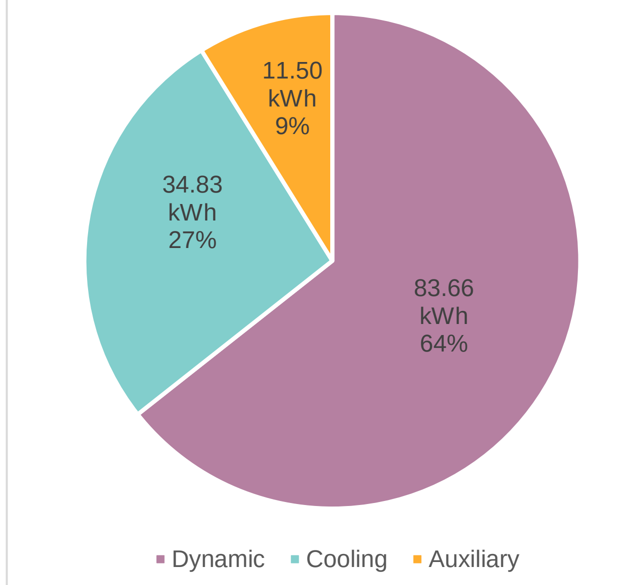
Total Daily Energy Consumption:

Summer:	129.99 KWH	Fall	126.96
Winter:	104.08 KWH	Spring	116.81

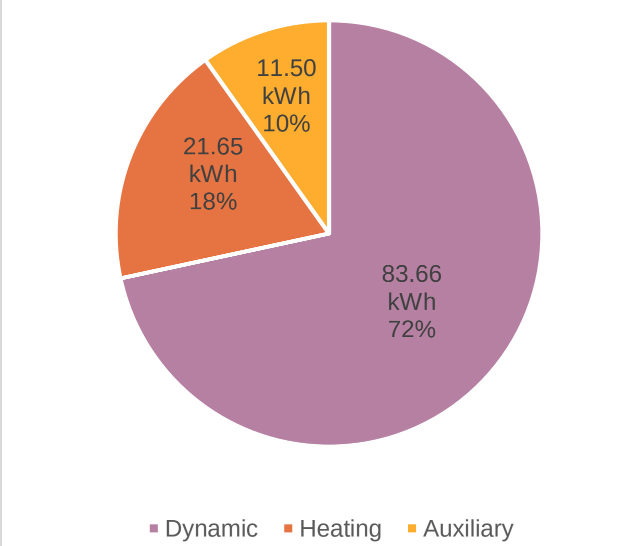
Winter Energy Consumption over a Single Day



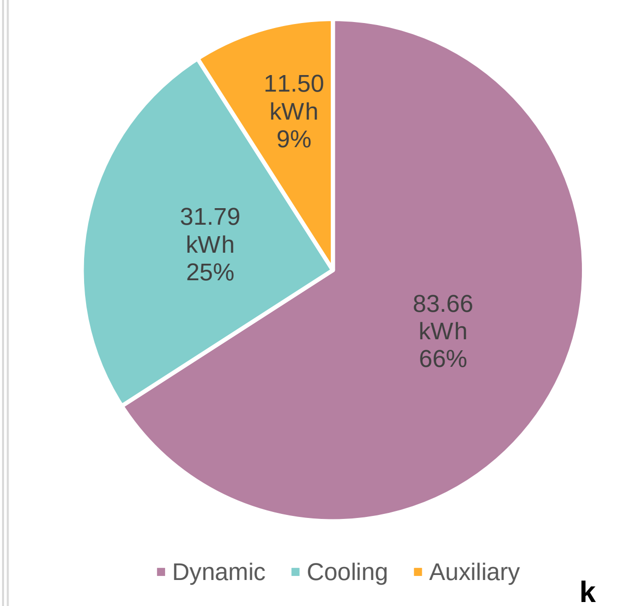
Summer Energy Consumption over a Single Day



Spring Energy Consumption over a Single Day



Fall Energy Consumption over a Single Day



Route 5 PM Results

Daily State of Charge

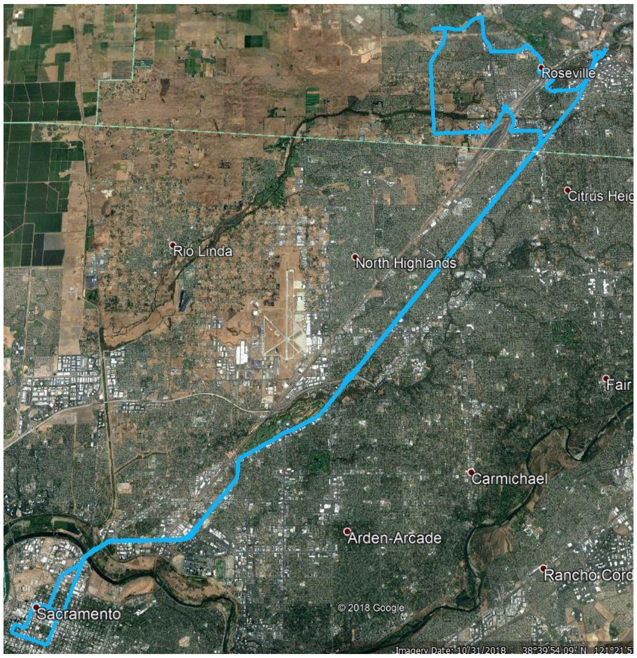
Winter

		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**104.08**	0.00	**335.92**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**129.99**	0.00	**310.01**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM
	6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

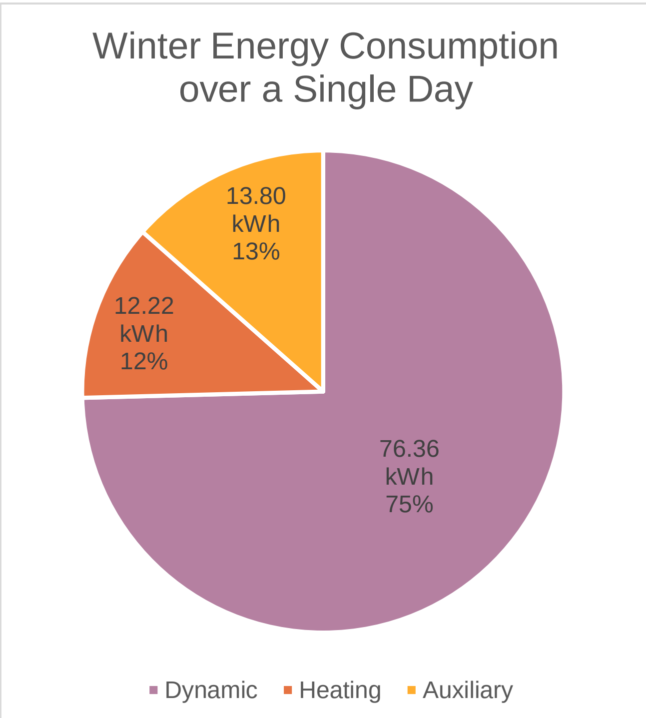
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
1.96 kWh/mi	2.19 kWh/mi	2.41 kWh/mi	2.47 kWh/mi

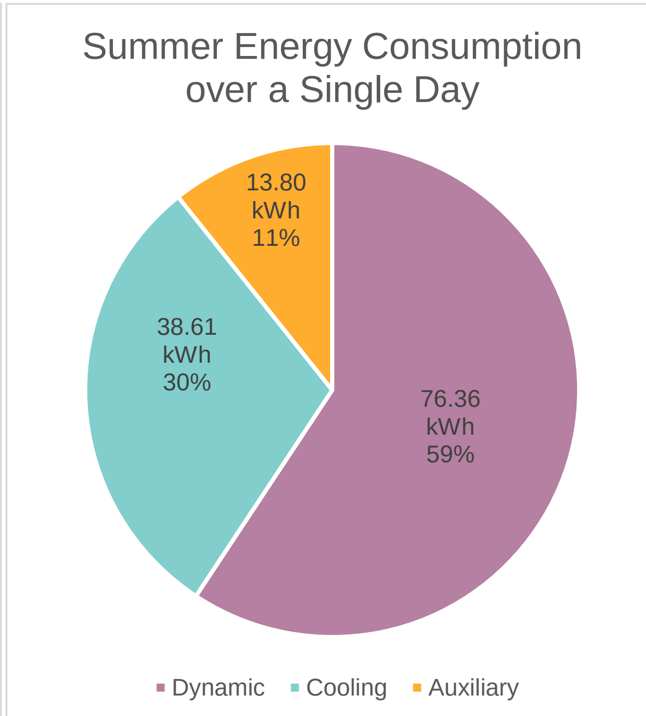
Route 6 PM Results

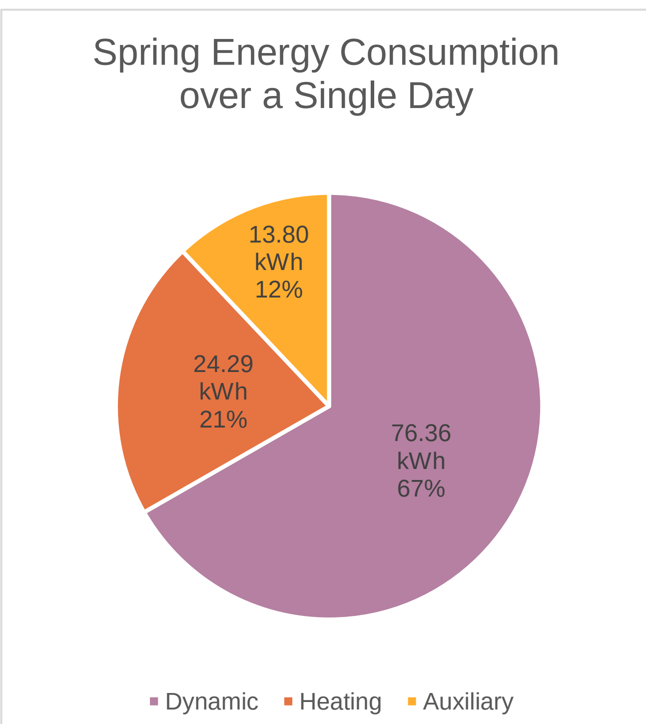
Daily Energy Consumption by Subsystem

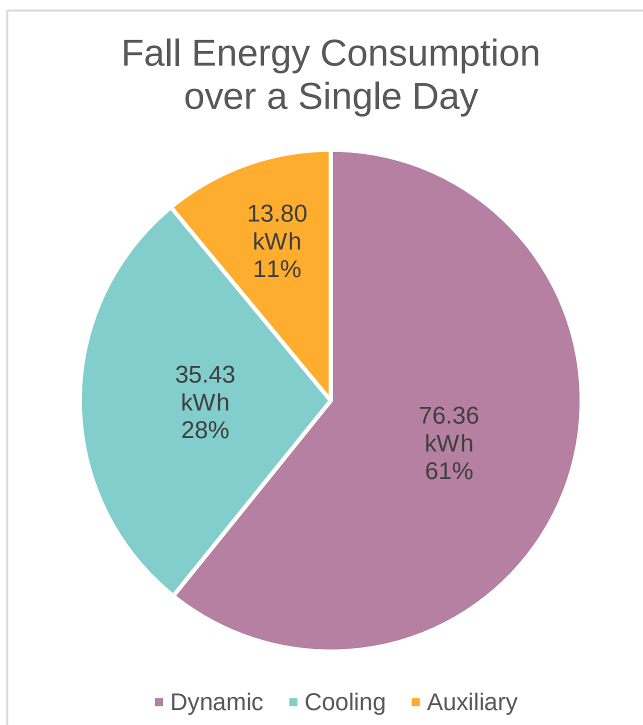
Total Daily Energy Consumption:

Summer:	128.77 KWH	Fall	125.60
Winter:	102.38 KWH	Spring	114.46









Route 6 PM Results

Daily State of Charge

Winter

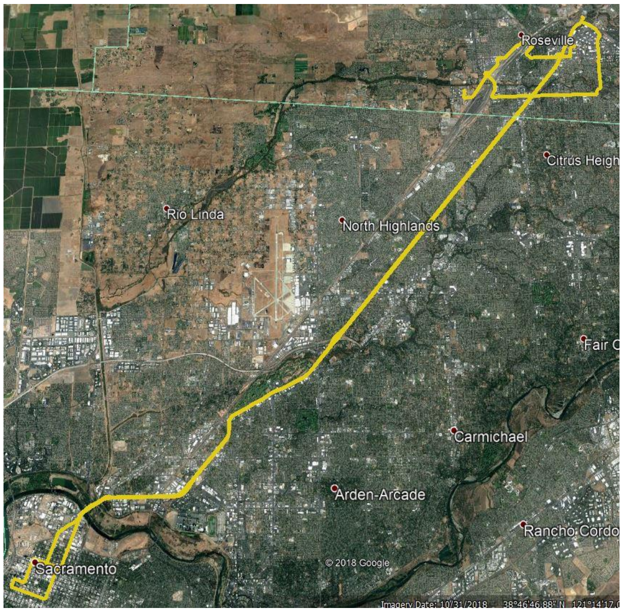
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**102.38**	0.00	**337.62**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**128.77**	0.00	**311.23**

Route 7 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM 6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

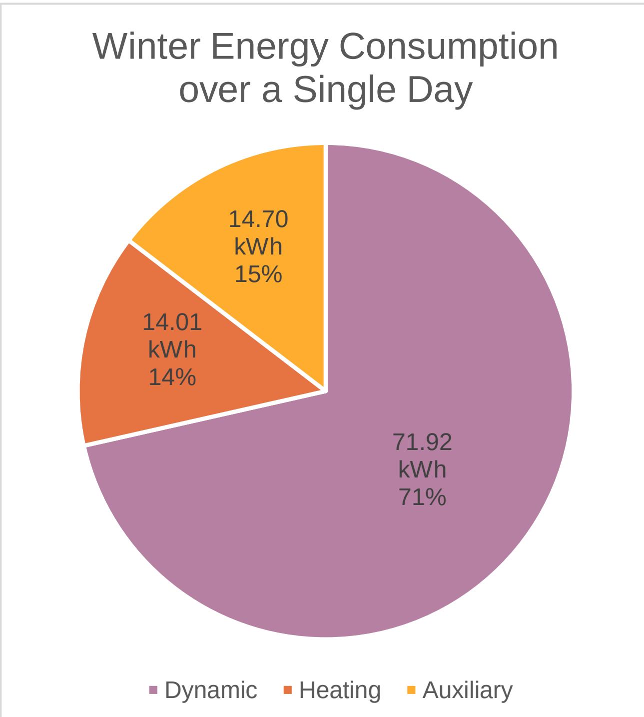
Average Winter:	Average Spring	Average Fall:	Average Summer:
1.97 kWh/mi	2.26 kWh/mi	2.52 kWh/mi	2.60 kWh/mi

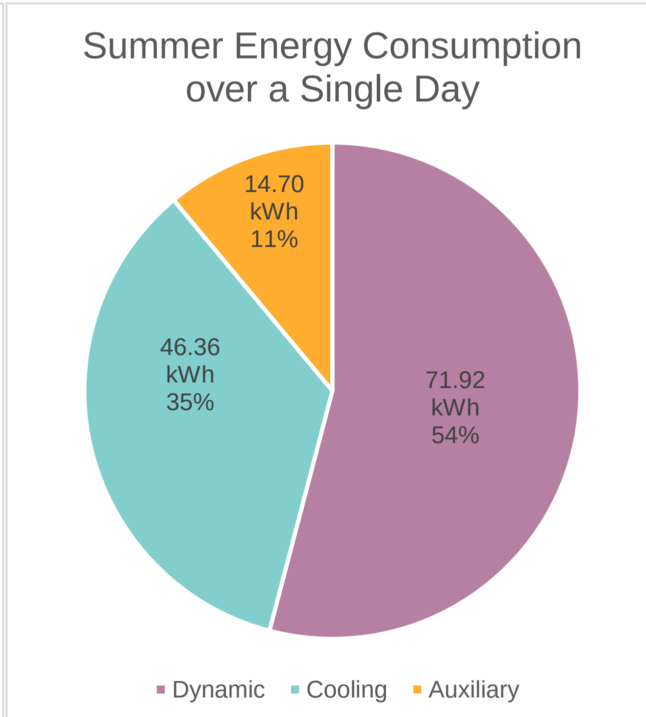
Route 7 PM Results

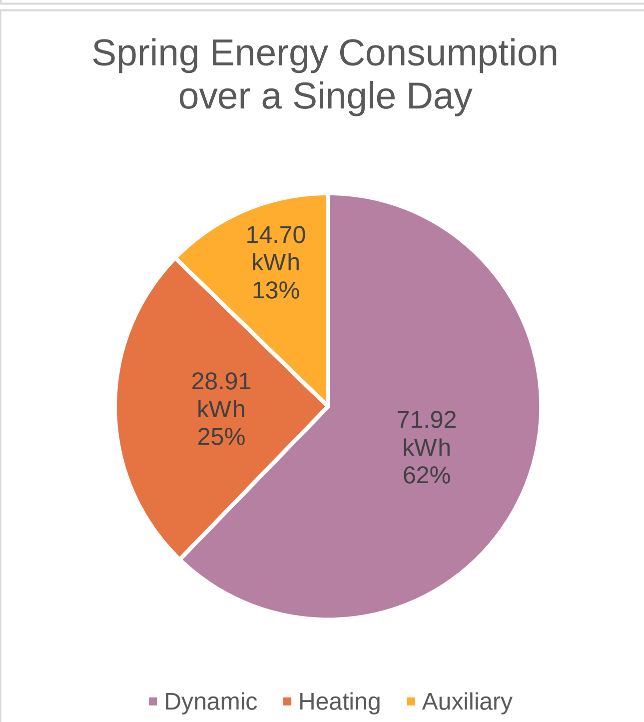
Daily Energy Consumption by Subsystem

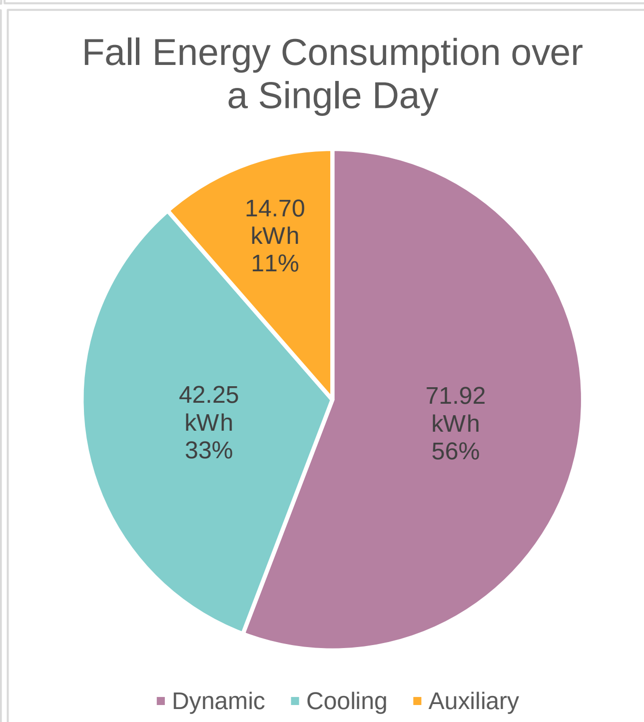
Total Daily Energy Consumption:

Summer:	132.98 KWH	Fall	128.87
Winter:	100.64 KWH	Spring	115.53









Route 7 PM Results

Daily State of Charge

Winter

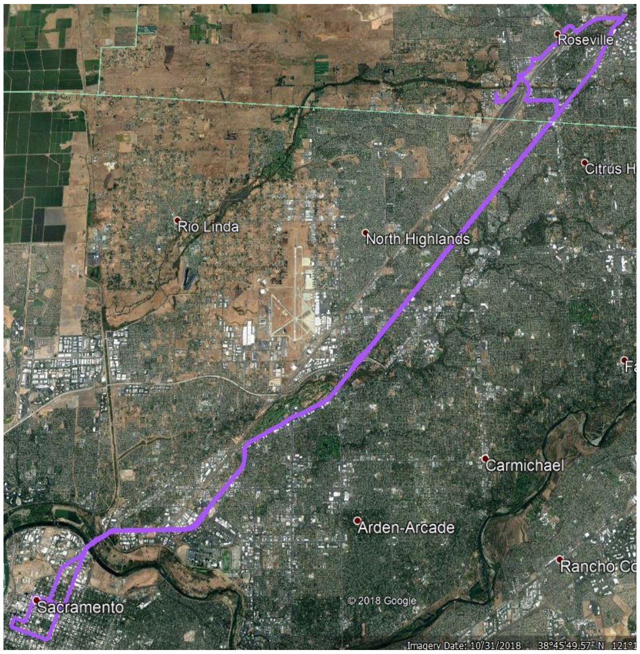
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**100.64**	0.00	**339.36**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**132.98**	0.00	**307.02**

Route 8 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	4 PM
	6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

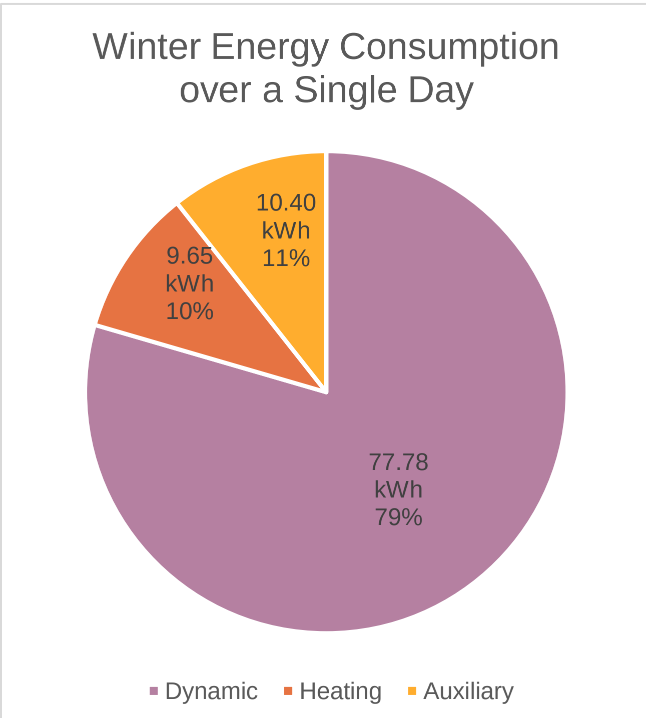
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.08 kWh/mi	2.26 kWh/mi	2.42 kWh/mi	2.52 kWh/mi

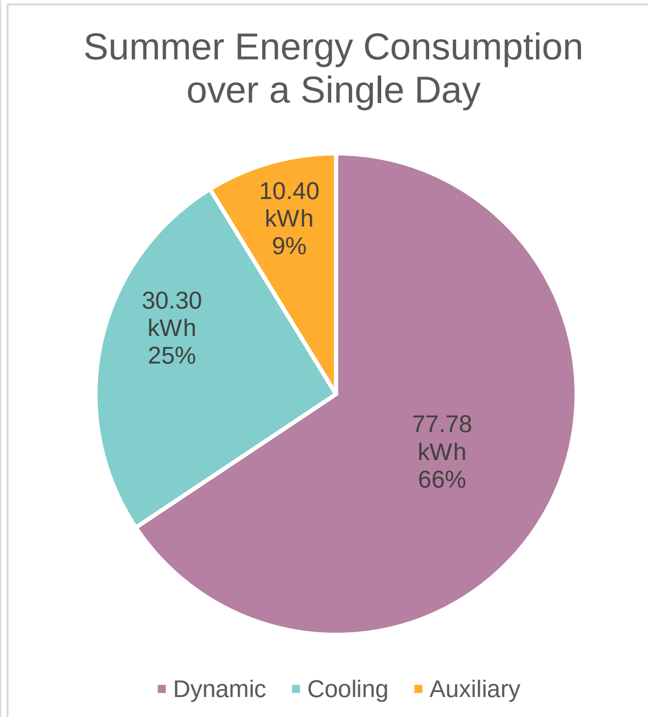
Route 8 PM Results

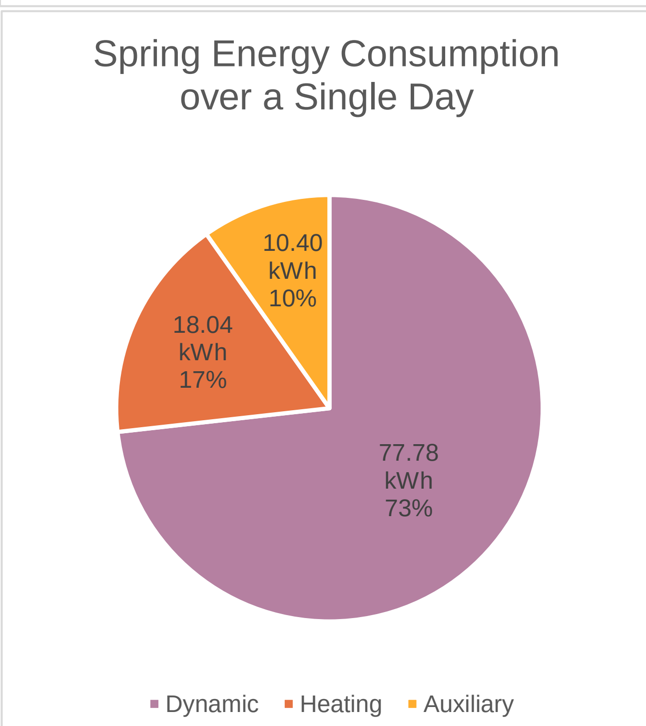
Daily Energy Consumption by Subsystem

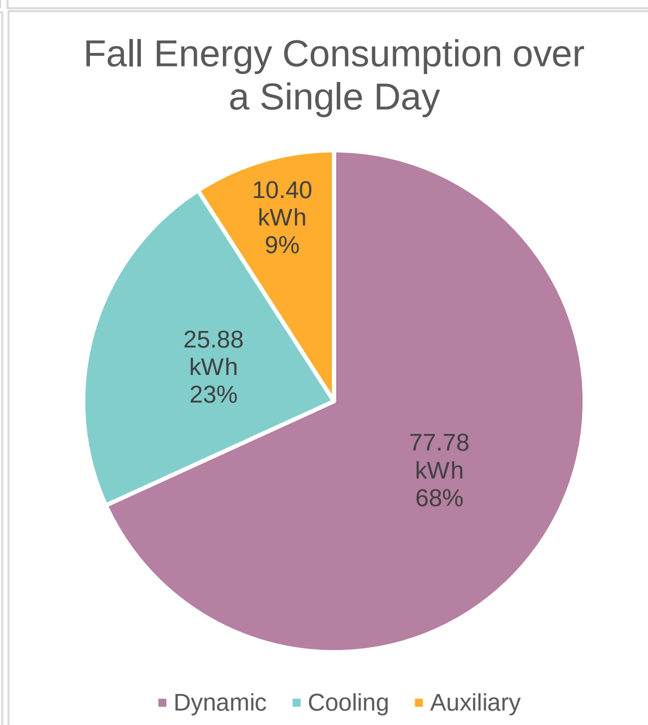
Total Daily Energy Consumption:

Summer:	118.48 KWH	Fall	114.06
Winter:	97.83 KWH	Spring	106.22









Route 8 PM Results

Daily State of Charge

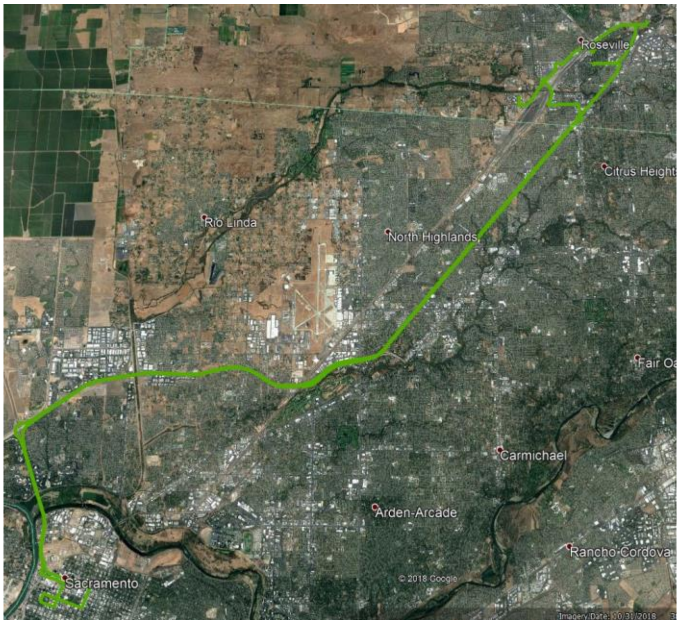
Winter

		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**97.83**	0.00	**342.17**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**118.48**	0.00	**321.52**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	7 AM
	9 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

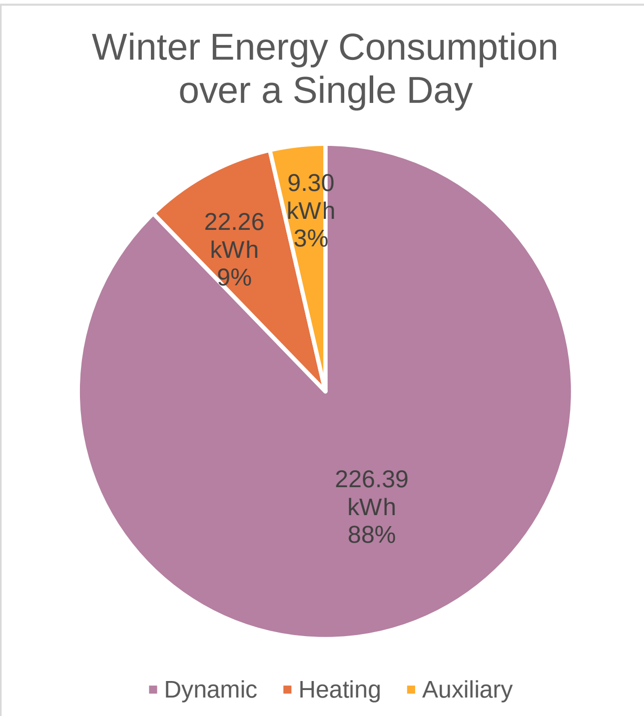
Average Winter:	Average Spring	Average Fall:	Average Summer:
4.88 kWh/mi	4.49 kWh/mi	4.63 kWh/mi	4.59 kWh/mi

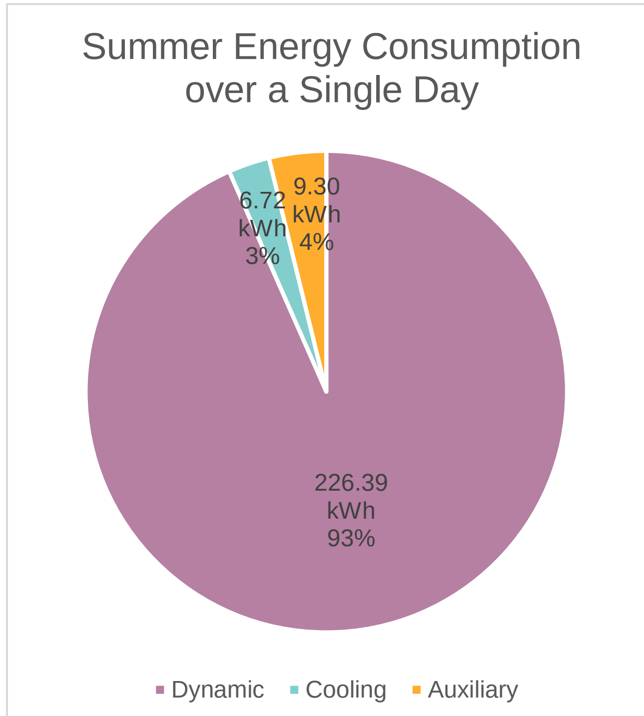
Alternative Route 10 AM Results

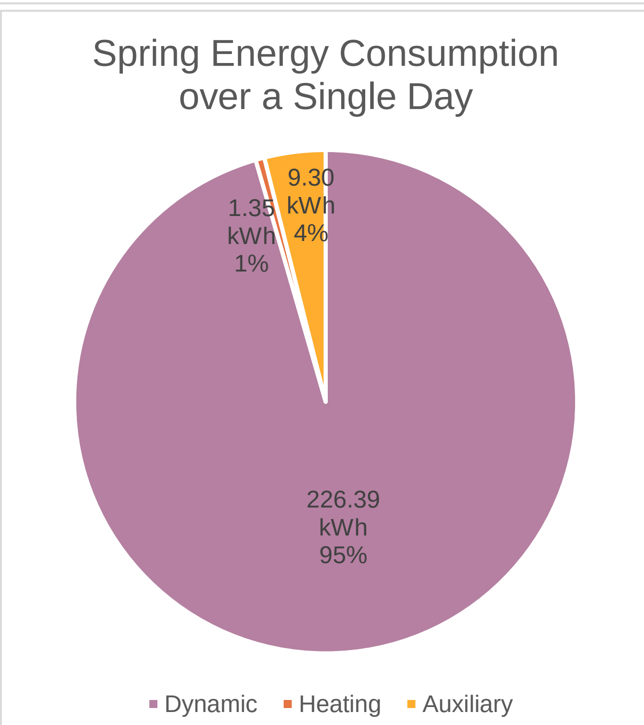
Daily Energy Consumption by Subsystem

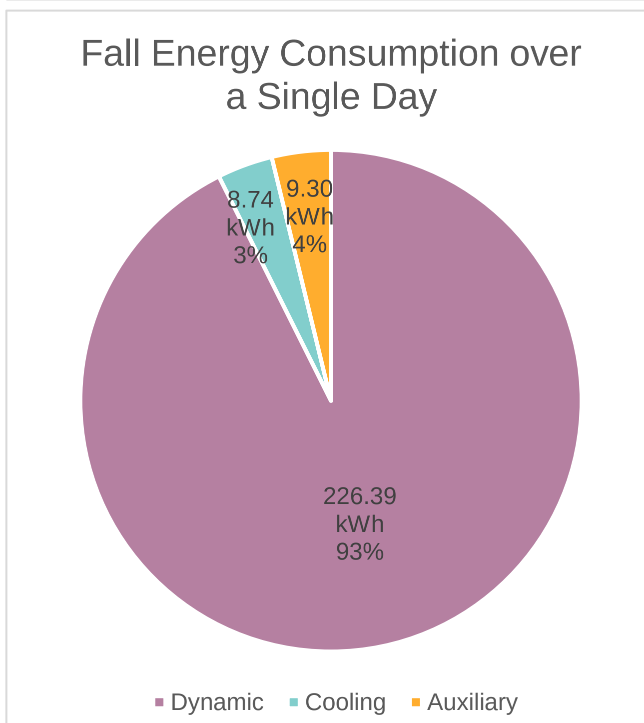
Total Daily Energy Consumption:

Summer:	242.41	KWH	Fall	244.43
Winter:	257.95	KWH	Spring	237.03









Alternative Route 10 AM Results

Daily State of Charge

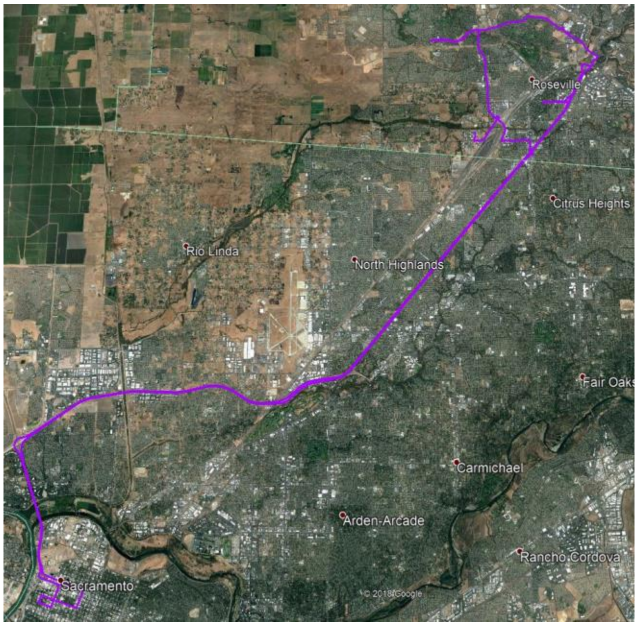
Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**257.95**	0.00	**182.05**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**242.41**	0.00	**197.59**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	5 AM
	9 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

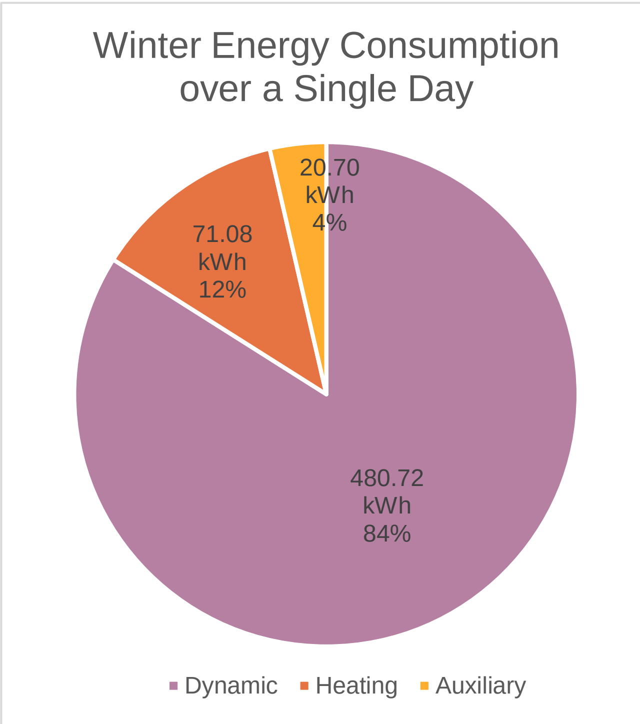
Average Winter:	Average Spring	Average Fall:	Average Summer:
5.45 kWh/mi	4.82 kWh/mi	5.00 kWh/mi	4.96 kWh/mi

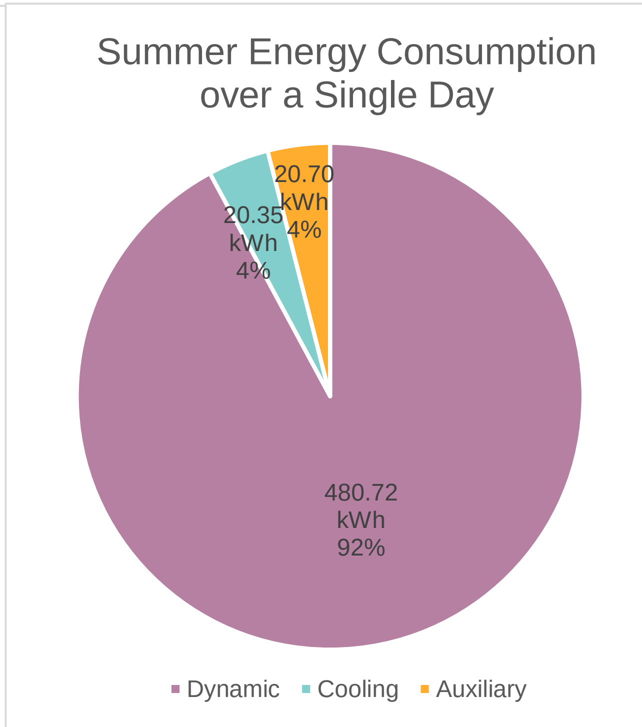
Alternative Route 2 and 10 AM Results

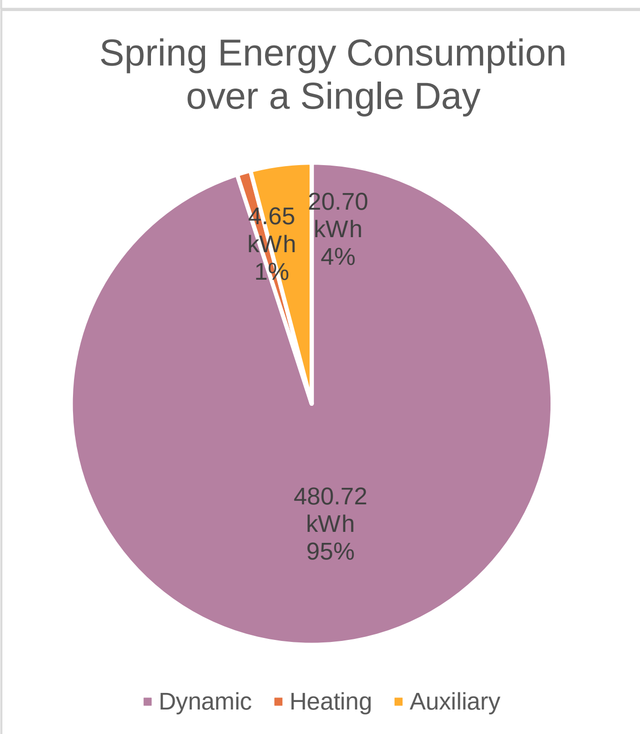
Daily Energy Consumption by Subsystem

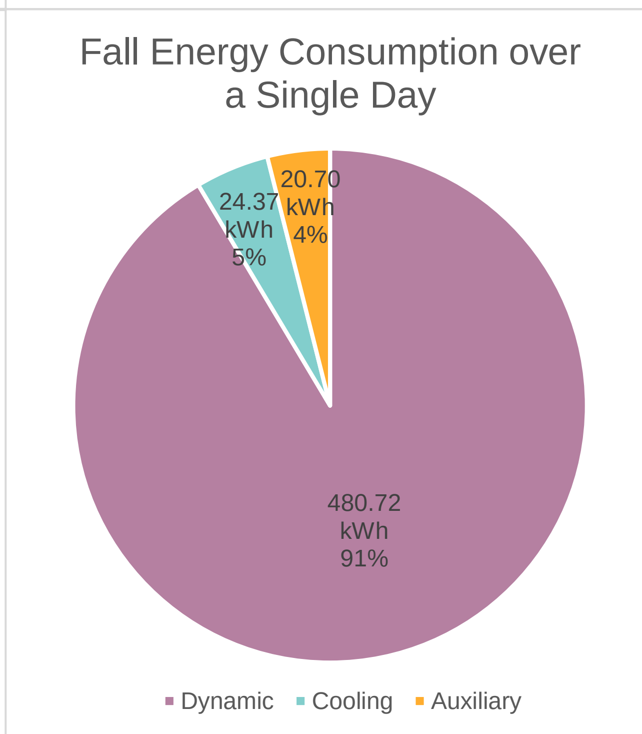
Total Daily Energy Consumption:

Summer:	521.78 KWH	Fall	525.79
Winter:	572.50 KWH	Spring	506.07









Alternative Route 2 and 10 AM Results

Daily State of Charge

Winter

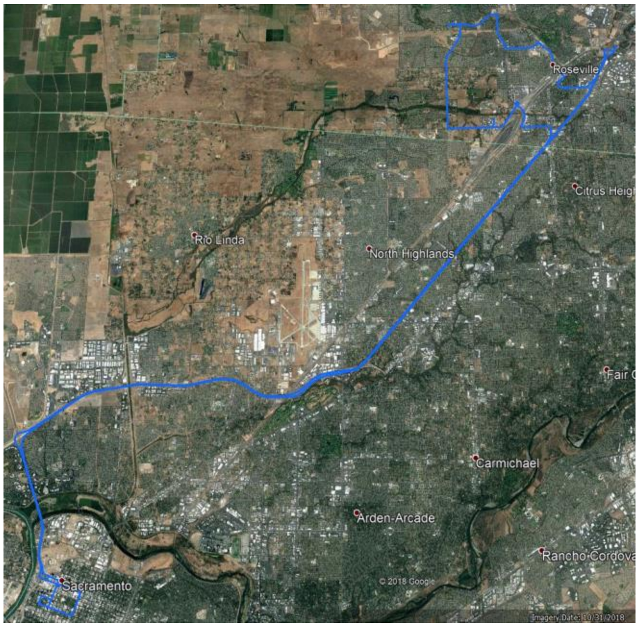
Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**572.50**	0.00	**-132.50**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**521.78**	0.00	**-81.78**

Alternative Route 2 and 9 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst XR 40
Battery Size:	440 KWH
Hours of Service	3 PM 7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

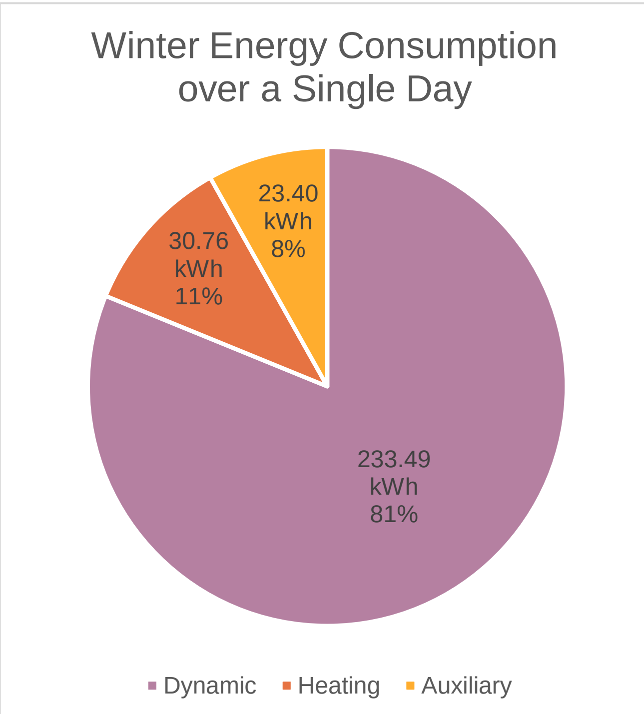
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.77 kWh/mi	3.01 kWh/mi	3.28 kWh/mi	3.37 kWh/mi

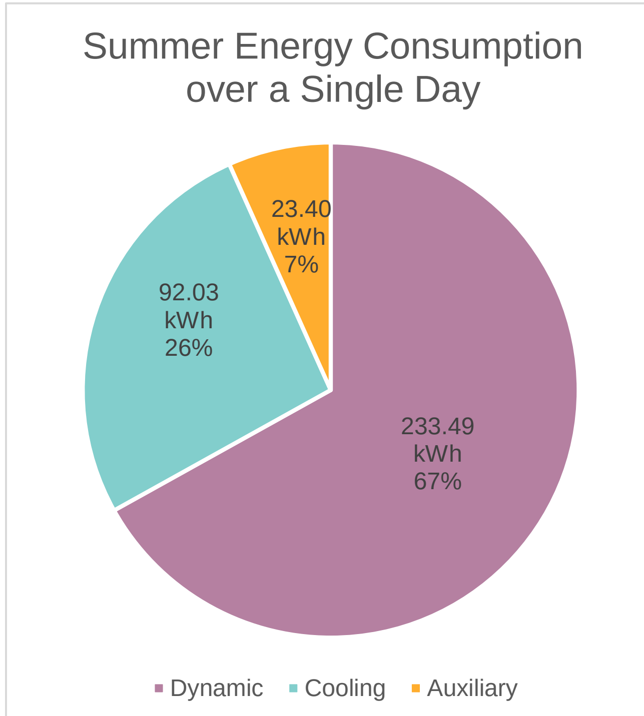
Alternative Route 2 and 9 PM Results

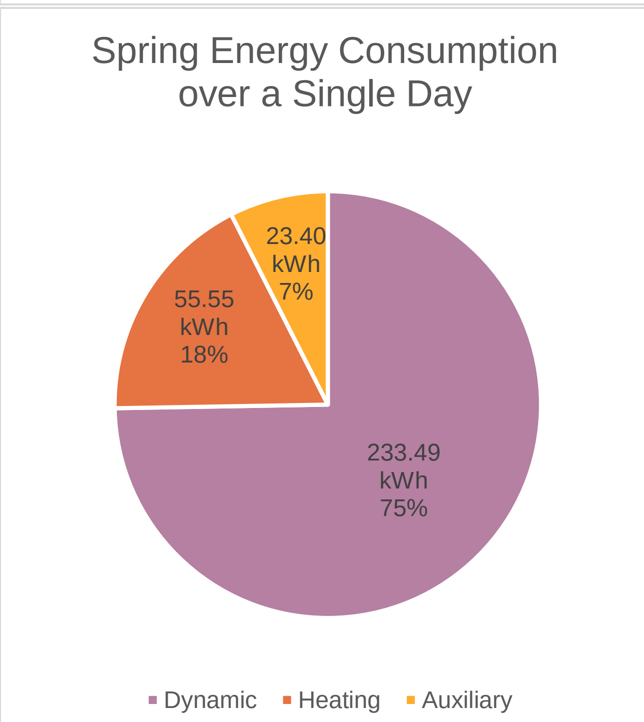
Daily Energy Consumption by Subsystem

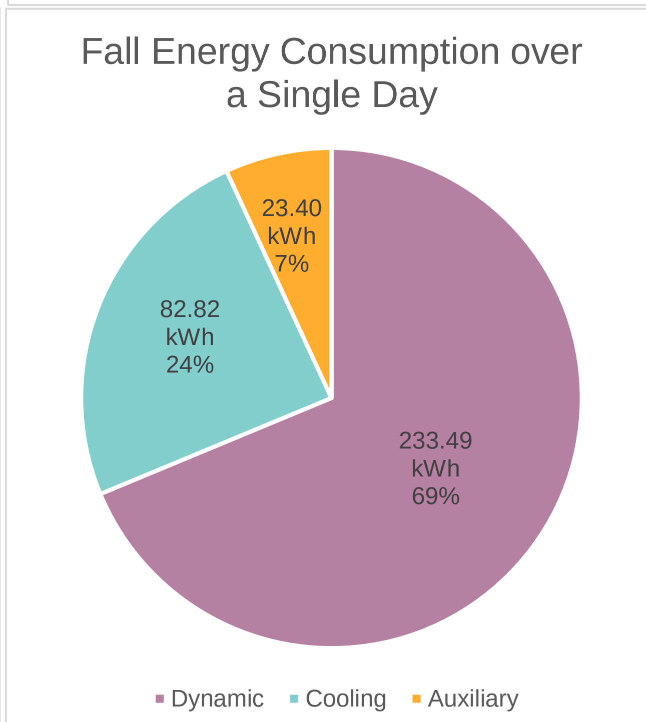
Total Daily Energy Consumption:

Summer:	348.92 KWH	Fall	339.71
Winter:	287.65 KWH	Spring	312.44









Alternative Route 2 and 9 PM Results

Daily State of Charge

Winter

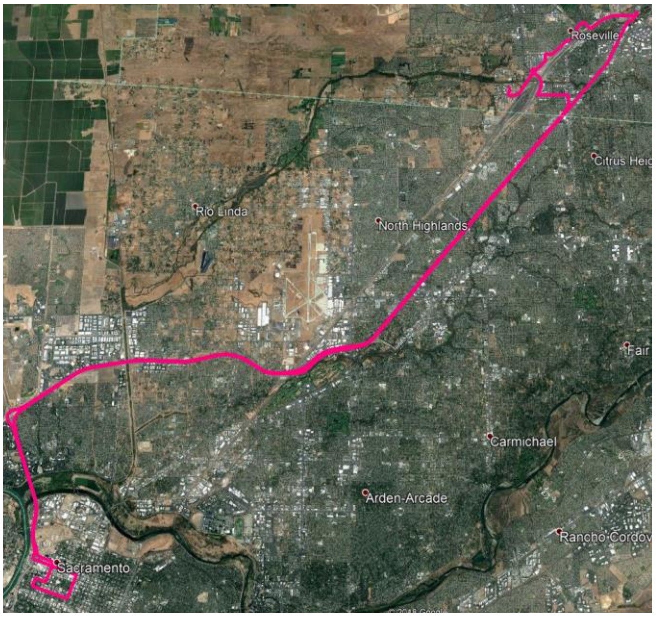
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**287.65**	0.00	**152.35**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**348.92**	0.00	**91.08**

Alternative Route 2 PM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	3 PM
	5 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

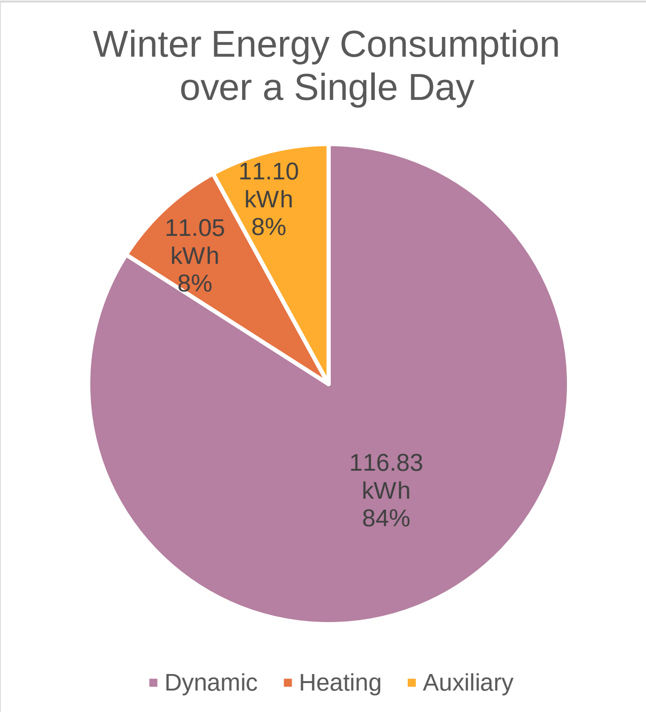
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.73 kWh/mi	3.06 kWh/mi	3.33 kWh/mi	3.43 kWh/mi

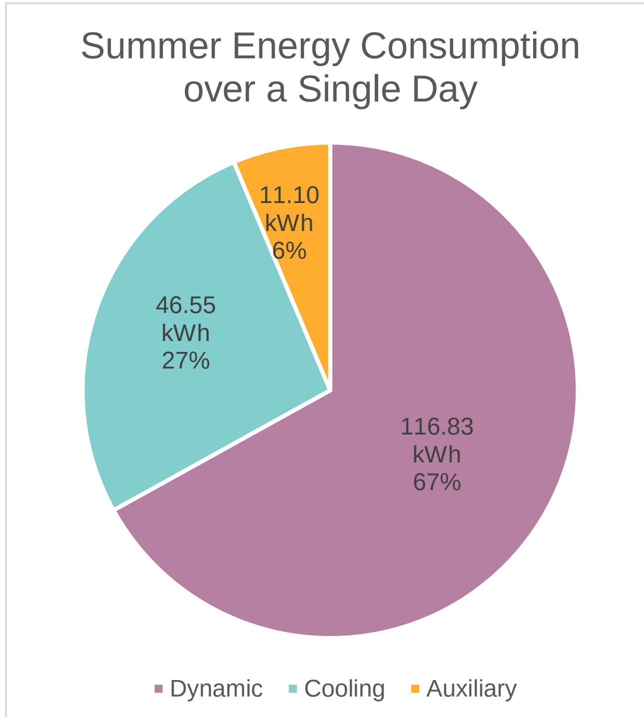
Alternative Route 2 PM Results

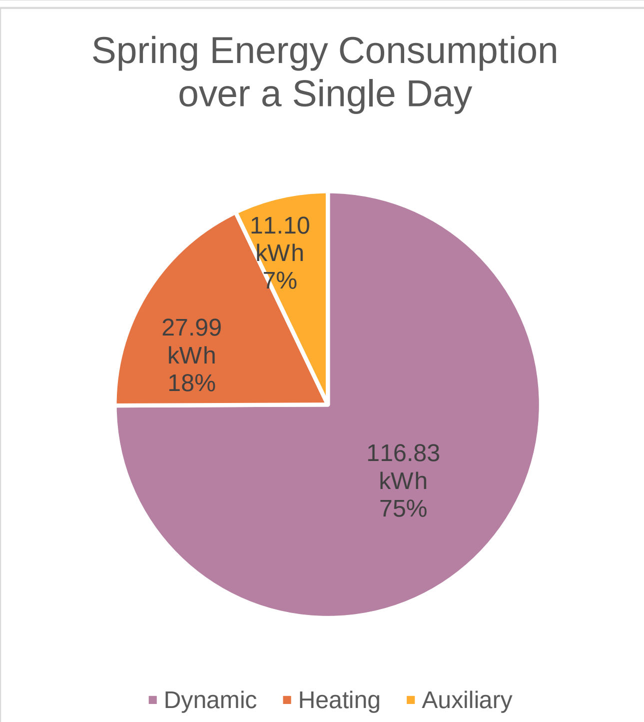
Daily Energy Consumption by Subsystem

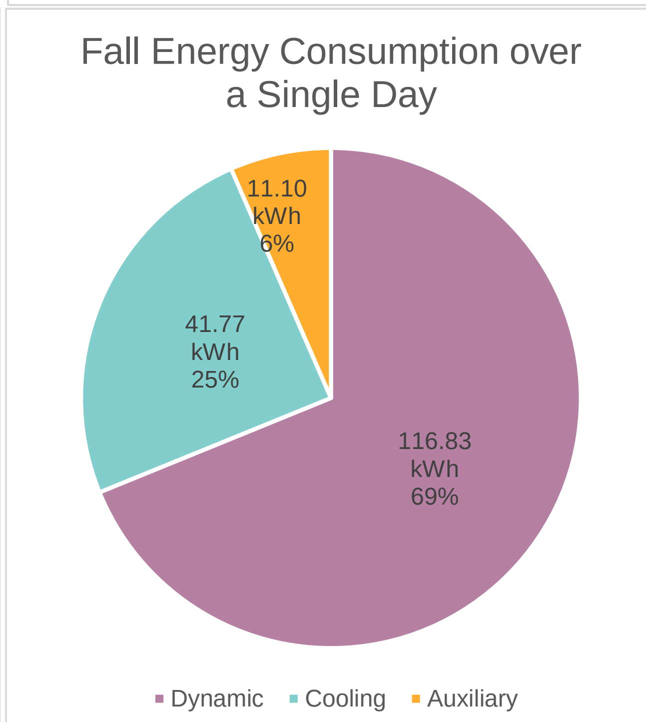
Total Daily Energy Consumption:

Summer:	174.48 KWH	Fall	169.70
Winter:	138.98 KWH	Spring	155.92









Alternative Route 2 PM Results

Daily State of Charge

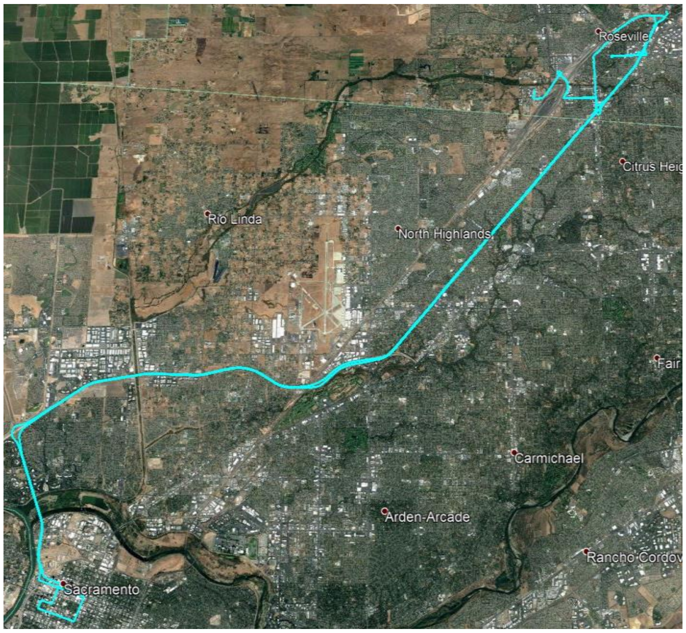
Winter

		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**138.98**	0.00	**301.02**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**174.48**	0.00	**265.52**

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 40
Battery Size: 440 KWH
Hours of Service 3 PM
7 PM

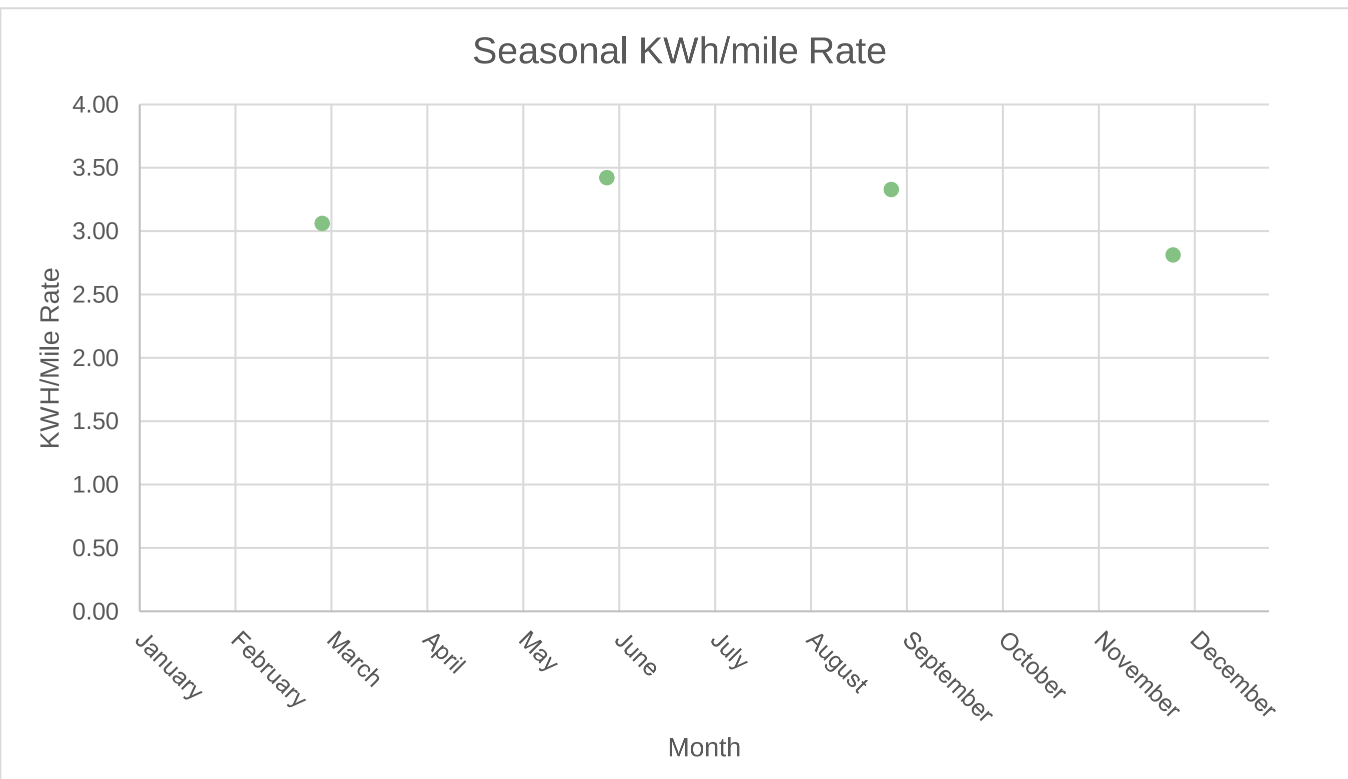
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.81 kWh/mi	3.06 kWh/mi	3.33 kWh/mi	3.42 kWh/mi

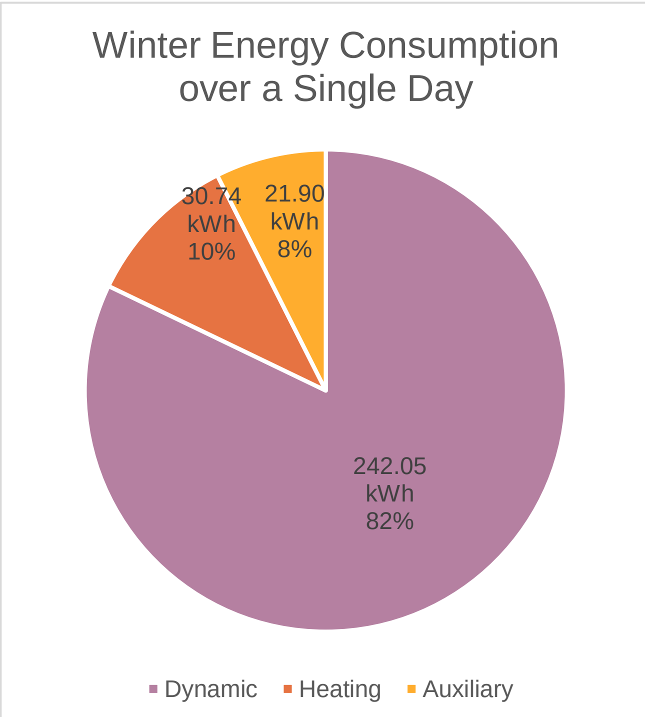


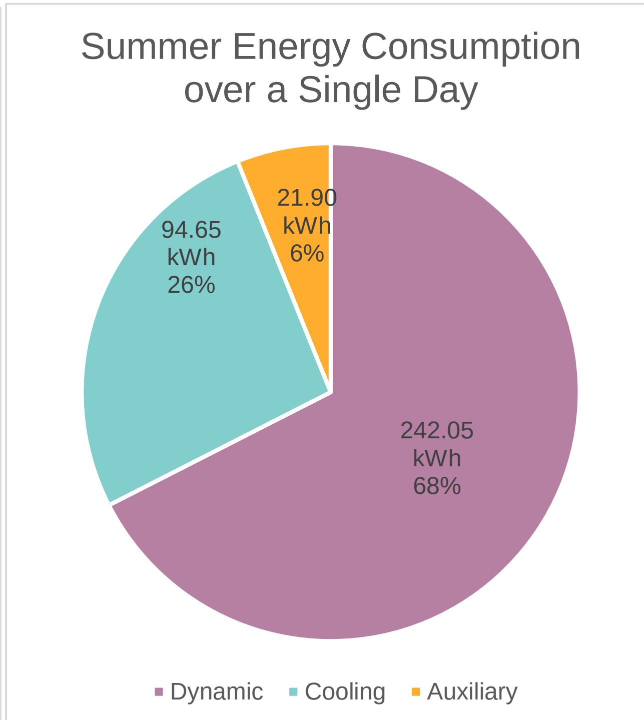
Alternative Route 3 and 10 PM Results

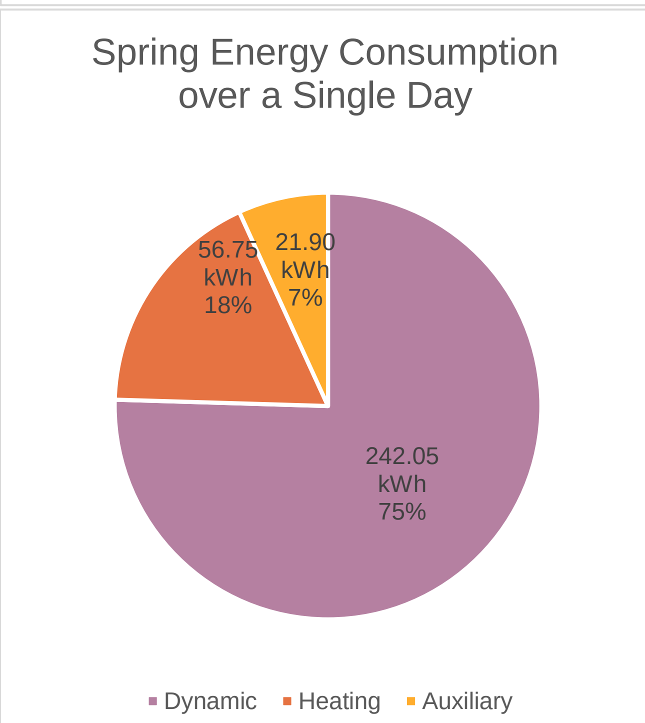
Daily Energy Consumption by Subsystem

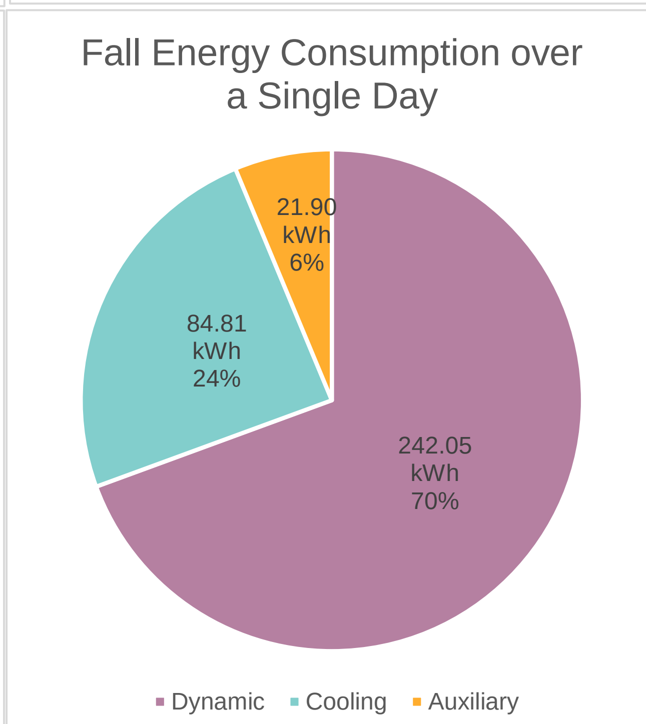
Total Daily Energy Consumption:

Summer:	358.60 KWH	Fall	348.75
Winter:	294.68 KWH	Spring	320.70









Alternative Route 3 and 10 PM Results

Daily State of Charge

Winter

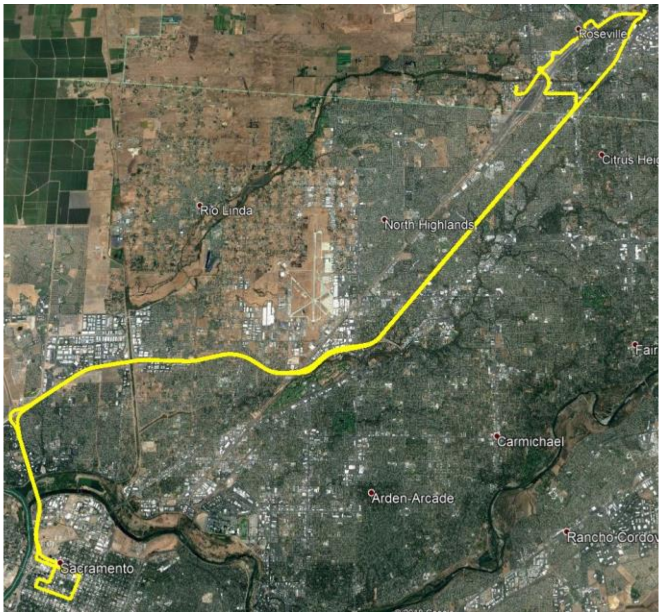
		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**294.68**	0.00	**145.32**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**358.60**	0.00	**81.40**

Alternate Route 3 PM Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 40

Battery Size: 440 KWH

Hours of Service 3 PM 5 PM

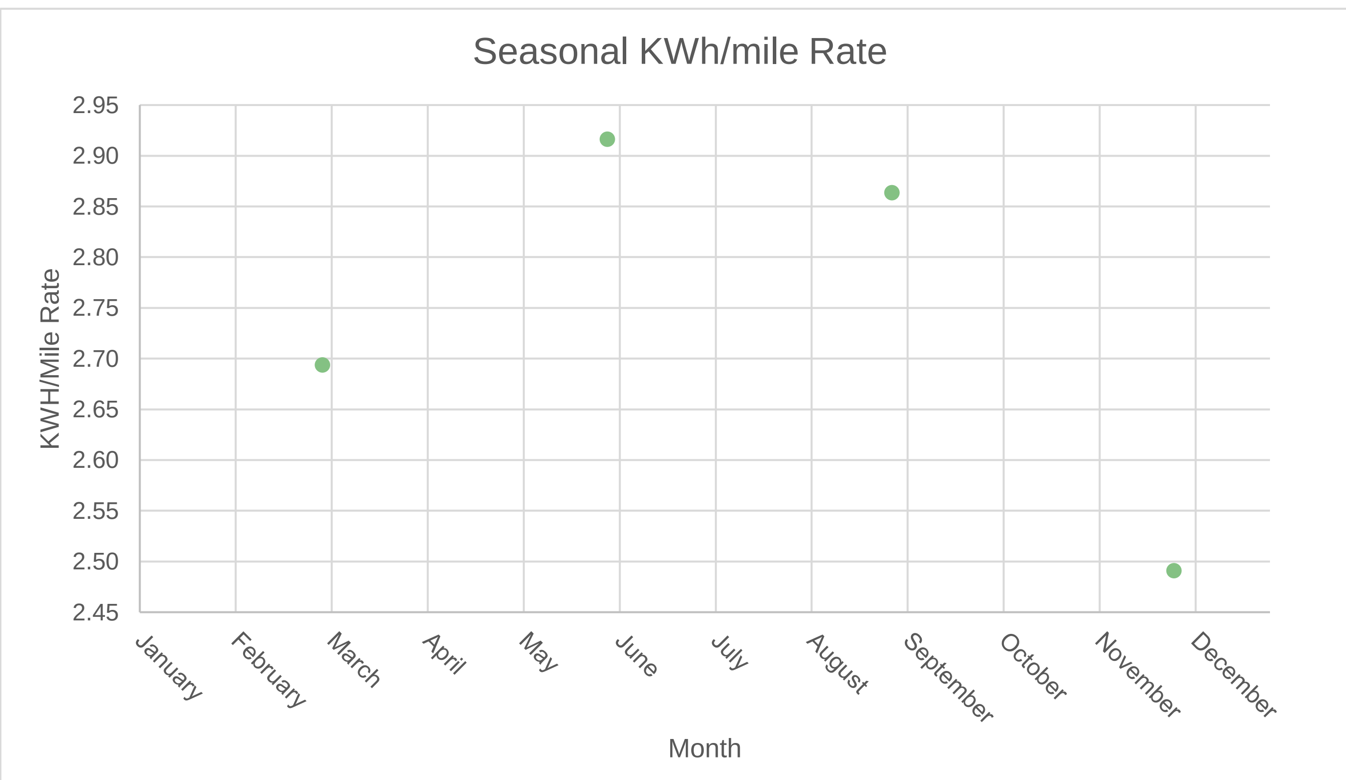
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.49 kWh/mi	2.69 kWh/mi	2.86 kWh/mi	2.92 kWh/mi

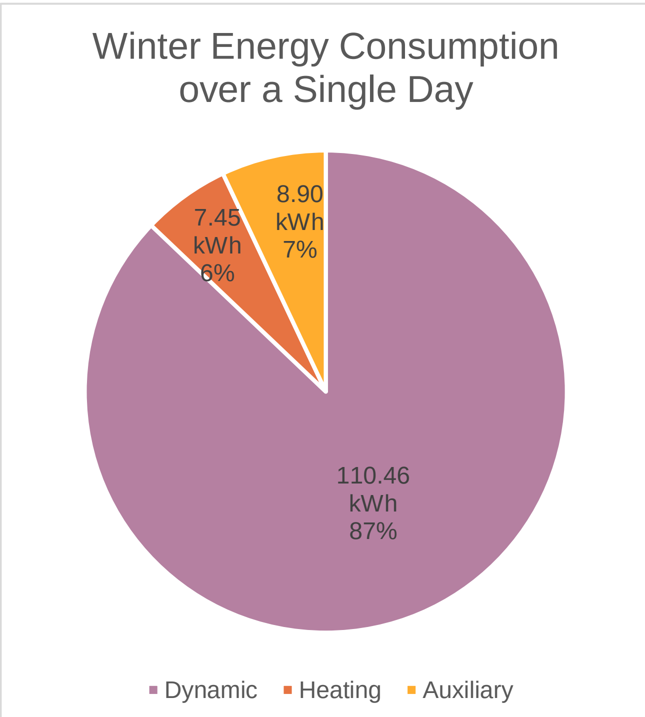


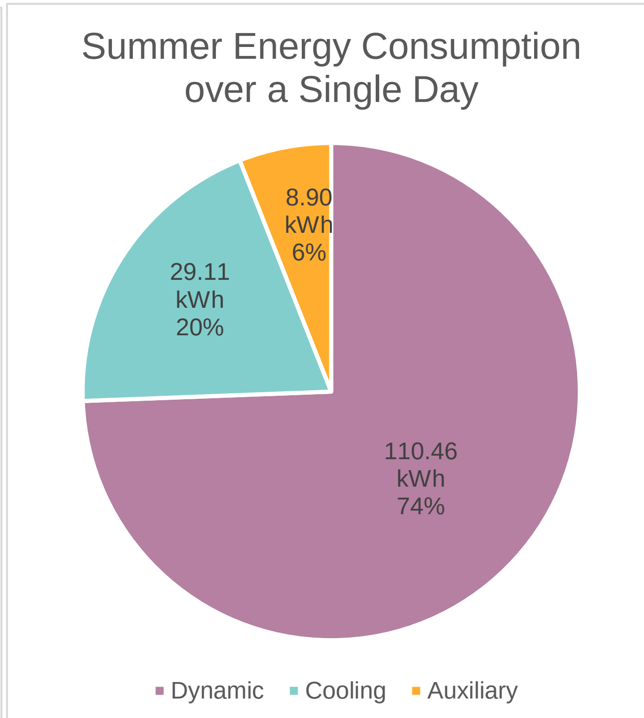
Alternate Route 3 PM Results

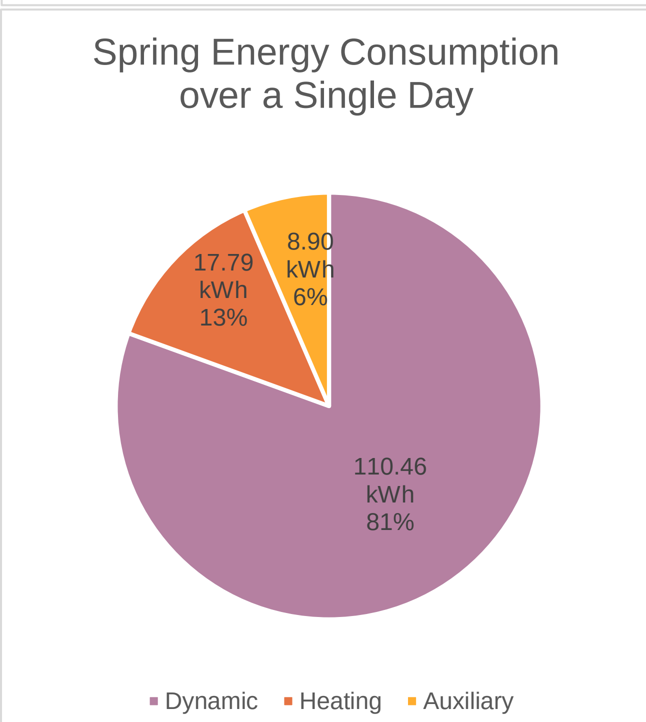
Daily Energy Consumption by Subsystem

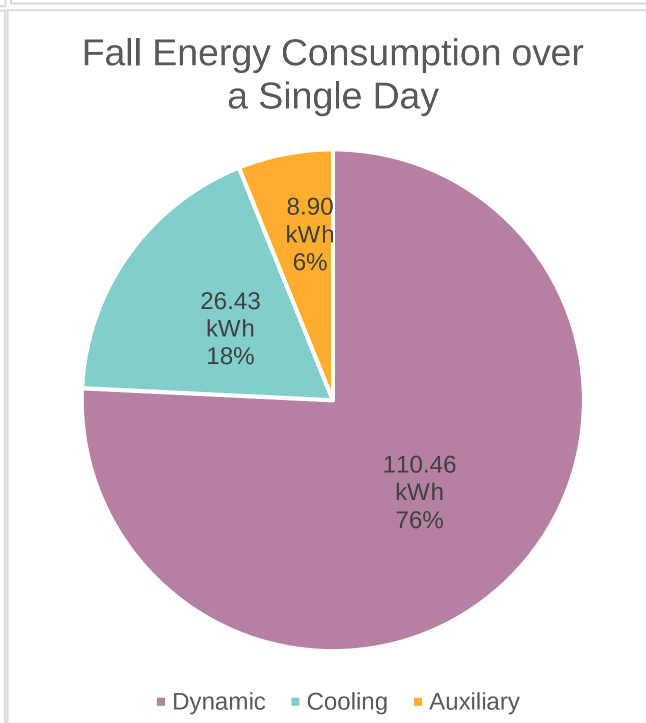
Total Daily Energy Consumption:

Summer:	148.47 KWH	Fall	145.79
Winter:	126.81 KWH	Spring	137.14









Alternate Route 3 PM Results

Daily State of Charge

Winter

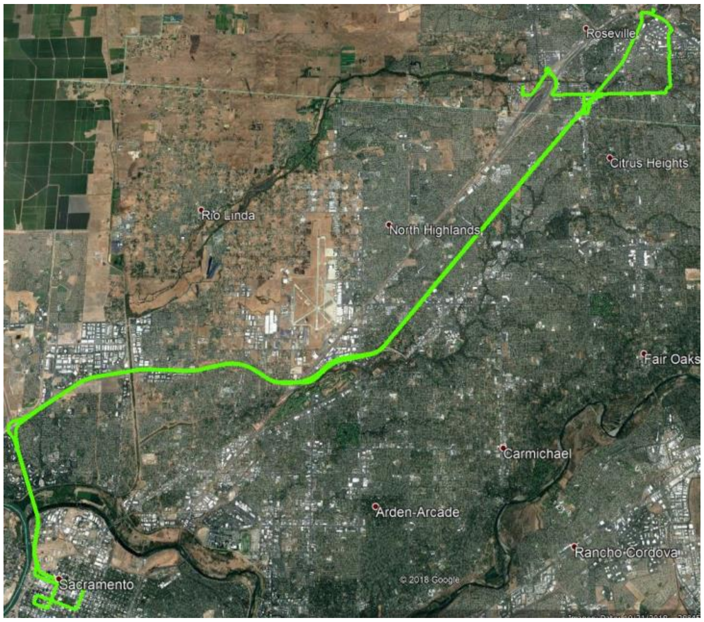
	SOC is below the lower bound			
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**126.81**	0.00	**313.19**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**148.47**	0.00	**291.53**

Alternative Route 4 AM Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 40
Battery Size:	440 KWH
Hours of Service	6 AM 8 AM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

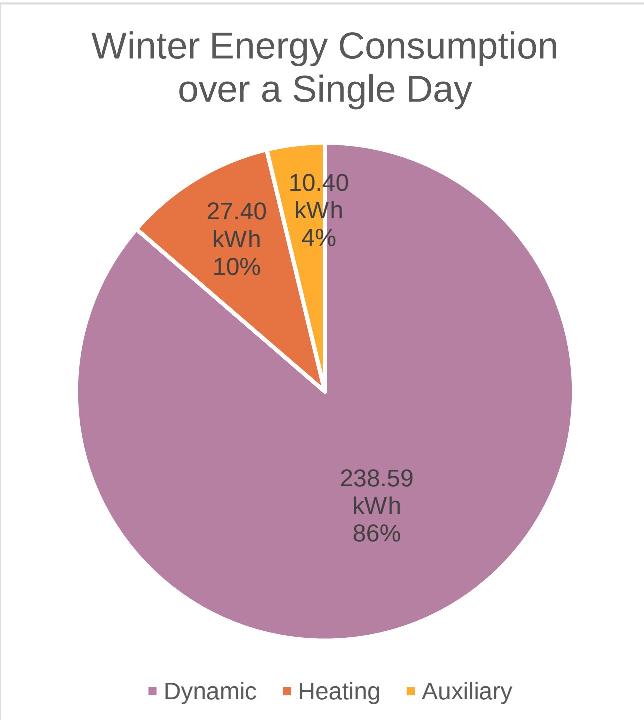
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
4.99 kWh/mi	4.50 kWh/mi	4.61 kWh/mi	4.61 kWh/mi

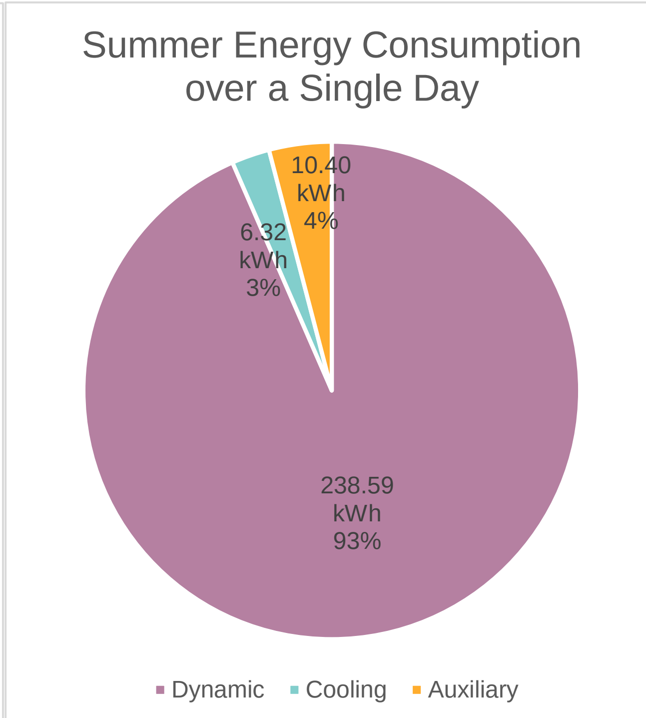
Alternative Route 4 AM Results

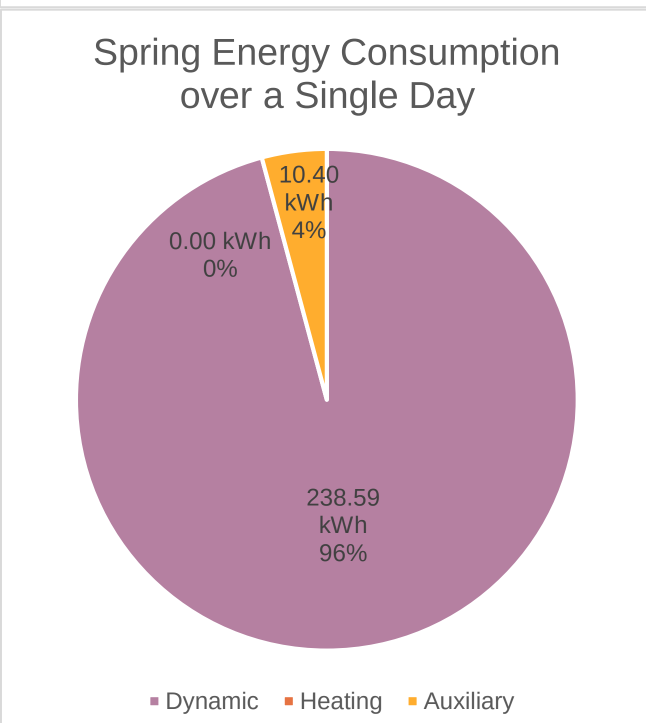
Daily Energy Consumption by Subsystem

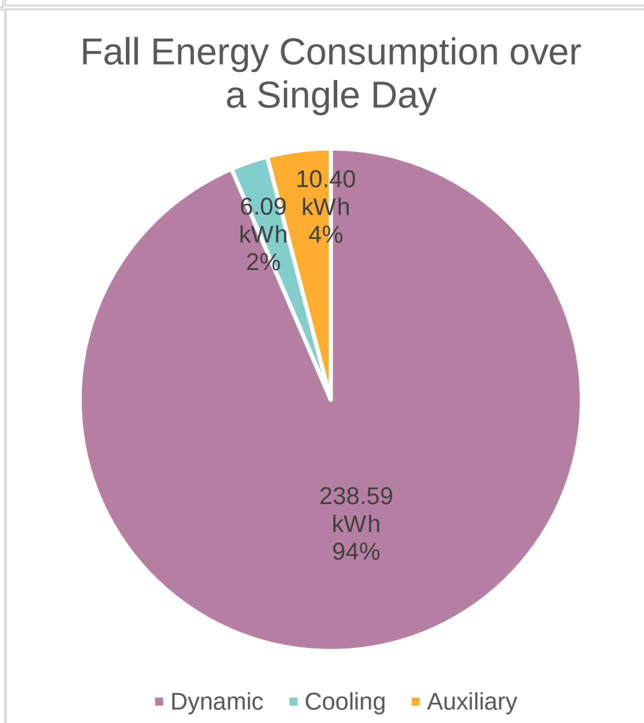
Total Daily Energy Consumption:

Summer:	255.32 KWH	Fall	255.08
Winter:	276.39 KWH	Spring	248.99









Alternative Route 4 AM Results

Daily State of Charge

Winter

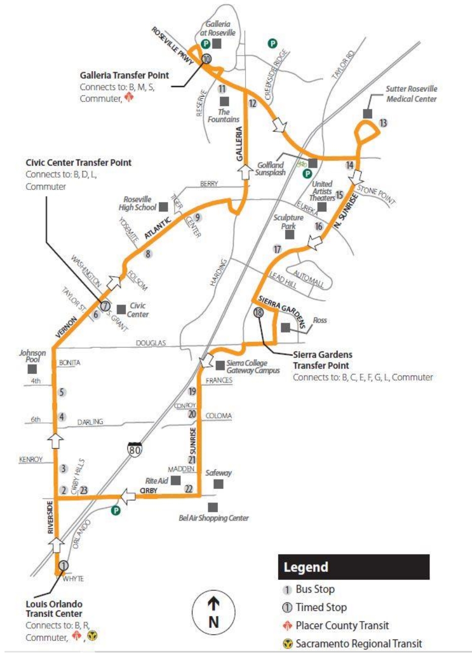
Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**276.39**	0.00	**163.61**

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**255.32**	0.00	**184.68**

Local Route A1 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM 10 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	9	Minutes

Seasonal kWh per Mile Rate

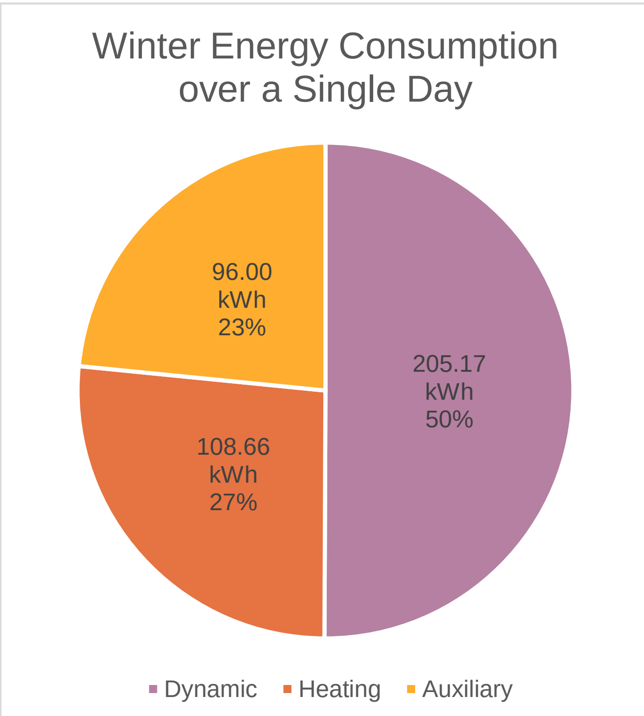
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.23 kWh/mi	2.02 kWh/mi	2.31 kWh/mi	2.40 kWh/mi

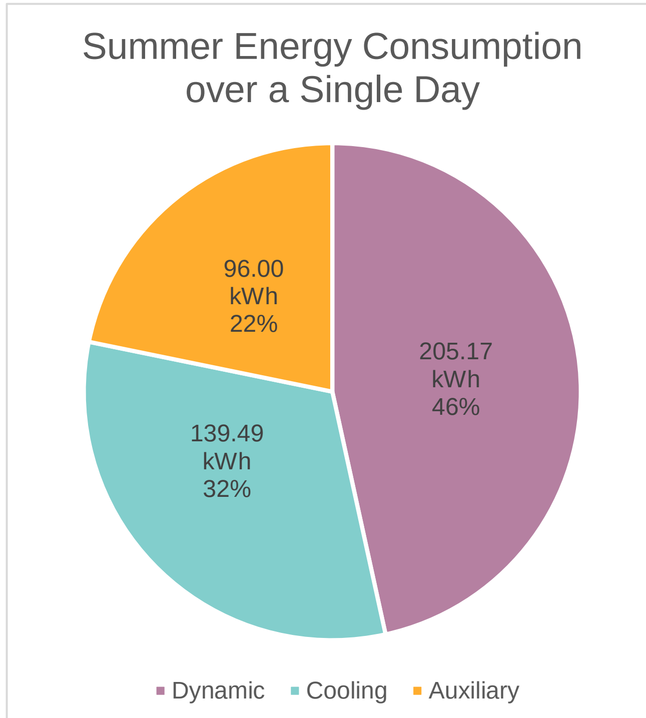
Local Route A1 Results

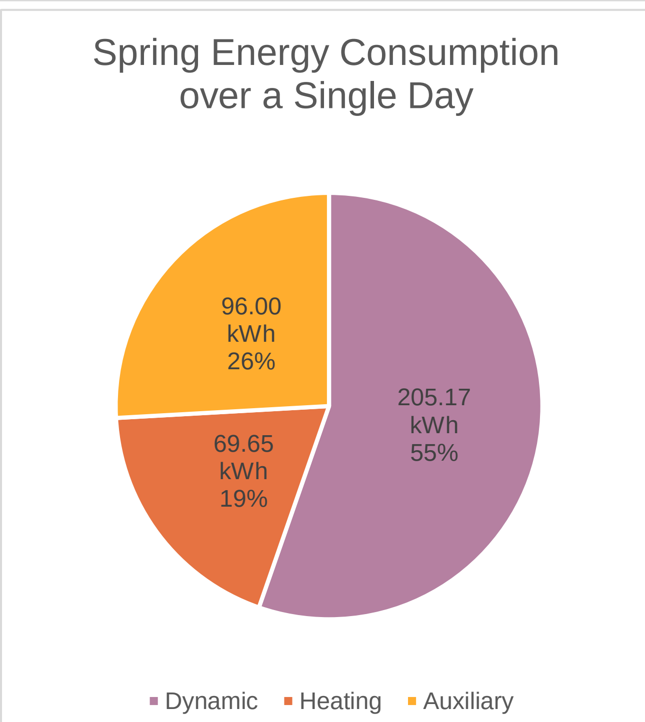
Daily Energy Consumption by Subsystem

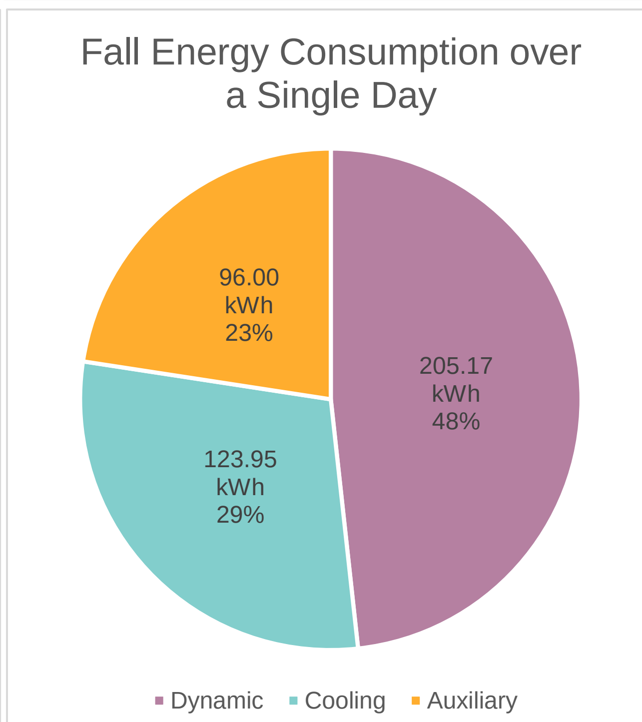
Total Daily Energy Consumption:

Summer:	440.66 KWH	Fall	425.13
Winter:	409.83 KWH	Spring	370.82









Local Route A1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**20.61**	0.00	**419.39**
2	**419.39**	**21.81**	42.43	**440.00**
3	**440.00**	**22.45**	0.00	**417.55**
4	**417.55**	**24.20**	45.00	**438.36**
5	**438.36**	**26.04**	0.00	**412.32**
6	**412.32**	**27.80**	45.00	**429.52**
7	**429.52**	**29.52**	0.00	**400.00**
8	**400.00**	**31.68**	45.00	**413.33**
9	**413.33**	**34.02**	0.00	**379.30**
10	**379.30**	**34.02**	45.00	**390.28**
11	**390.28**	**33.71**	0.00	**356.57**
12	**356.57**	**31.28**	45.00	**370.29**
13	**370.29**	**29.39**	0.00	**340.89**
14	**340.89**	**27.38**	45.00	**358.51**
15	**358.51**	**24.11**	0.00	**334.40**
16	**334.40**	**22.64**	45.00	**356.76**

Local Route A1 Results

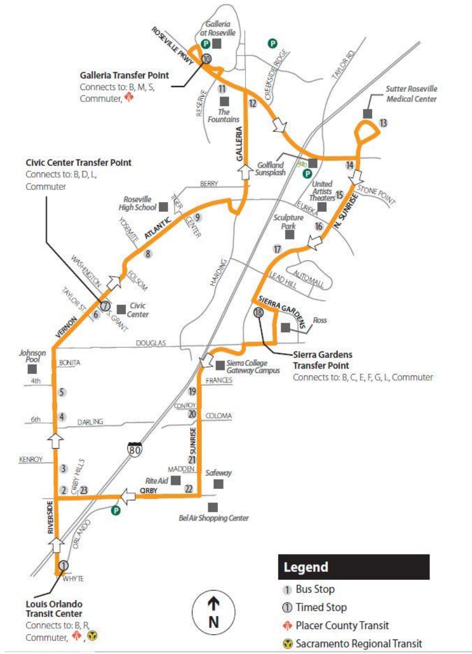
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**30.63**	0.00	**409.37**
2	**409.37**	**29.65**	45.00	**424.72**
3	**424.72**	**28.67**	0.00	**396.05**
4	**396.05**	**27.69**	45.00	**413.36**
5	**413.36**	**26.73**	0.00	**386.63**
6	**386.63**	**25.77**	45.00	**405.86**
7	**405.86**	**24.83**	0.00	**381.02**
8	**381.02**	**23.91**	45.00	**402.12**
9	**402.12**	**22.94**	0.00	**379.18**
10	**379.18**	**21.77**	45.00	**402.41**
11	**402.41**	**22.67**	0.00	**379.74**
12	**379.74**	**23.49**	45.00	**401.25**
13	**401.25**	**24.19**	0.00	**377.06**
14	**377.06**	**24.90**	45.00	**397.16**
15	**397.16**	**25.63**	0.00	**371.53**
16	**371.53**	**26.36**	45.00	**390.17**

Saturday Local Route A1 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.	
Battery Size:	440	KWH
Hours of Service	8	AM
	5	PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	9	Minutes

Seasonal kWh per Mile Rate

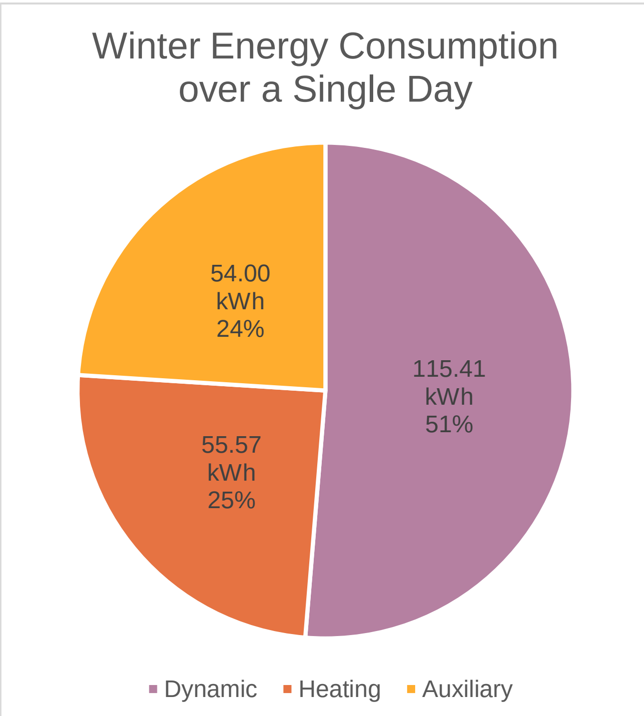
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.17 kWh/mi	2.18 kWh/mi	2.54 kWh/mi	2.55 kWh/mi

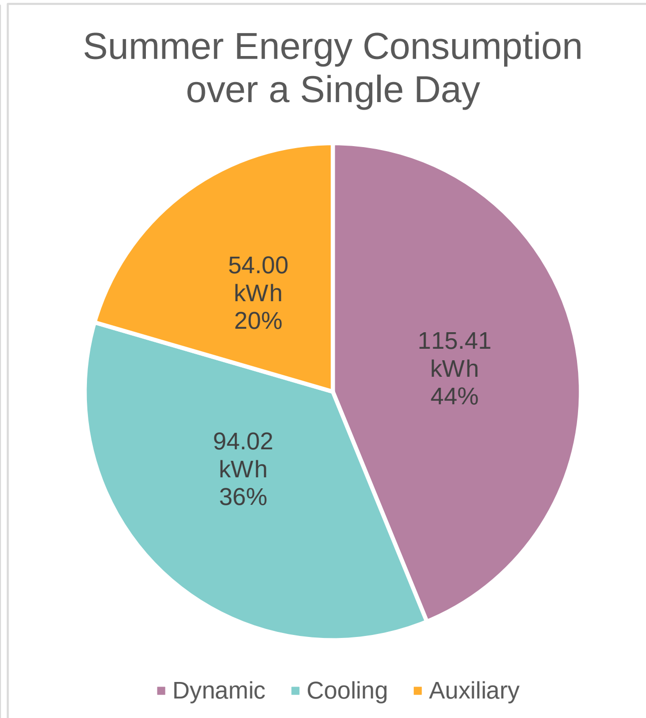
Saturday Local Route A1 Results

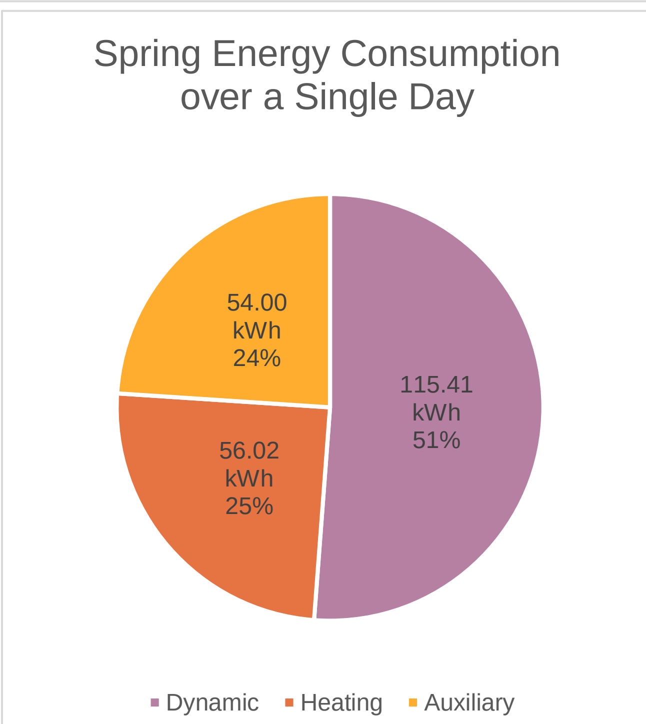
Daily Energy Consumption by Subsystem

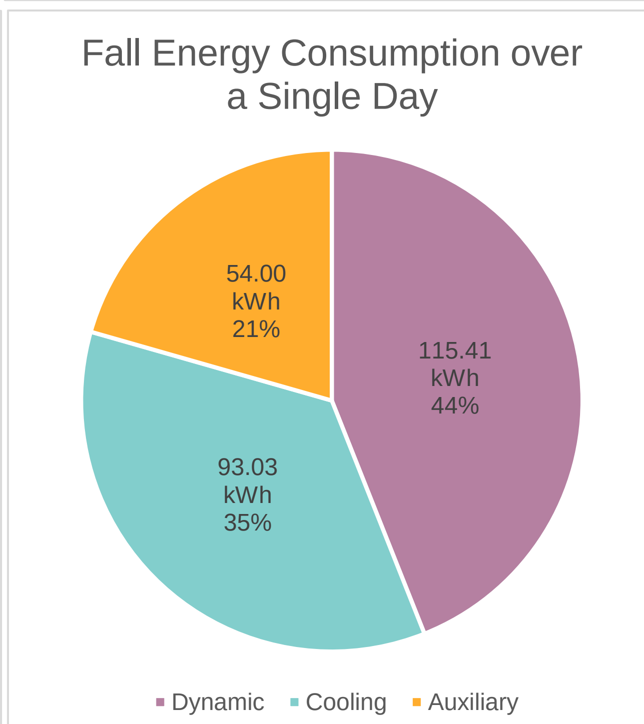
Total Daily Energy Consumption:

Summer:	263.43 KWH	Fall	262.44
Winter:	224.98 KWH	Spring	225.43









Saturday Local Route A1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**22.45**	0.00	**417.55**
2	**417.55**	**24.20**	45.00	**438.36**
3	**438.36**	**26.04**	0.00	**412.32**
4	**412.32**	**27.80**	45.00	**429.52**
5	**429.52**	**29.52**	0.00	**400.00**
6	**400.00**	**31.68**	45.00	**413.33**
7	**413.33**	**34.02**	0.00	**379.30**
8	**379.30**	**34.02**	45.00	**390.28**
9	**390.28**	**33.71**	0.00	**356.57**

Saturday Local Route A1 Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**28.67**	0.00	**411.33**
2	**411.33**	**27.69**	45.00	**428.64**
3	**428.64**	**26.73**	0.00	**401.91**
4	**401.91**	**25.77**	45.00	**421.13**
5	**421.13**	**24.83**	0.00	**396.30**
6	**396.30**	**23.91**	45.00	**417.39**
7	**417.39**	**22.94**	0.00	**394.46**
8	**394.46**	**21.77**	45.00	**417.69**
9	**417.69**	**22.67**	0.00	**395.02**

Electric Bus Corridor Model Results

Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	9	Minutes

Seasonal kWh per Mile Rate

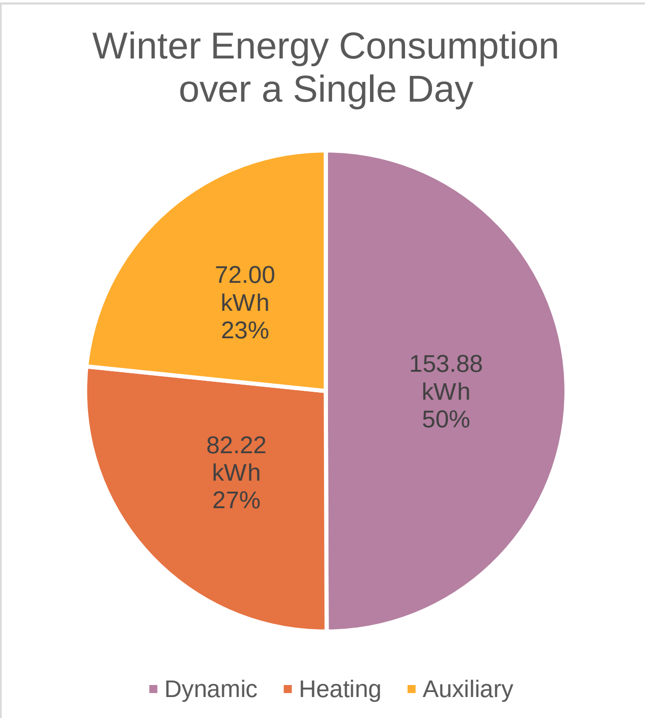
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.23 kWh/mi	2.08 kWh/mi	2.38 kWh/mi	2.46 kWh/mi

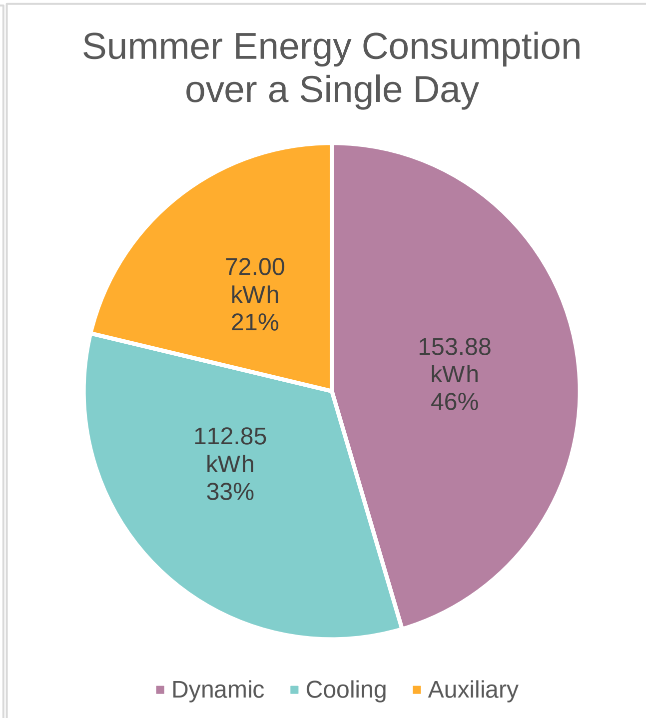
Local Route A2 Results

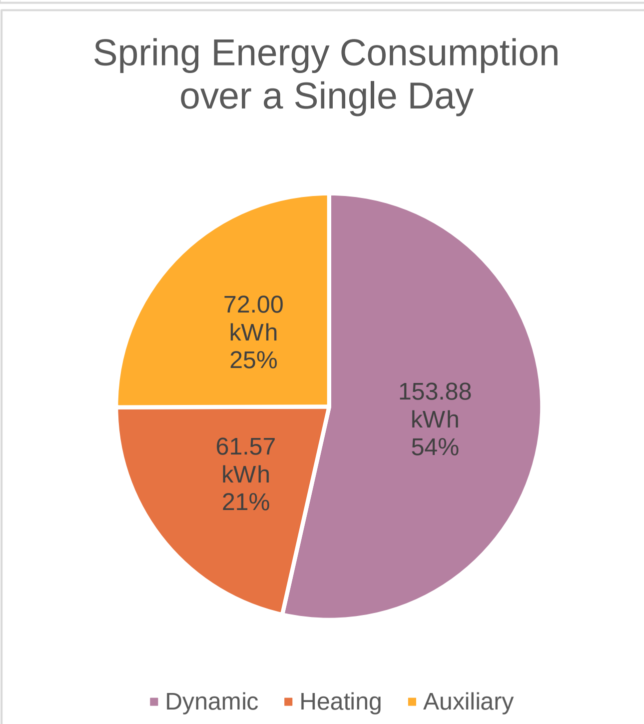
Daily Energy Consumption by Subsystem

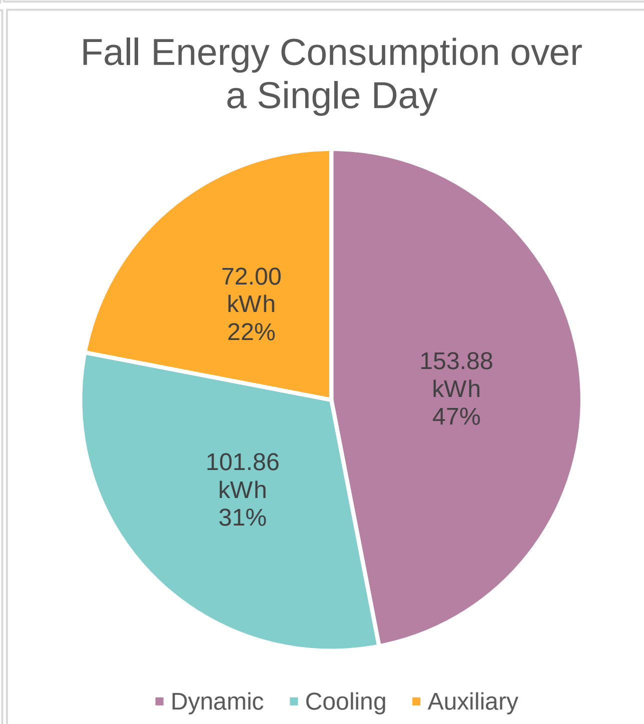
Total Daily Energy Consumption:

Summer:	338.73 KWH	Fall	327.74
Winter:	308.11 KWH	Spring	287.45









Local Route A2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**20.61**	0.00	**419.39**
2	**419.39**	**21.81**	42.43	**440.00**
3	**440.00**	**22.45**	0.00	**417.55**
4	**417.55**	**24.20**	45.00	**438.36**
5	**438.36**	**26.04**	0.00	**412.32**
6	**412.32**	**29.52**	45.00	**427.80**
7	**427.80**	**31.68**	0.00	**396.12**
8	**396.12**	**34.02**	45.00	**407.10**
9	**407.10**	**34.02**	0.00	**373.08**
10	**373.08**	**33.71**	45.00	**384.37**
11	**384.37**	**31.28**	0.00	**353.08**
12	**353.08**	**29.39**	45.00	**368.69**

Local Route A2 Results

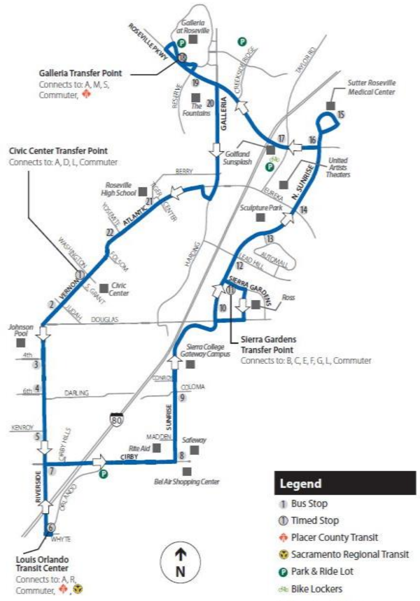
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**30.63**	0.00	**409.37**
2	**409.37**	**29.65**	45.00	**424.72**
3	**424.72**	**28.67**	0.00	**396.05**
4	**396.05**	**27.69**	45.00	**413.36**
5	**413.36**	**26.73**	0.00	**386.63**
6	**386.63**	**25.77**	45.00	**405.86**
7	**405.86**	**23.91**	0.00	**381.95**
8	**381.95**	**22.94**	45.00	**404.01**
9	**404.01**	**21.77**	0.00	**382.24**
10	**382.24**	**22.67**	45.00	**404.57**
11	**404.57**	**23.49**	0.00	**381.08**
12	**381.08**	**24.19**	45.00	**401.89**

Local Route B1 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst XR 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	8	Minutes

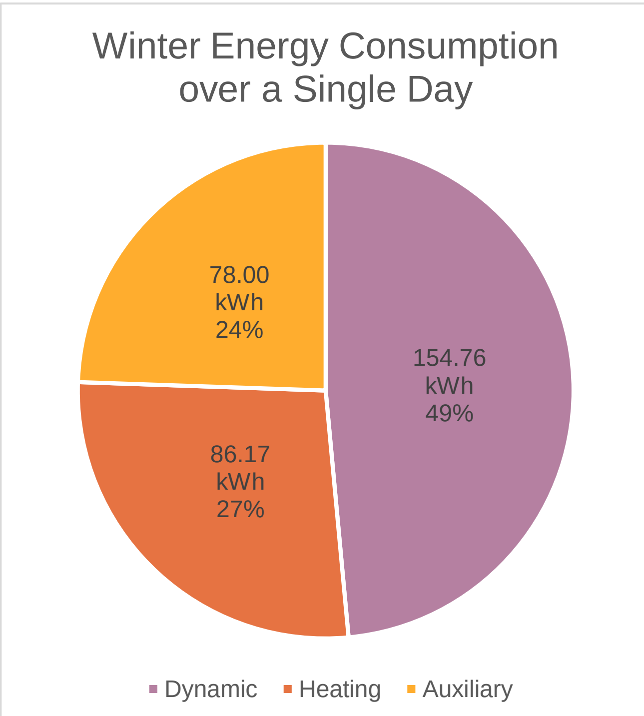
Seasonal kWh per Mile Rate

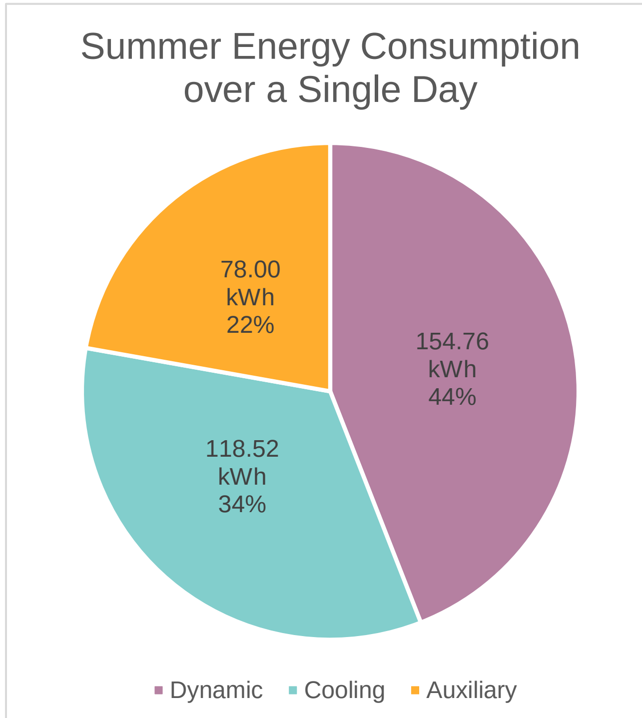
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.21 kWh/mi	2.06 kWh/mi	2.36 kWh/mi	2.43 kWh/mi

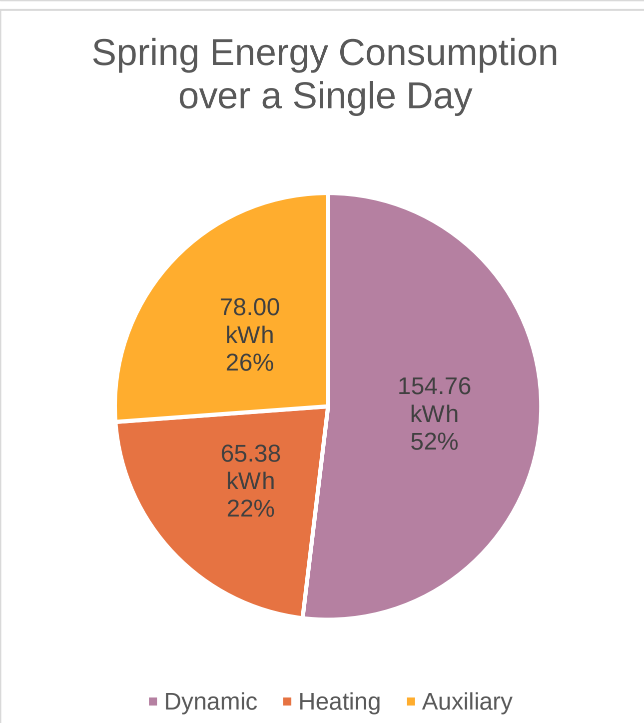
Daily Energy Consumption by Subsystem

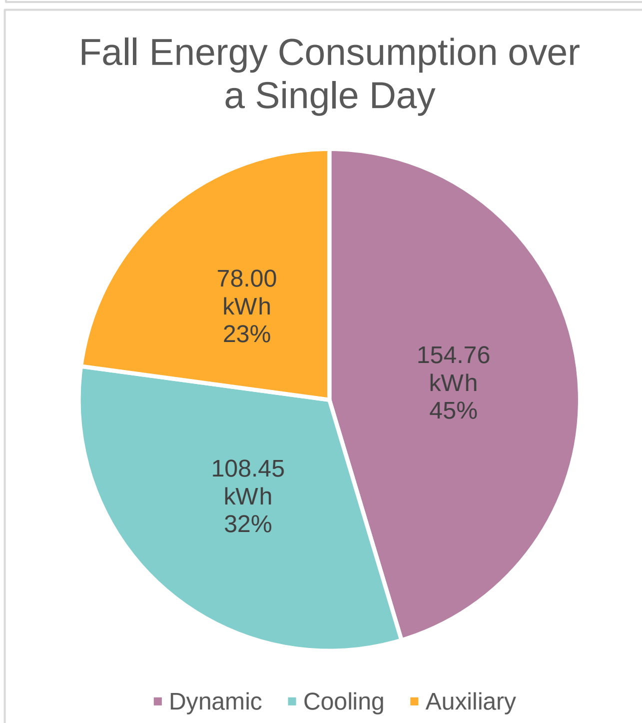
Total Daily Energy Consumption:

Summer:	351.28 KWH	Fall	341.21
Winter:	318.93 KWH	Spring	298.14









Local Route B1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**19.67**	0.00	**420.33**
2	**420.33**	**20.86**	40.00	**439.47**
3	**439.47**	**21.47**	0.00	**417.99**
4	**417.99**	**23.19**	40.00	**434.80**
5	**434.80**	**24.99**	0.00	**409.81**
6	**409.81**	**26.68**	40.00	**423.13**
7	**423.13**	**28.33**	0.00	**394.80**
8	**394.80**	**30.40**	40.00	**404.40**
9	**404.40**	**32.62**	0.00	**371.78**
10	**371.78**	**32.62**	40.00	**379.16**
11	**379.16**	**32.31**	0.00	**346.85**
12	**346.85**	**29.97**	40.00	**356.88**
13	**356.88**	**28.15**	0.00	**328.72**

Local Route B1 Results

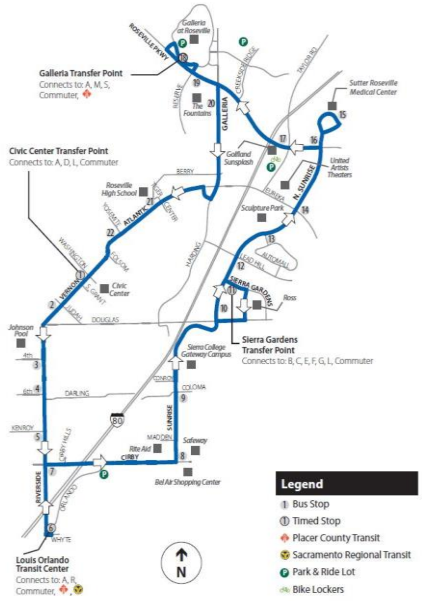
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**29.45**	0.00	**410.55**
2	**410.55**	**28.49**	40.00	**422.06**
3	**422.06**	**27.53**	0.00	**394.53**
4	**394.53**	**26.58**	40.00	**407.95**
5	**407.95**	**25.63**	0.00	**382.32**
6	**382.32**	**24.69**	40.00	**397.63**
7	**397.63**	**23.77**	0.00	**373.86**
8	**373.86**	**22.86**	40.00	**391.00**
9	**391.00**	**21.91**	0.00	**369.09**
10	**369.09**	**20.78**	40.00	**388.31**
11	**388.31**	**21.65**	0.00	**366.66**
12	**366.66**	**22.45**	40.00	**384.21**
13	**384.21**	**23.14**	0.00	**361.07**

Saturday Local Route B1 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst XR 35 ft.	
Battery Size:	440	KWH
Hours of Service	8	AM
	5	PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	9	Minutes

Seasonal kWh per Mile Rate

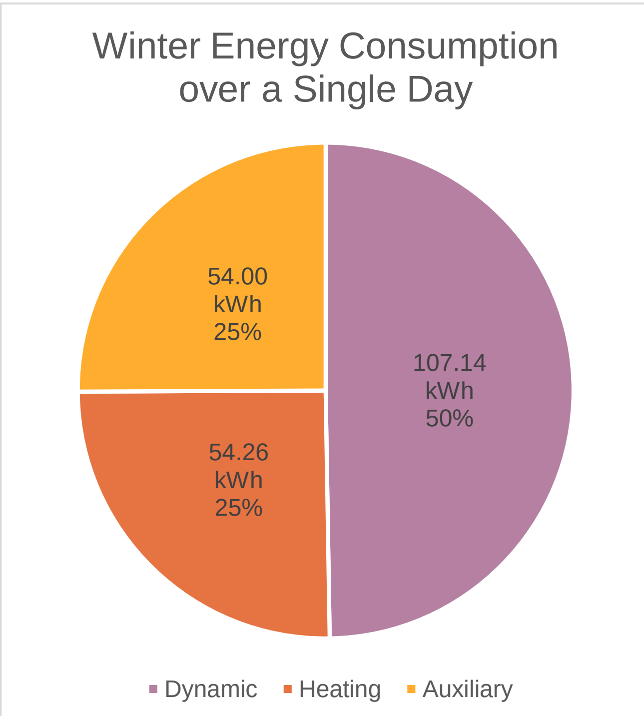
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.15 kWh/mi	2.16 kWh/mi	2.52 kWh/mi	2.52 kWh/mi

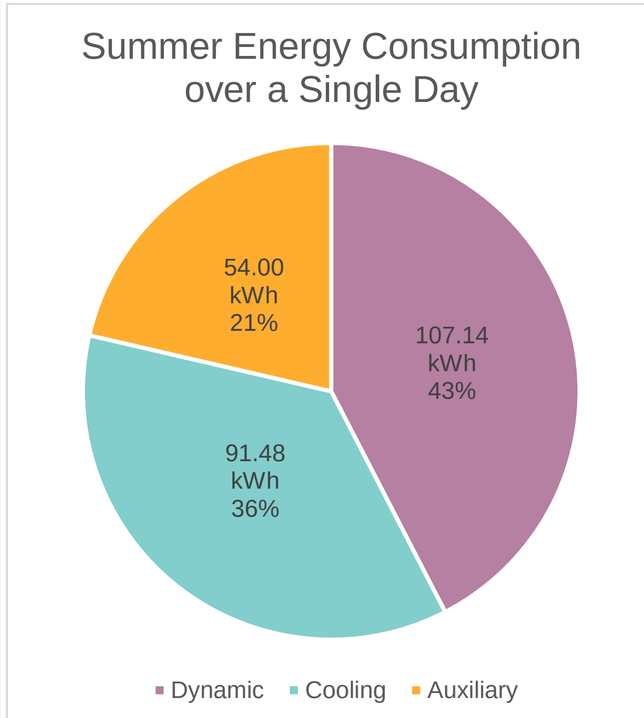
Saturday Local Route B1 Results

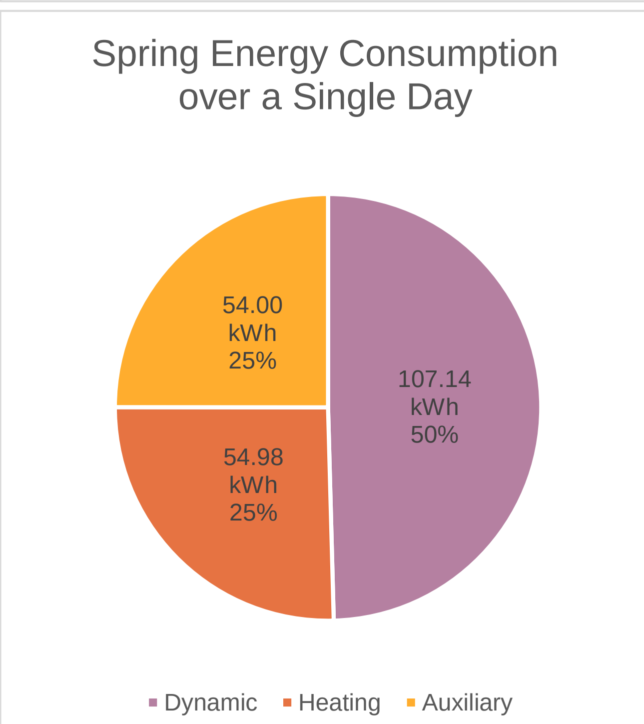
Daily Energy Consumption by Subsystem

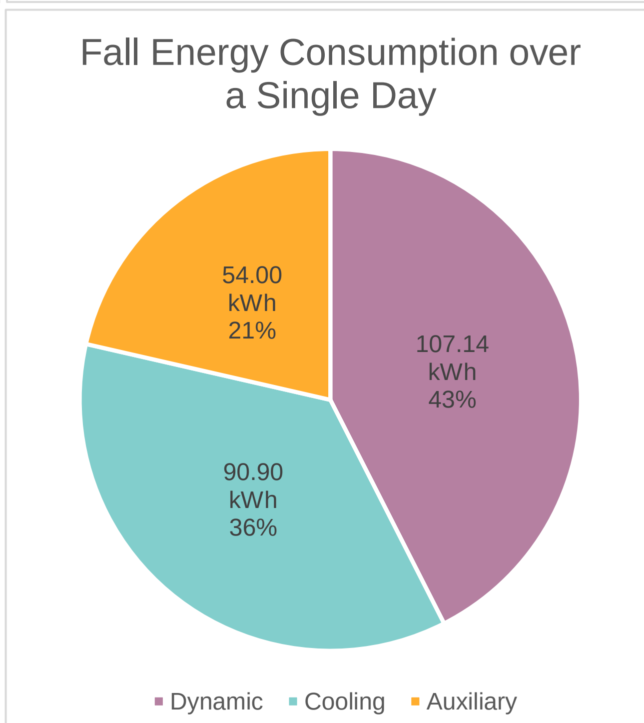
Total Daily Energy Consumption:

Summer:	252.62 KWH	Fall	252.04
Winter:	215.40 KWH	Spring	216.12









Saturday Local Route B1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**21.47**	0.00	**418.53**
2	**418.53**	**23.19**	44.67	**440.00**
3	**440.00**	**24.99**	0.00	**415.01**
4	**415.01**	**26.68**	45.00	**433.33**
5	**433.33**	**28.33**	0.00	**405.00**
6	**405.00**	**30.40**	45.00	**419.61**
7	**419.61**	**32.62**	0.00	**386.98**
8	**386.98**	**32.62**	45.00	**399.36**
9	**399.36**	**32.31**	0.00	**367.05**

Saturday Local Route B1 Results

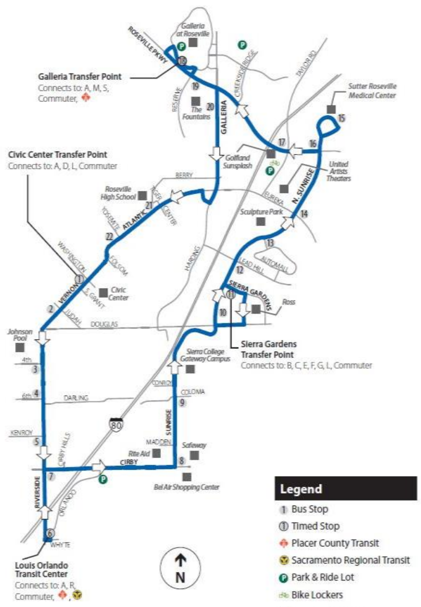
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**27.53**	0.00	**412.47**
2	**412.47**	**26.58**	45.00	**430.89**
3	**430.89**	**25.63**	0.00	**405.26**
4	**405.26**	**24.69**	45.00	**425.57**
5	**425.57**	**23.77**	0.00	**401.80**
6	**401.80**	**22.86**	45.00	**423.94**
7	**423.94**	**21.91**	0.00	**402.03**
8	**402.03**	**20.78**	45.00	**426.25**
9	**426.25**	**21.65**	0.00	**404.60**

Local Route B2 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM 10 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	9	Minutes

Total Daily Energy Consumption:

Summer:	422.02	Fall:	407.06
Winter:	392.59	Spring:	354.53

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.16 kWh/mi	1.91 kWh/mi	2.18 kWh/mi	2.33 kWh/mi

Local Route B2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**19.67**	0.00	**420.33**
2	**420.33**	**20.86**	40.53	**440.00**
3	**440.00**	**21.47**	0.00	**418.53**
4	**418.53**	**23.19**	44.67	**440.00**
5	**440.00**	**24.99**	0.00	**415.01**
6	**415.01**	**26.68**	45.00	**433.33**
7	**433.33**	**28.33**	0.00	**405.00**
8	**405.00**	**30.40**	45.00	**419.61**
9	**419.61**	**32.62**	0.00	**386.98**
10	**386.98**	**32.62**	45.00	**399.36**
11	**399.36**	**32.31**	0.00	**367.05**
12	**367.05**	**29.97**	45.00	**382.08**
13	**382.08**	**28.15**	0.00	**353.92**
14	**353.92**	**26.20**	45.00	**372.72**
15	**372.72**	**22.98**	0.00	**349.74**
16	**349.74**	**21.55**	45.00	**373.19**

Local Route B2 Results

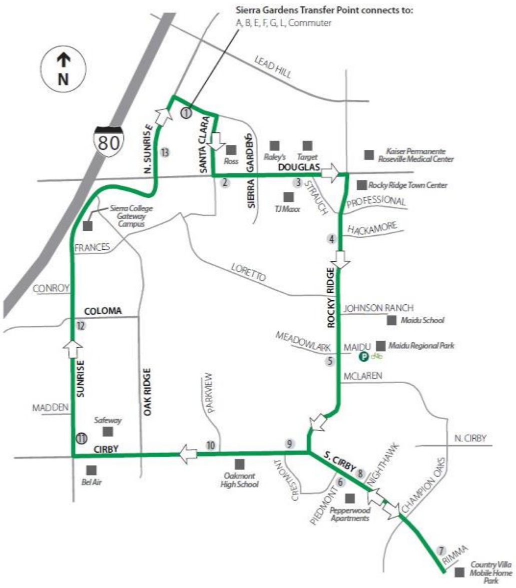
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**29.45**	0.00	**410.55**
2	**410.55**	**28.49**	45.00	**427.06**
3	**427.06**	**27.53**	0.00	**399.53**
4	**399.53**	**26.58**	45.00	**417.95**
5	**417.95**	**25.63**	0.00	**392.32**
6	**392.32**	**24.69**	45.00	**412.63**
7	**412.63**	**23.77**	0.00	**388.86**
8	**388.86**	**22.86**	45.00	**411.00**
9	**411.00**	**21.91**	0.00	**389.09**
10	**389.09**	**20.78**	45.00	**413.31**
11	**413.31**	**21.65**	0.00	**391.66**
12	**391.66**	**22.45**	45.00	**414.21**
13	**414.21**	**23.14**	0.00	**391.07**
14	**391.07**	**23.84**	45.00	**412.23**
15	**412.23**	**24.55**	0.00	**387.68**
16	**387.68**	**25.27**	45.00	**407.41**

Local Route C Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

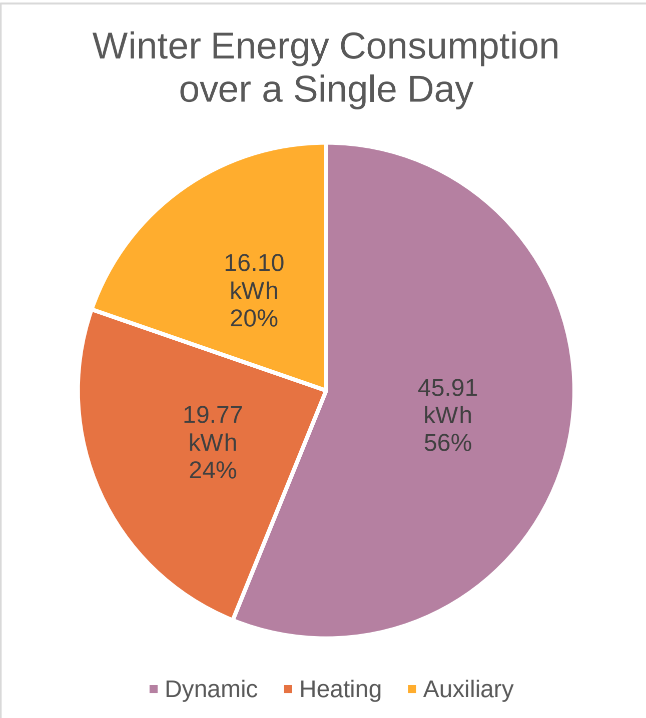
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.08 kWh/mi	1.93 kWh/mi	2.19 kWh/mi	2.26 kWh/mi

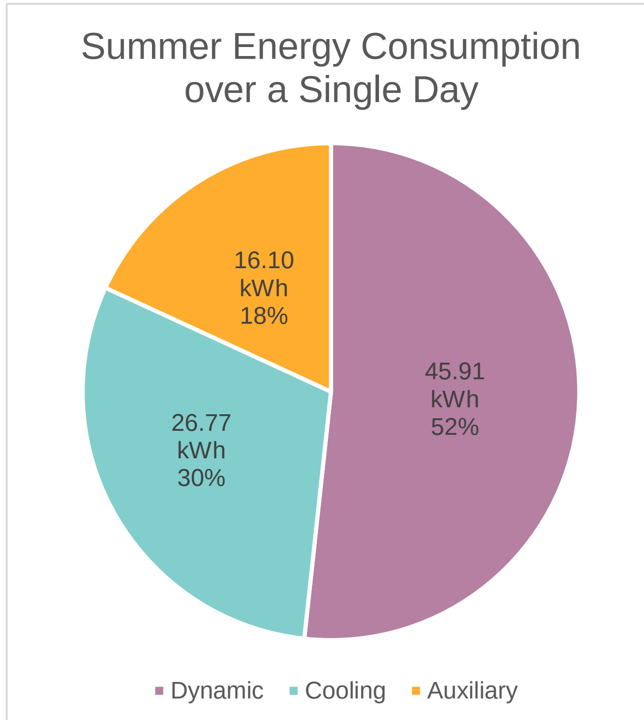
Local Route C Results

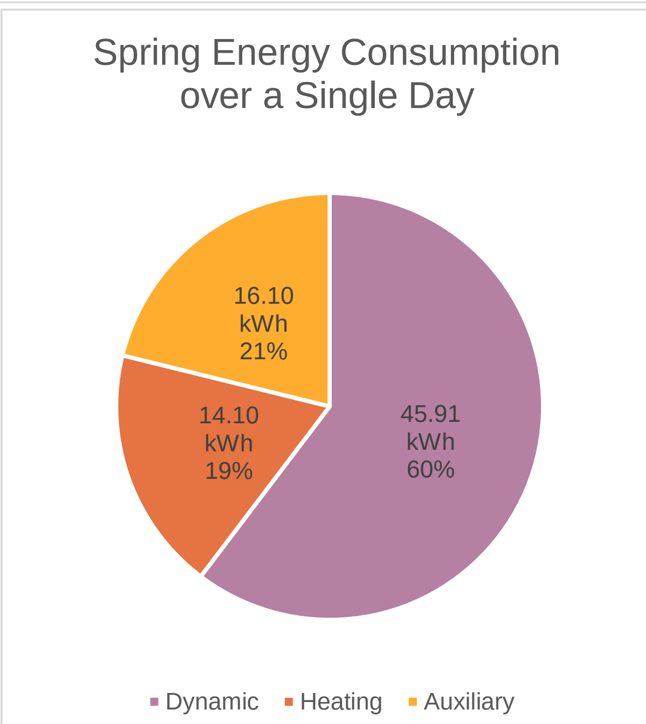
Daily Energy Consumption by Subsystem

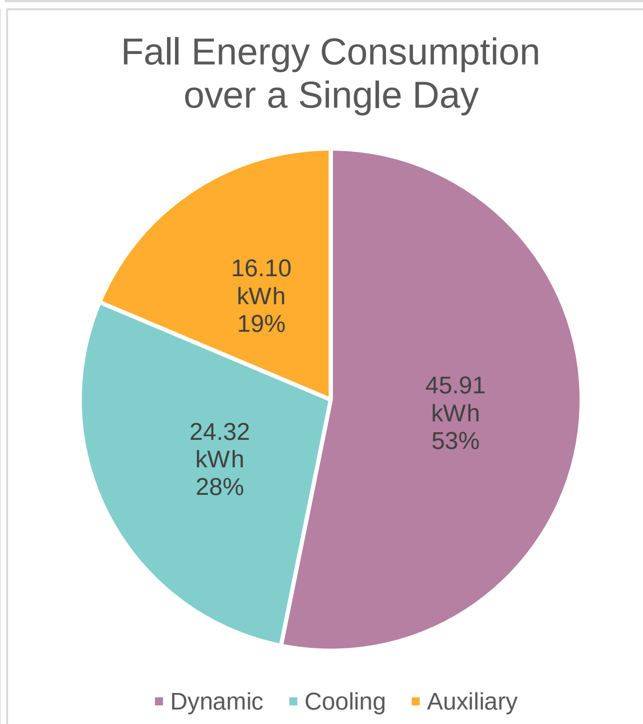
Total Daily Energy Consumption:

Summer:	88.78 KWH	Fall	86.34
Winter:	81.78 KWH	Spring	76.11









Local Route C Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**9.85**	0.00	**430.15**
2	**430.15**	**10.78**	0.00	**419.37**
3	**419.37**	**12.20**	0.00	**407.17**
4	**407.17**	**13.76**	0.00	**393.41**
5	**393.41**	**14.71**	0.00	**378.70**
6	**378.70**	**14.60**	0.00	**364.11**
7	**364.11**	**12.89**	0.00	**351.22**

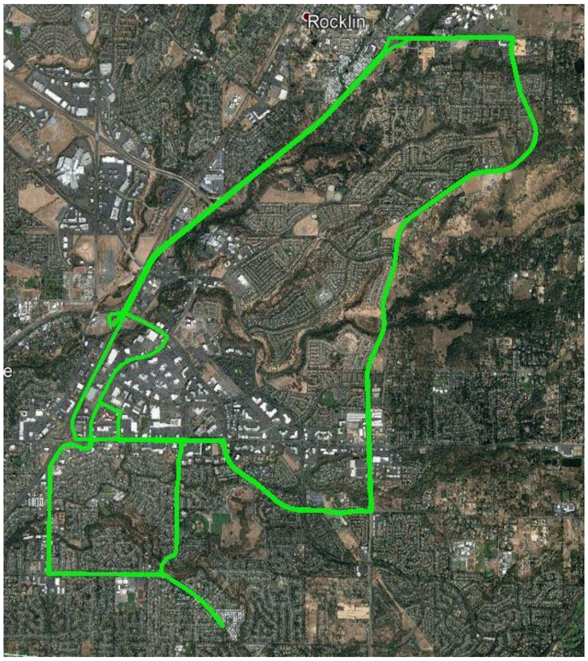
Local Route C Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**13.55**	0.00	**426.45**
2	**426.45**	**12.77**	0.00	**413.68**
3	**413.68**	**12.00**	0.00	**401.68**
4	**401.68**	**11.25**	0.00	**390.43**
5	**390.43**	**10.50**	0.00	**379.93**
6	**379.93**	**10.72**	0.00	**369.22**
7	**369.22**	**10.99**	0.00	**358.22**

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 35 ft.

Battery Size: 440 KWH

Hours of Service 6 AM 6 PM

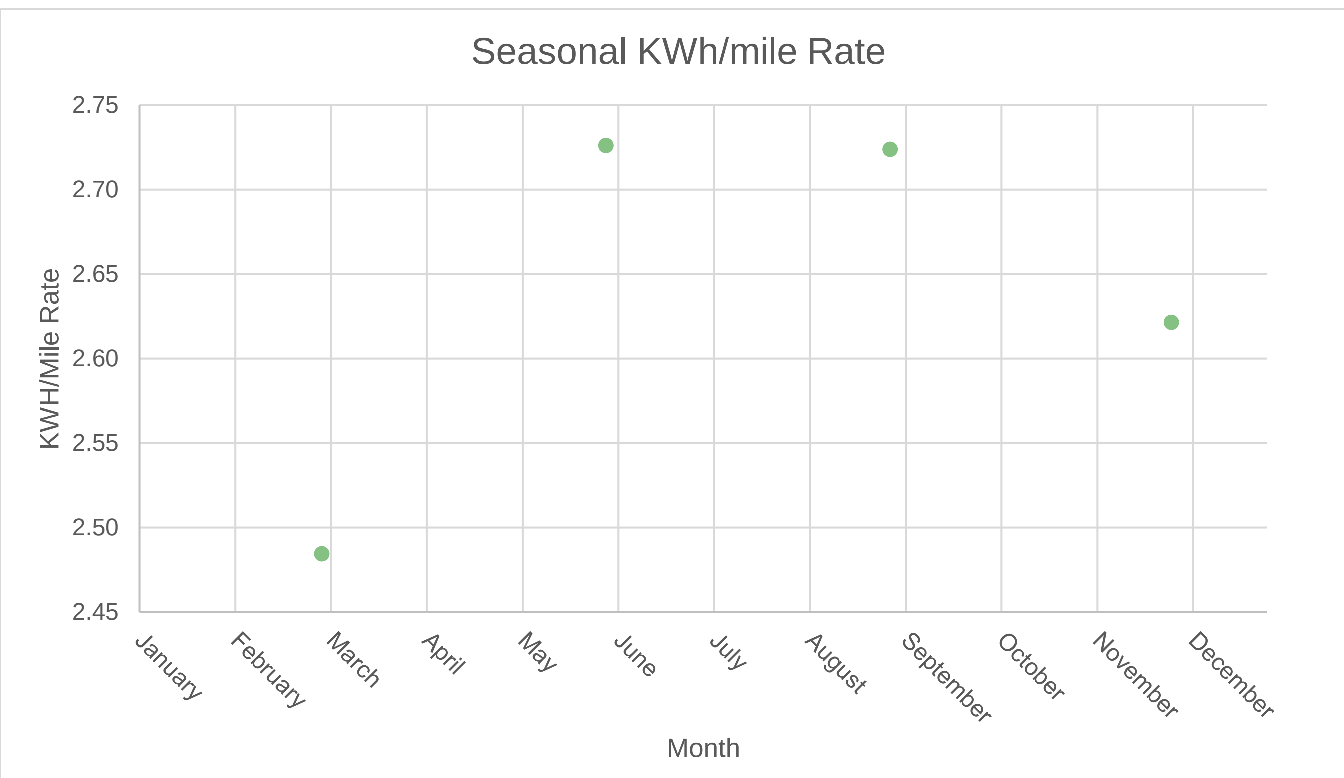
Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	1	Lap
Time at Charger:	14	Minutes

Seasonal kWh per Mile Rate

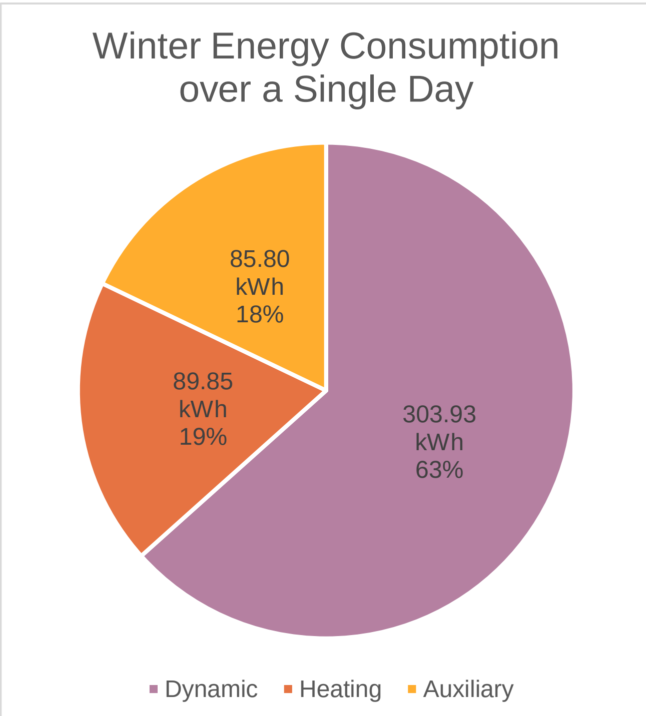
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.62 kWh/mi	2.48 kWh/mi	2.72 kWh/mi	2.73 kWh/mi

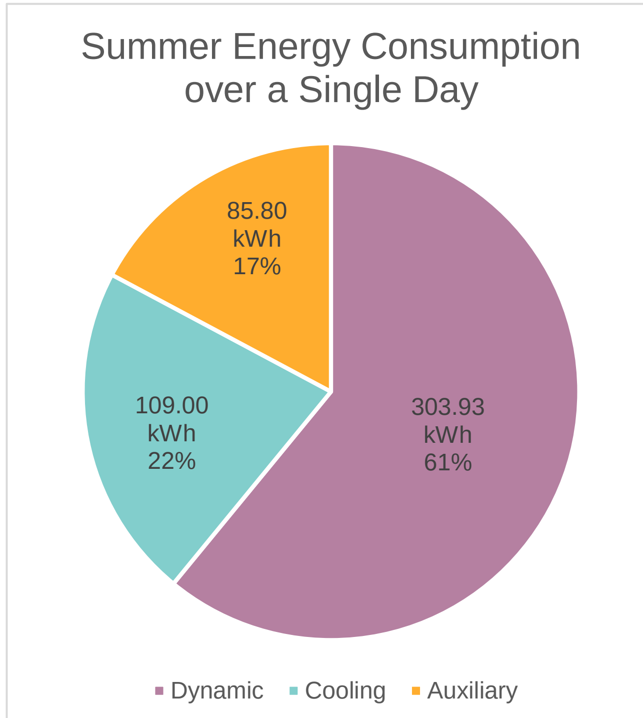


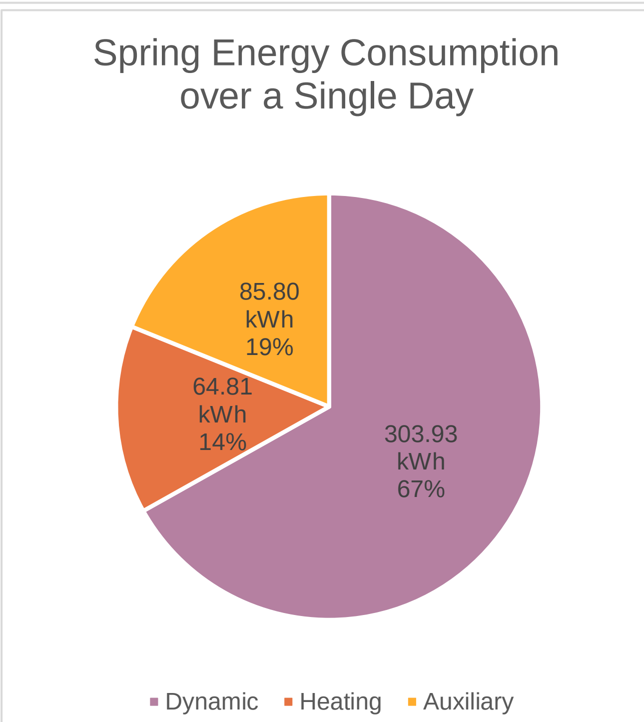
Daily Energy Consumption by Subsystem

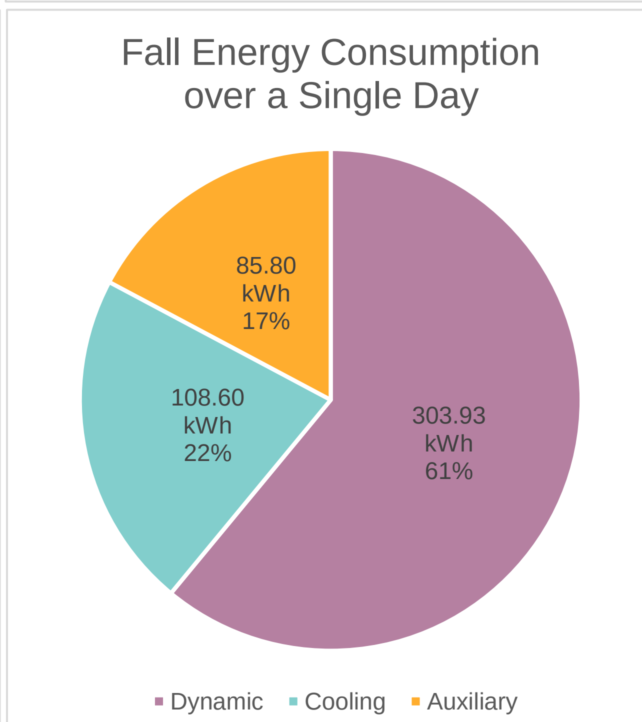
Total Daily Energy Consumption:

Summer:	498.73 KWH	Fall	498.33
Winter:	479.58 KWH	Spring	454.54









Local Route C, G, F, E Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**71.18**	70.00	**438.82**
2	**438.82**	**75.66**	70.00	**433.16**
3	**433.16**	**81.99**	70.00	**421.17**
4	**421.17**	**87.96**	70.00	**403.21**
5	**403.21**	**91.31**	70.00	**381.90**
6	**381.90**	**90.63**	70.00	**361.27**

Local Route C, G, F, E Results

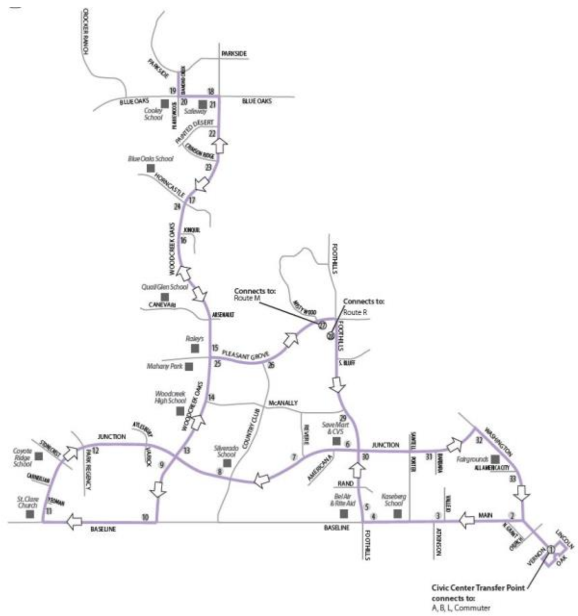
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**89.23**	70.00	**420.77**
2	**420.77**	**85.13**	70.00	**405.64**
3	**405.64**	**81.06**	70.00	**394.58**
4	**394.58**	**77.03**	70.00	**387.55**
5	**387.55**	**73.00**	70.00	**384.55**
6	**384.55**	**74.13**	70.00	**380.42**

Local Route D Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	13	Minutes

Seasonal kWh per Mile Rate

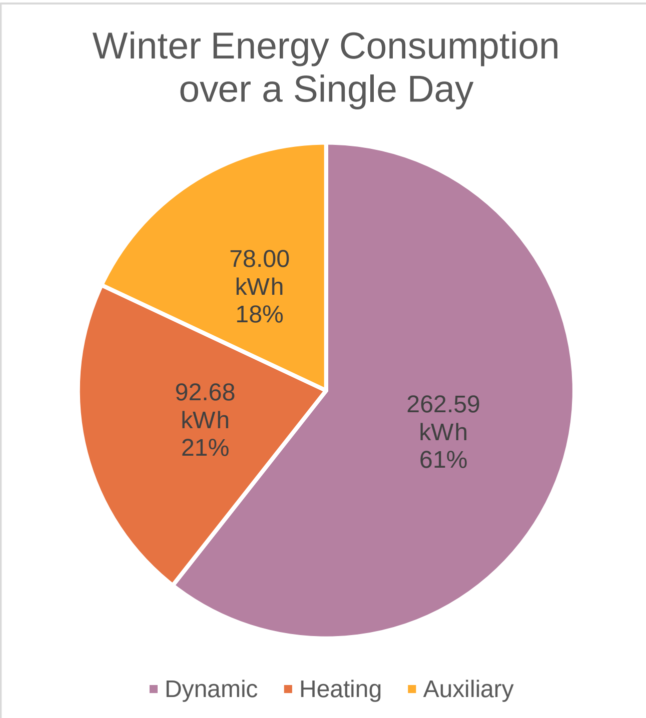
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.05 kWh/mi	1.91 kWh/mi	2.13 kWh/mi	2.18 kWh/mi

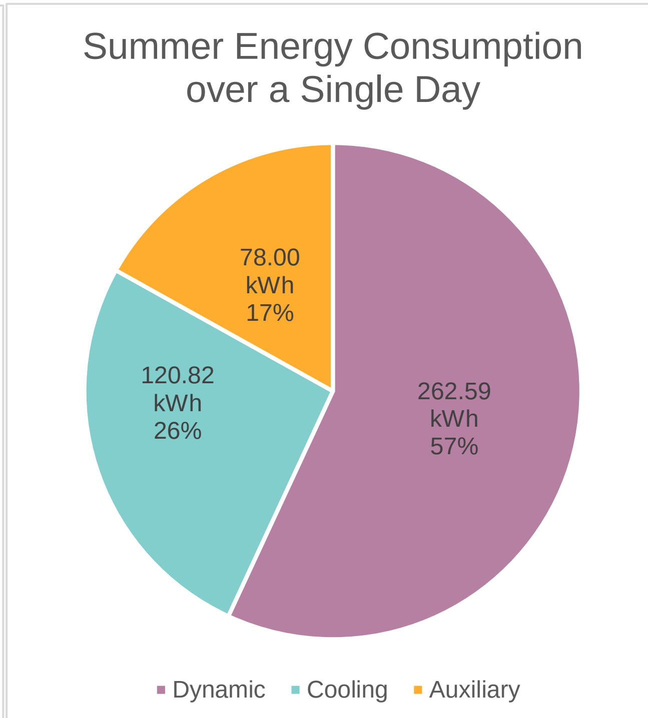
Local Route D Results

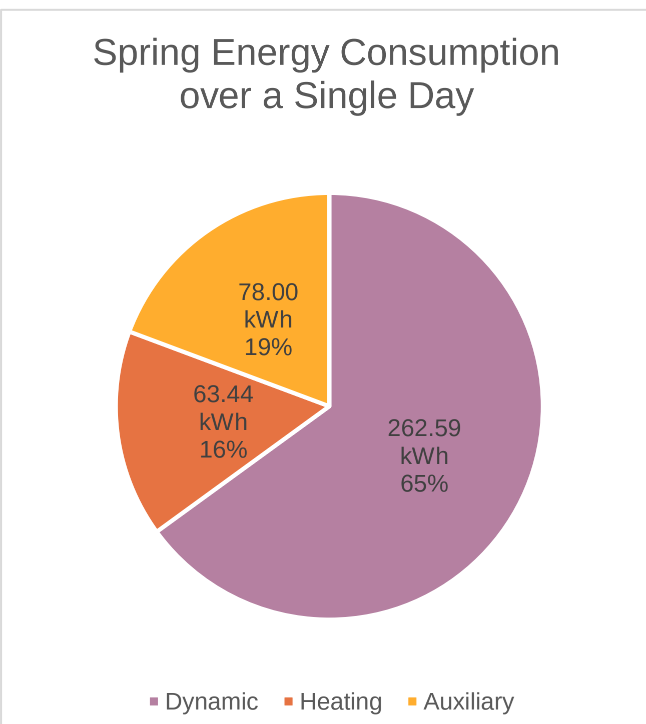
Daily Energy Consumption by Subsystem

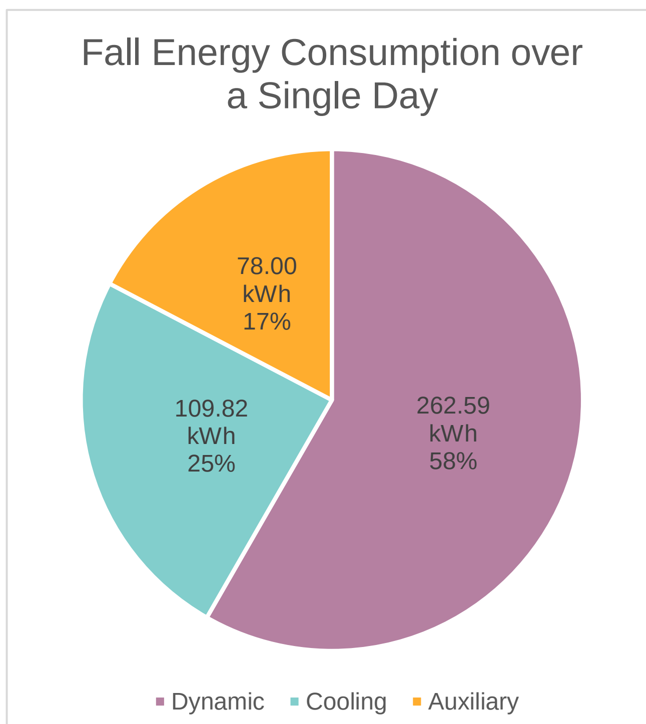
Total Daily Energy Consumption:

Summer:	461.41	KWH	Fall	450.41
Winter:	433.27	KWH	Spring	404.03









Local Route D Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**27.64**	0.00	**412.36**
2	**412.36**	**28.80**	56.44	**440.00**
3	**440.00**	**29.45**	0.00	**410.55**
4	**410.55**	**31.23**	60.69	**440.00**
5	**440.00**	**33.13**	0.00	**406.87**
6	**406.87**	**34.98**	65.00	**436.88**
7	**436.88**	**36.82**	0.00	**400.07**
8	**400.07**	**39.11**	65.00	**425.95**
9	**425.95**	**41.63**	0.00	**384.33**
10	**384.33**	**41.63**	65.00	**407.70**
11	**407.70**	**41.34**	0.00	**366.36**
12	**366.36**	**38.81**	65.00	**392.55**
13	**392.55**	**36.83**	0.00	**355.72**

Local Route D Results

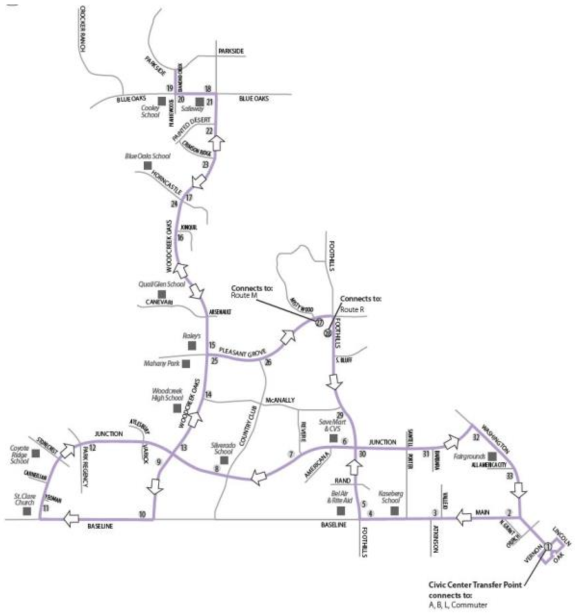
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**38.59**	0.00	**401.41**
2	**401.41**	**37.56**	65.00	**428.85**
3	**428.85**	**36.53**	0.00	**392.32**
4	**392.32**	**35.51**	65.00	**421.81**
5	**421.81**	**34.50**	0.00	**387.31**
6	**387.31**	**33.50**	65.00	**418.81**
7	**418.81**	**32.51**	0.00	**386.29**
8	**386.29**	**31.55**	65.00	**419.75**
9	**419.75**	**30.53**	0.00	**389.22**
10	**389.22**	**29.30**	65.00	**424.92**
11	**424.92**	**30.24**	0.00	**394.68**
12	**394.68**	**31.11**	65.00	**428.57**
13	**428.57**	**31.84**	0.00	**396.73**

Saturday Local Route D Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	8 AM
	5 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	300	KW
Visit every	2	Laps
Time at Charger:	12	Minutes

Seasonal kWh per Mile Rate

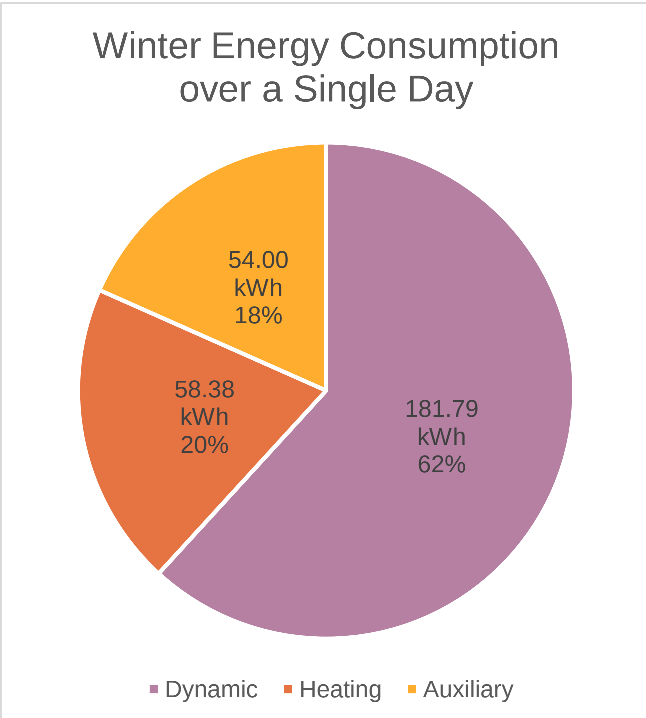
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.01 kWh/mi	1.97 kWh/mi	2.24 kWh/mi	2.25 kWh/mi

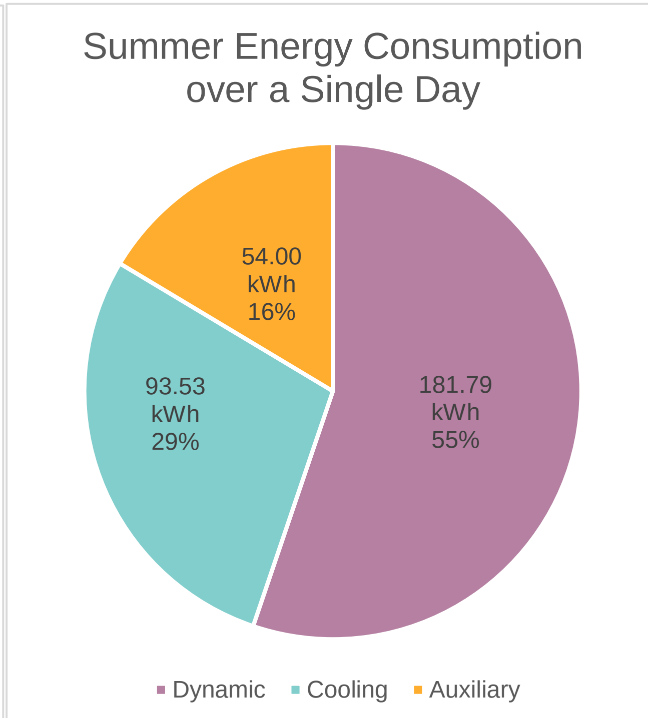
Saturday Local Route D Results

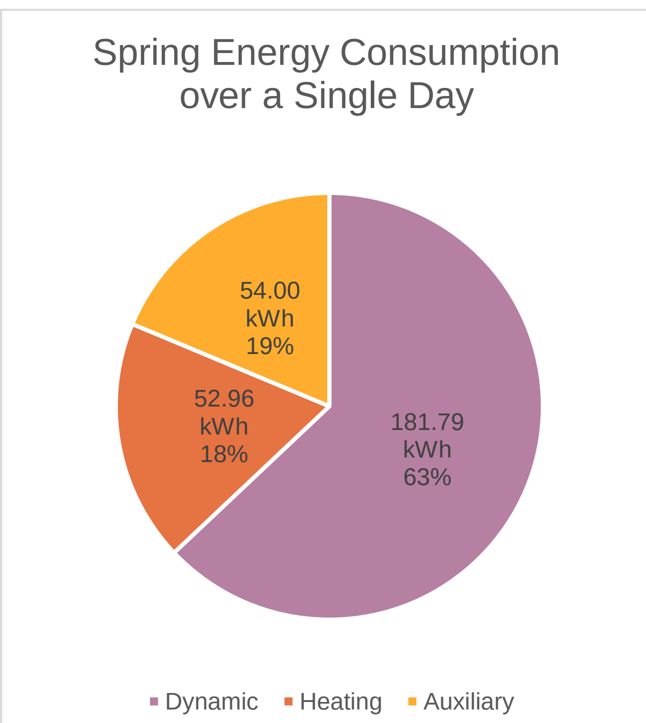
Daily Energy Consumption by Subsystem

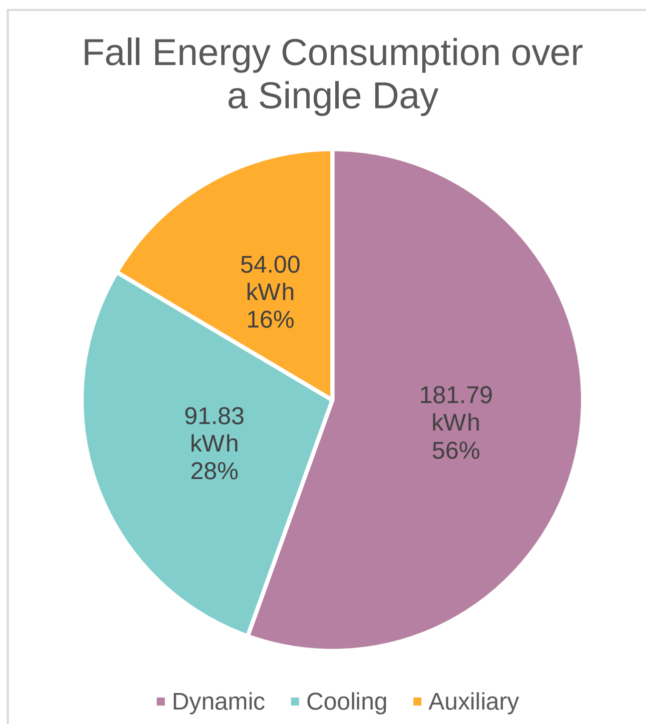
Total Daily Energy Consumption:

Summer:	329.32 KWH	Fall	327.62
Winter:	294.17 KWH	Spring	288.75









Saturday Local Route D Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**29.45**	0.00	**410.55**
2	**410.55**	**31.23**	60.00	**439.31**
3	**439.31**	**33.13**	0.00	**406.18**
4	**406.18**	**34.98**	60.00	**431.20**
5	**431.20**	**36.82**	0.00	**394.38**
6	**394.38**	**39.11**	60.00	**415.27**
7	**415.27**	**41.63**	0.00	**373.64**
8	**373.64**	**41.63**	60.00	**392.02**
9	**392.02**	**41.34**	0.00	**350.68**

Saturday Local Route D Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**36.53**	0.00	**403.47**
2	**403.47**	**35.51**	60.00	**427.96**
3	**427.96**	**34.50**	0.00	**393.46**
4	**393.46**	**33.50**	60.00	**419.96**
5	**419.96**	**32.51**	0.00	**387.44**
6	**387.44**	**31.55**	60.00	**415.90**
7	**415.90**	**30.53**	0.00	**385.37**
8	**385.37**	**29.30**	60.00	**416.07**
9	**416.07**	**30.24**	0.00	**385.83**

Electric Bus Corridor Model Results

Background

Bus Model: Proterra Catalyst E2 35 ft.

Battery Size: 440 KWH

Hours of Service 6 AM 6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output: 60 KW

Time at Charger: 8 Hours

Seasonal kWh per Mile Rate

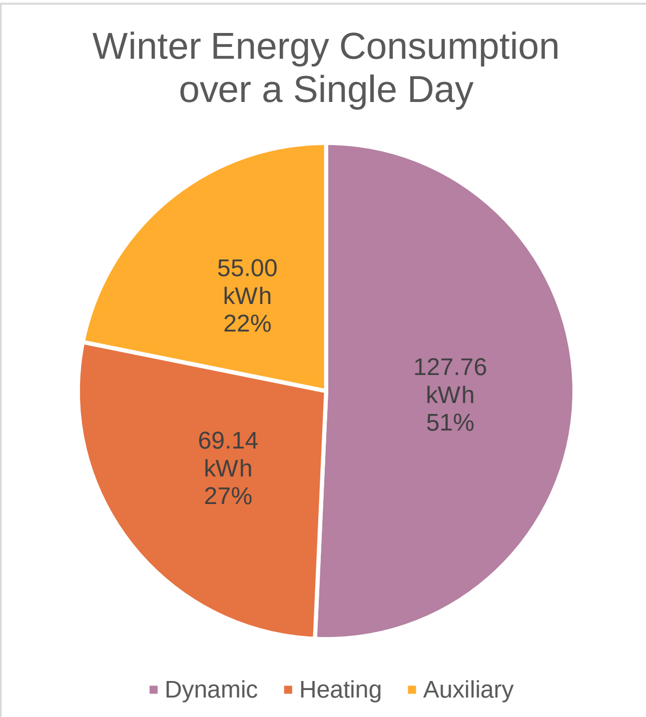
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.18 kWh/mi	1.99 kWh/mi	2.29 kWh/mi	2.35 kWh/mi

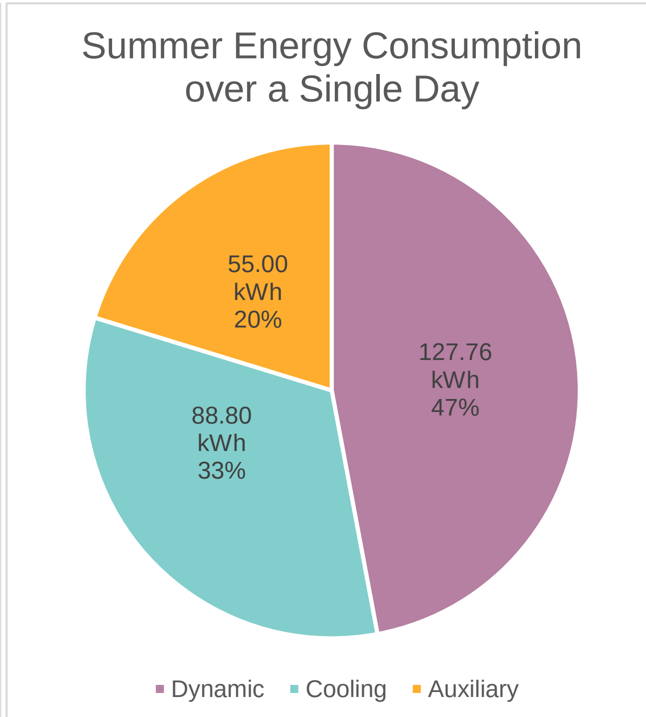
Local Route L Results

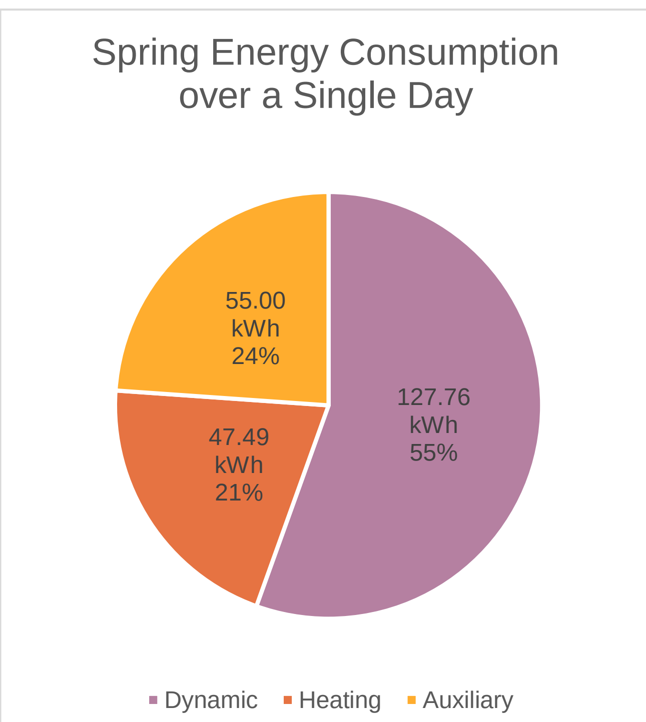
Daily Energy Consumption by Subsystem

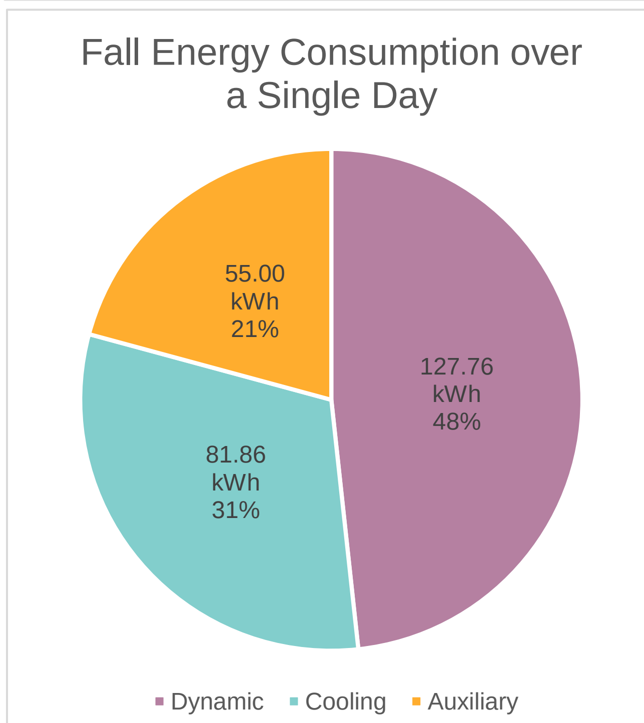
Total Daily Energy Consumption:

Summer:	271.56 KWH	Fall	264.61
Winter:	251.90 KWH	Spring	230.25









Local Route L Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**17.74**	0.00	**422.26**
2	**422.26**	**18.78**	0.00	**403.48**
3	**403.48**	**19.37**	0.00	**384.10**
4	**384.10**	**20.92**	0.00	**363.18**
5	**363.18**	**22.60**	0.00	**340.58**
6	**340.58**	**25.90**	0.00	**314.68**
7	**314.68**	**27.97**	0.00	**286.70**
8	**286.70**	**30.26**	0.00	**256.44**
9	**256.44**	**30.26**	0.00	**226.18**
10	**226.18**	**30.01**	0.00	**196.17**
11	**196.17**	**27.73**	0.00	**168.44**

Local Route L Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**27.19**	0.00	**412.81**
2	**412.81**	**26.31**	0.00	**386.50**
3	**386.50**	**25.44**	0.00	**361.06**
4	**361.06**	**24.57**	0.00	**336.48**
5	**336.48**	**23.71**	0.00	**312.77**
6	**312.77**	**22.87**	0.00	**289.90**
7	**289.90**	**21.21**	0.00	**268.69**
8	**268.69**	**20.35**	0.00	**248.34**
9	**248.34**	**19.29**	0.00	**229.05**
10	**229.05**	**20.10**	0.00	**208.95**
11	**208.95**	**20.84**	0.00	**188.10**

Saturday Local Route L Results

Electric Bus Corridor Model Results

Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	8 AM
	5 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

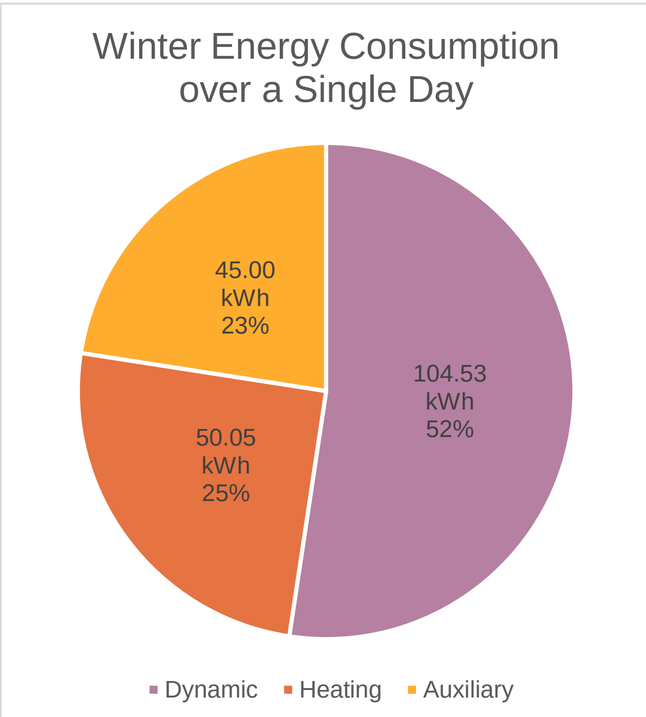
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.11 kWh/mi	2.07 kWh/mi	2.43 kWh/mi	2.45 kWh/mi

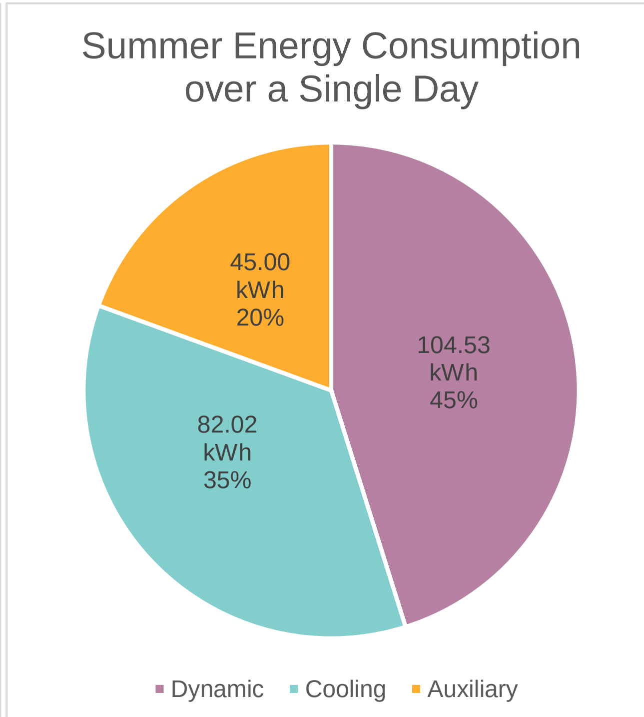
Saturday Local Route L Results

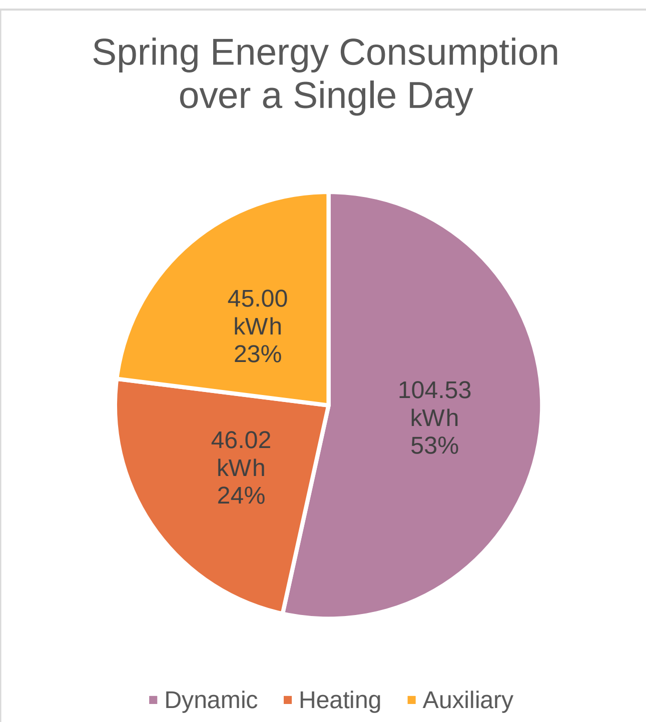
Daily Energy Consumption by Subsystem

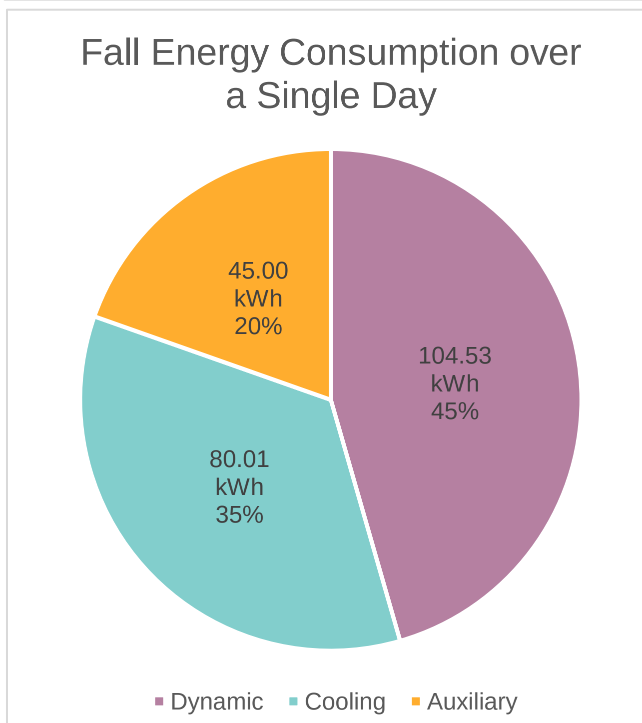
Total Daily Energy Consumption:

Summer:	231.55 KWH	Fall	229.54
Winter:	199.58 KWH	Spring	195.55









Saturday Local Route L Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**19.37**	0.00	**420.63**
2	**420.63**	**20.92**	0.00	**399.71**
3	**399.71**	**22.60**	0.00	**377.11**
4	**377.11**	**24.25**	0.00	**352.86**
5	**352.86**	**25.90**	0.00	**326.96**
6	**326.96**	**27.97**	0.00	**298.98**
7	**298.98**	**30.26**	0.00	**268.72**
8	**268.72**	**30.26**	0.00	**238.46**
9	**238.46**	**30.01**	0.00	**208.45**

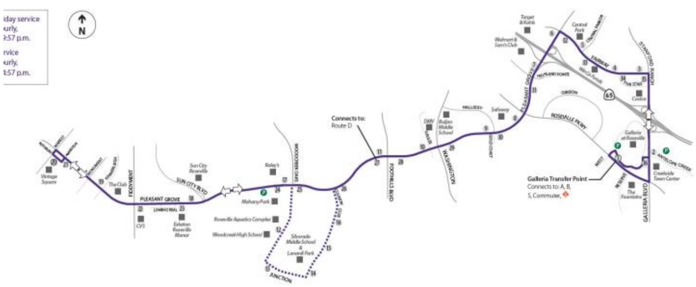
Saturday Local Route L Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**25.44**	0.00	**414.56**
2	**414.56**	**24.57**	0.00	**389.99**
3	**389.99**	**23.71**	0.00	**366.27**
4	**366.27**	**22.87**	0.00	**343.41**
5	**343.41**	**22.03**	0.00	**321.37**
6	**321.37**	**21.21**	0.00	**300.16**
7	**300.16**	**20.35**	0.00	**279.81**
8	**279.81**	**19.29**	0.00	**260.52**
9	**260.52**	**20.10**	0.00	**240.42**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst XR 35 ft.
Battery Size:	440 KWH
Hours of Service	5 AM
	10 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	13	Minutes

Seasonal kWh per Mile Rate

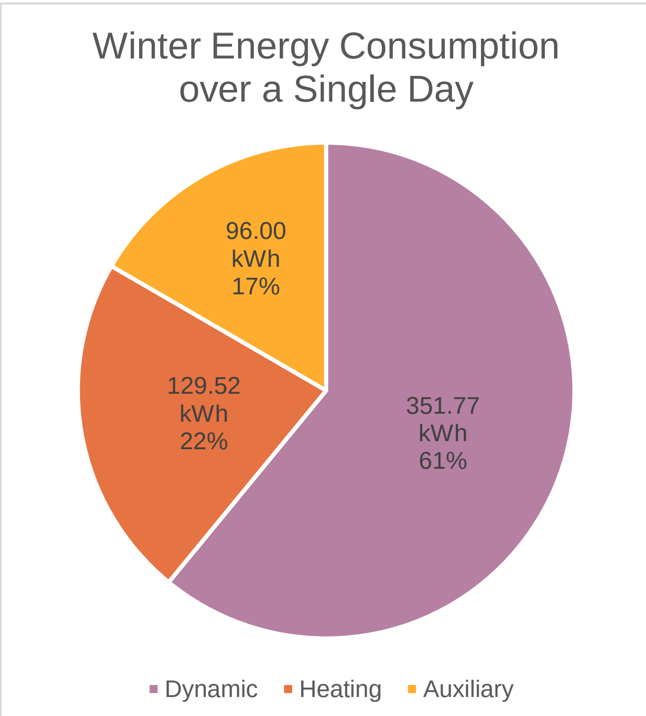
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.17 kWh/mi	1.93 kWh/mi	2.14 kWh/mi	2.21 kWh/mi

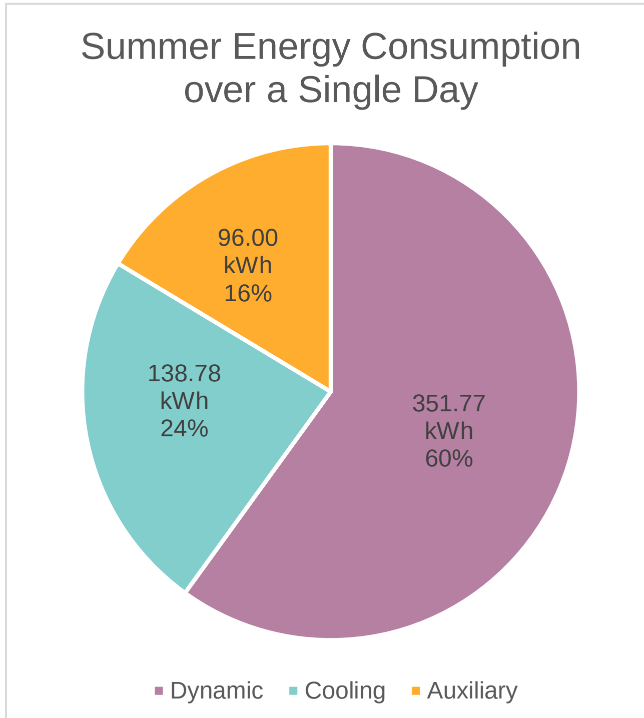
Local Route M Results

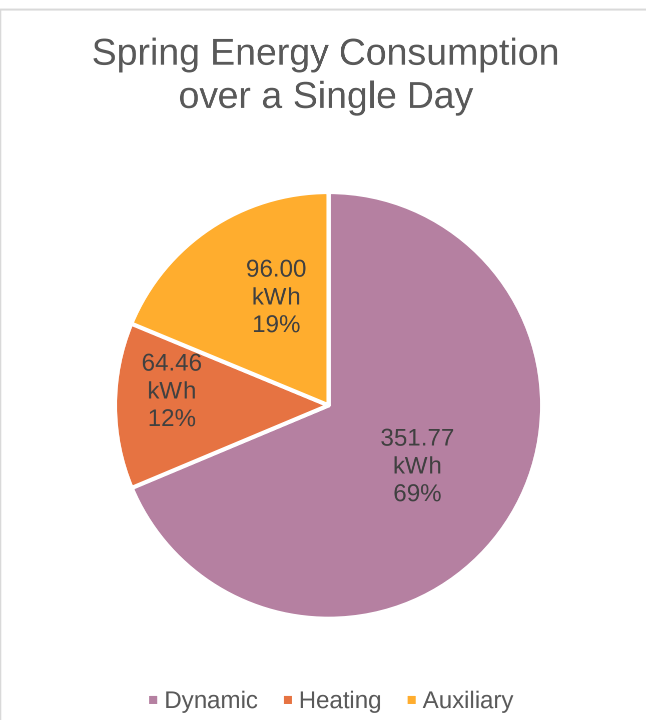
Daily Energy Consumption by Subsystem

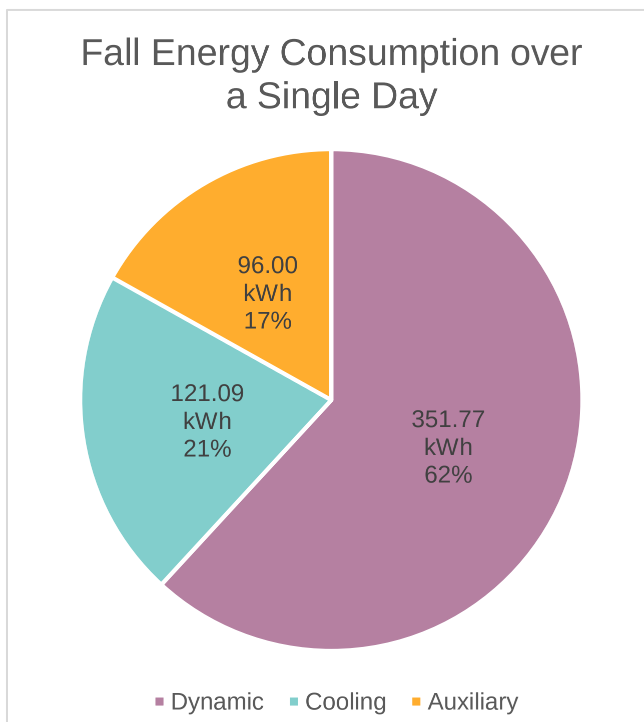
Total Daily Energy Consumption:

Summer:	586.55 KWH	Fall	568.86
Winter:	577.29 KWH	Spring	512.23









Local Route M Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**27.70**	0.00	**412.30**
2	**412.30**	**29.51**	57.21	**440.00**
3	**440.00**	**30.72**	0.00	**409.28**
4	**409.28**	**31.44**	62.16	**440.00**
5	**440.00**	**33.31**	0.00	**406.69**
6	**406.69**	**35.36**	65.00	**436.33**
7	**436.33**	**37.39**	0.00	**398.94**
8	**398.94**	**42.02**	65.00	**421.92**
9	**421.92**	**44.86**	0.00	**377.06**
10	**377.06**	**44.86**	65.00	**397.19**
11	**397.19**	**44.58**	0.00	**352.62**
12	**352.62**	**41.79**	65.00	**375.83**
13	**375.83**	**39.59**	0.00	**336.24**
14	**336.24**	**37.32**	65.00	**363.92**
15	**363.92**	**33.90**	0.00	**330.02**
16	**330.02**	**32.21**	65.00	**362.81**

Local Route M Results

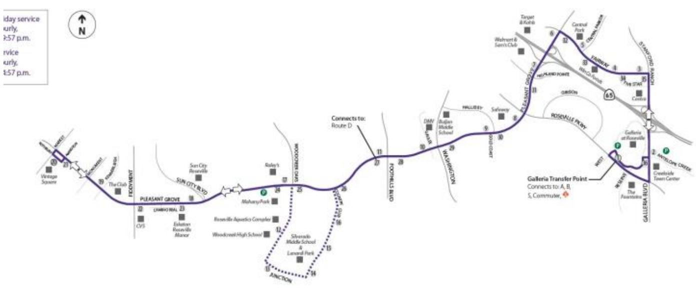
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**42.16**	0.00	**397.84**
2	**397.84**	**41.08**	65.00	**421.76**
3	**421.76**	**39.99**	0.00	**381.77**
4	**381.77**	**38.91**	65.00	**407.86**
5	**407.86**	**37.84**	0.00	**370.03**
6	**370.03**	**36.77**	65.00	**398.25**
7	**398.25**	**35.72**	0.00	**362.53**
8	**362.53**	**34.69**	65.00	**392.84**
9	**392.84**	**32.61**	0.00	**360.22**
10	**360.22**	**31.29**	65.00	**393.93**
11	**393.93**	**32.31**	0.00	**361.62**
12	**361.62**	**33.22**	65.00	**393.40**
13	**393.40**	**33.99**	0.00	**359.41**
14	**359.41**	**34.77**	65.00	**389.64**
15	**389.64**	**35.56**	0.00	**354.08**
16	**354.08**	**36.37**	65.00	**382.71**

Local Route M Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst XR 35 ft.

Battery Size: 440 KWH

Hours of Service 8 AM 5 PM

Charging Station Design

☑ On-Route Charging

Charger's output:	300	KW
Visit every	2	Lap
Time at Charger:	14	Minutes

Seasonal kWh per Mile Rate

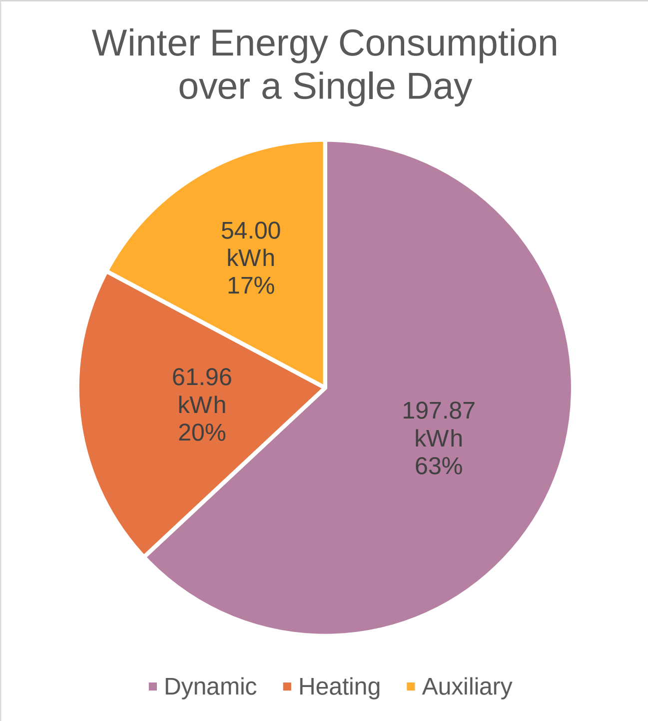
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.10 kWh/mi	2.07 kWh/mi	2.35 kWh/mi	2.37 kWh/mi

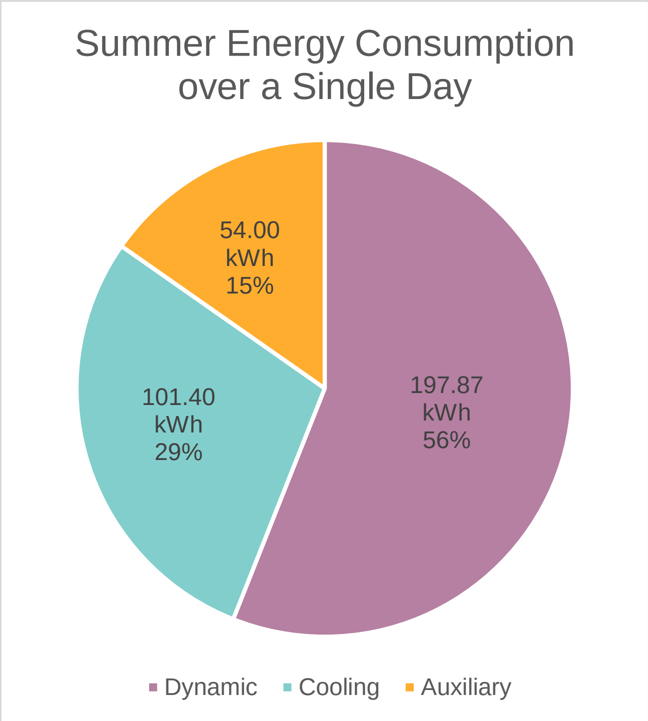
Local Route M Results

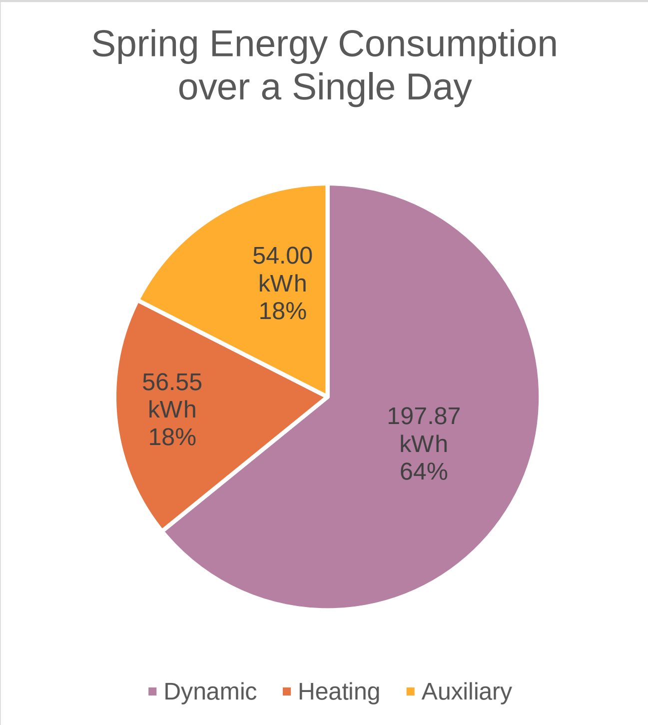
Daily Energy Consumption by Subsystem

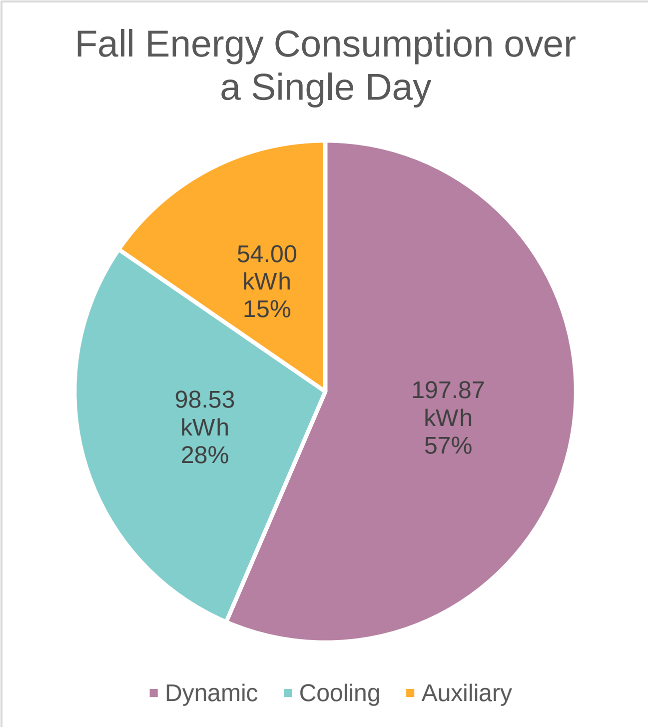
Total Daily Energy Consumption:

Summer:	353.27 KWH	Fall	350.40
Winter:	313.83 KWH	Spring	308.42









Local Route M Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**31.44**	0.00	**408.56**
2	**408.56**	**33.31**	64.75	**440.00**
3	**440.00**	**35.36**	0.00	**404.64**
4	**404.64**	**37.39**	70.00	**437.25**
5	**437.25**	**39.45**	0.00	**397.80**
6	**397.80**	**42.02**	70.00	**425.79**
7	**425.79**	**44.86**	0.00	**380.92**
8	**380.92**	**44.86**	70.00	**406.06**
9	**406.06**	**44.58**	0.00	**361.48**

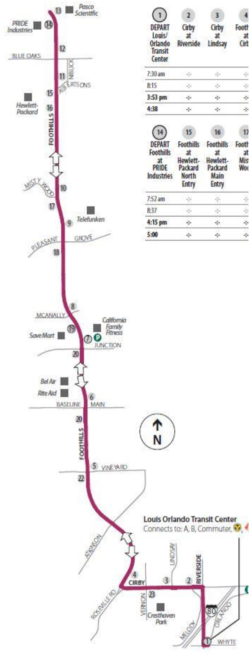
Local Route M Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**38.91**	0.00	**401.09**
2	**401.09**	**37.84**	70.00	**433.25**
3	**433.25**	**36.77**	0.00	**396.48**
4	**396.48**	**35.72**	70.00	**430.76**
5	**430.76**	**34.69**	0.00	**396.07**
6	**396.07**	**33.68**	70.00	**432.38**
7	**432.38**	**32.61**	0.00	**399.77**
8	**399.77**	**31.29**	70.00	**438.48**
9	**438.48**	**32.31**	0.00	**406.17**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	7 AM
	9 AM

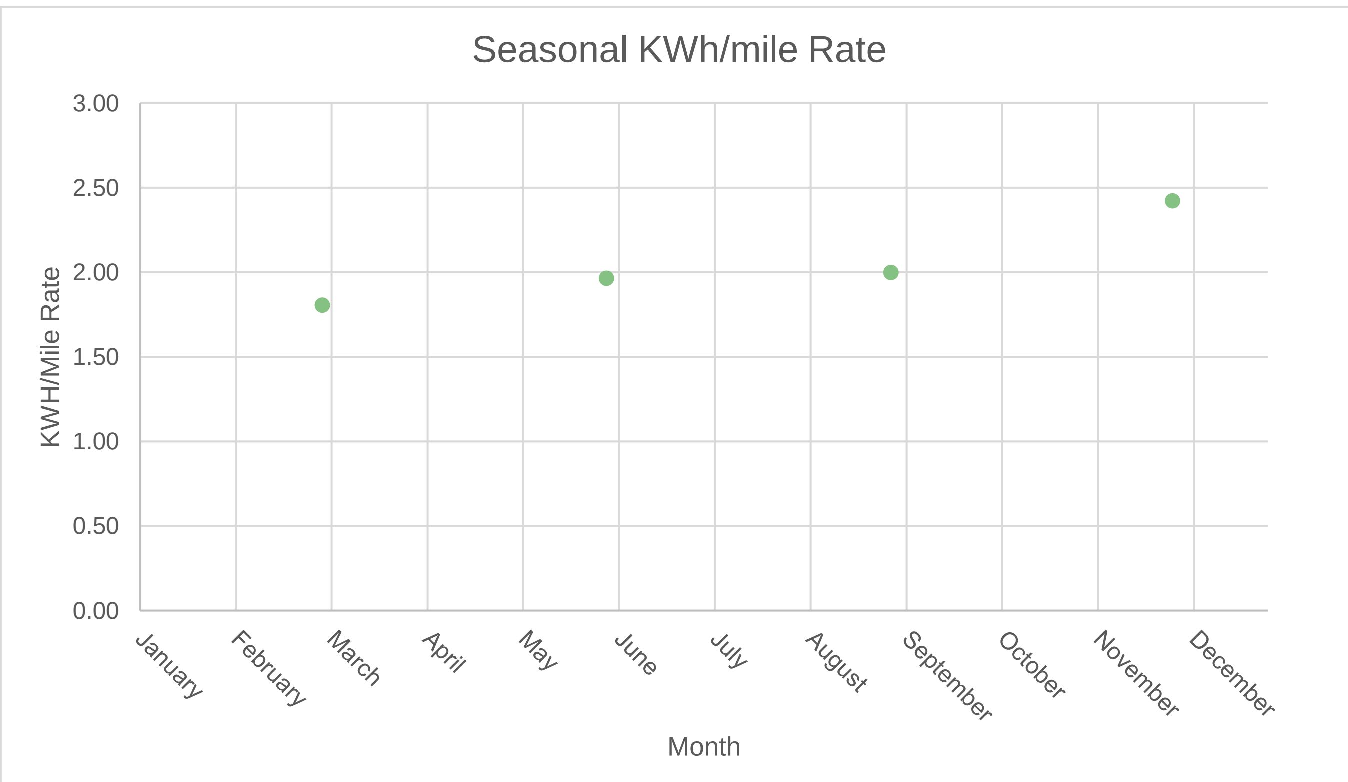
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.42 kWh/mi	1.81 kWh/mi	2.00 kWh/mi	1.96 kWh/mi

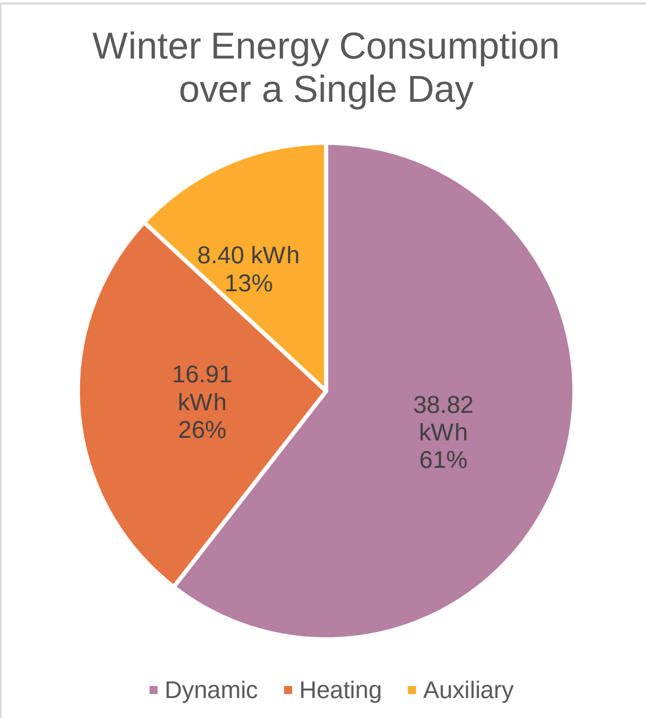


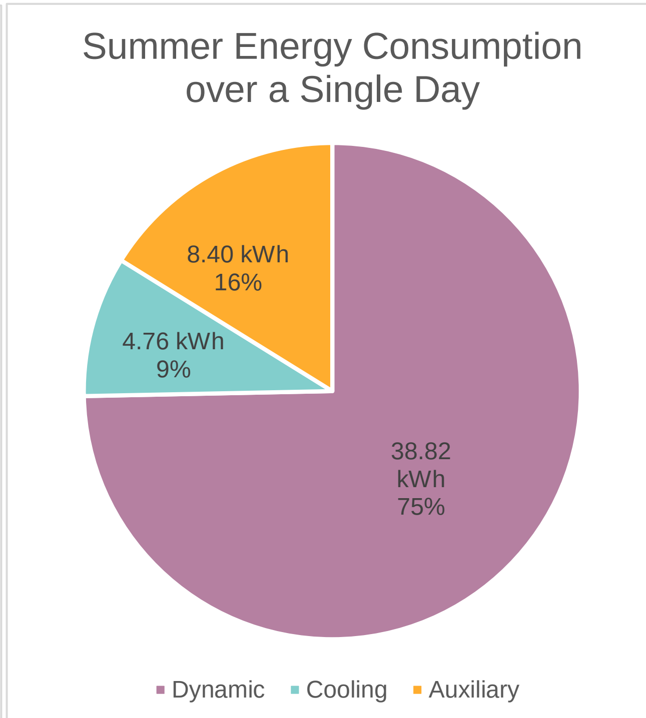
Local Route R AM Results

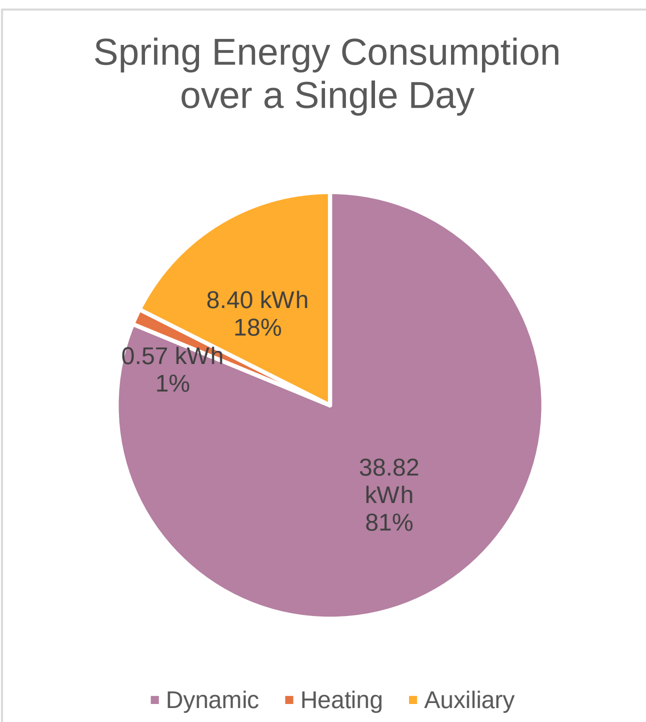
Daily Energy Consumption by Subsystem

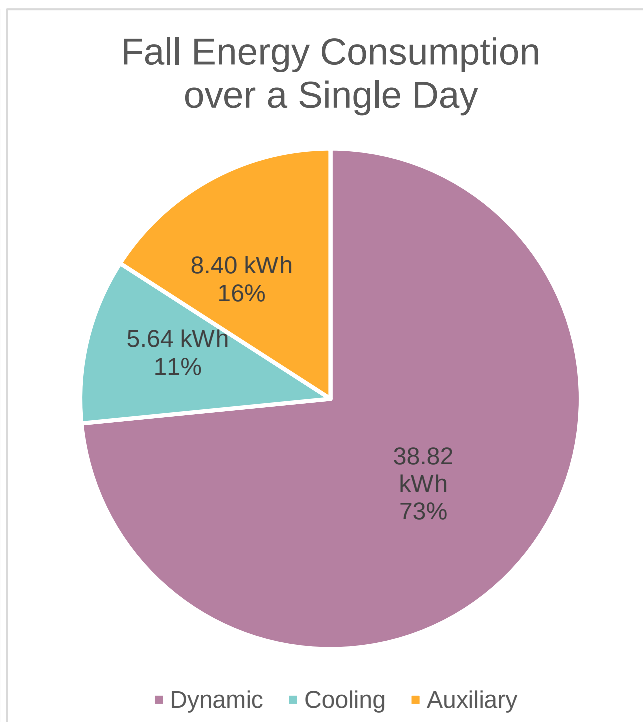
Total Daily Energy Consumption:

Summer:	51.98 KWH	Fall	52.86
Winter:	64.13 KWH	Spring	47.79









Local Route R AM Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**25.72**	0.00	**414.28**
2	**414.28**	**26.26**	0.00	**388.02**

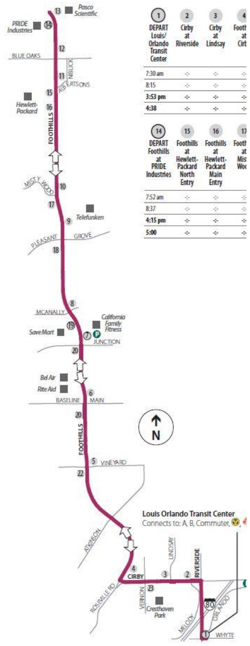
Local Route R AM Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**32.46**	0.00	**407.54**
2	**407.54**	**31.67**	0.00	**375.87**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 35 ft.
Battery Size:	440 KWH
Hours of Service	4 PM
	6 PM

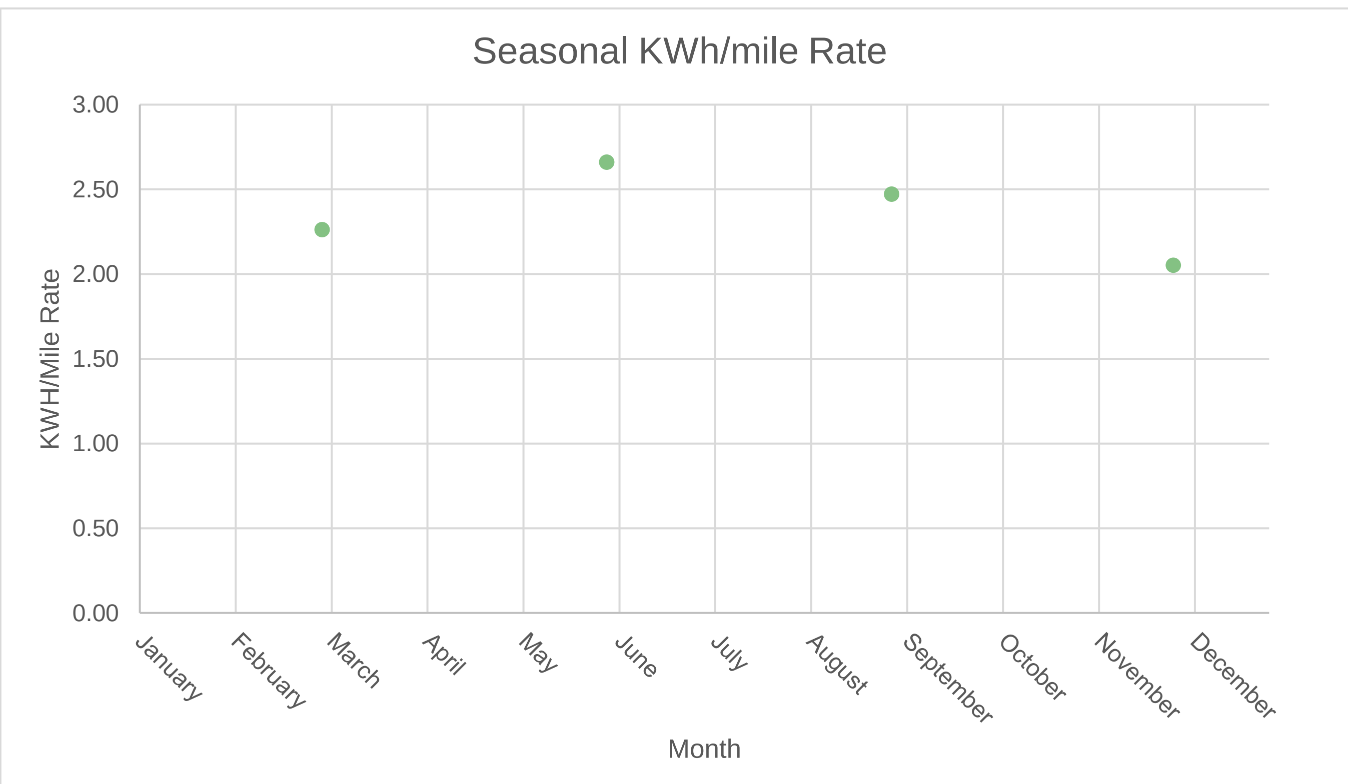
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.05 kWh/mi	2.26 kWh/mi	2.47 kWh/mi	2.66 kWh/mi

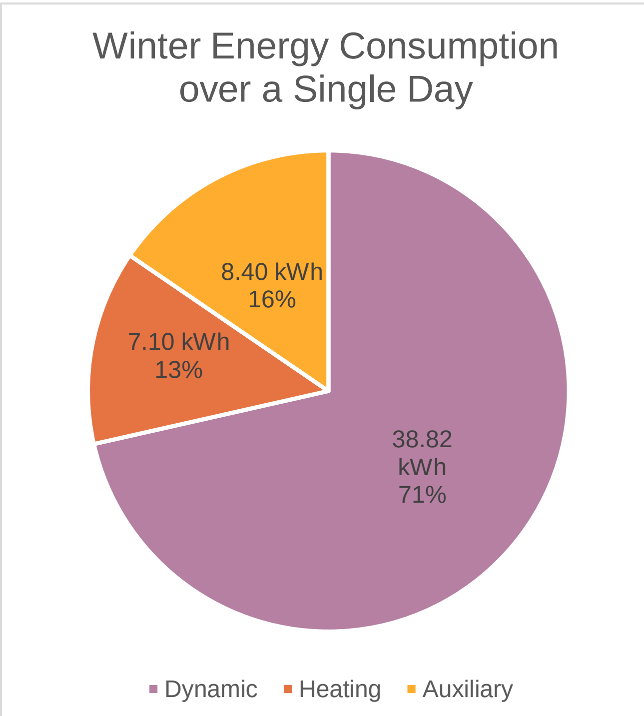


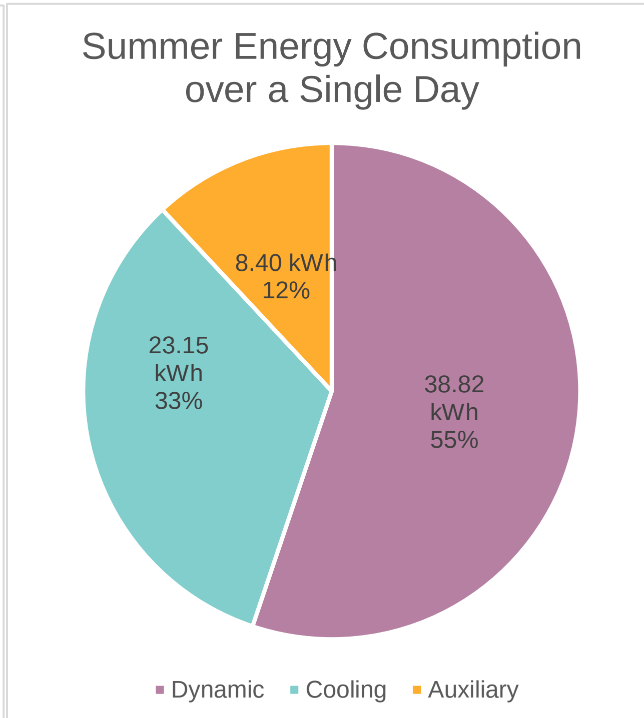
Local Route R PM Results

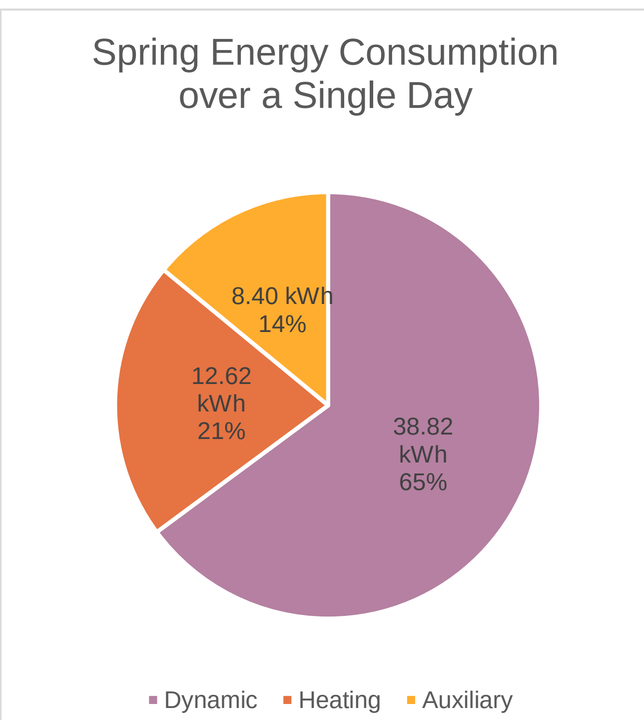
Daily Energy Consumption by Subsystem

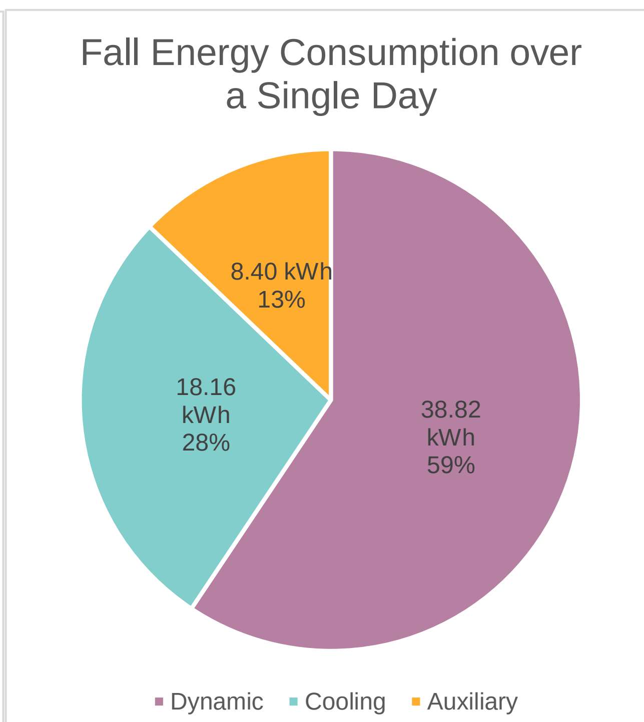
Total Daily Energy Consumption:

Summer:	70.36 KWH	Fall	65.37
Winter:	54.32 KWH	Spring	59.83









Local Route R PM Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**36.23**	0.00	**403.77**
2	**403.77**	**34.13**	0.00	**369.64**

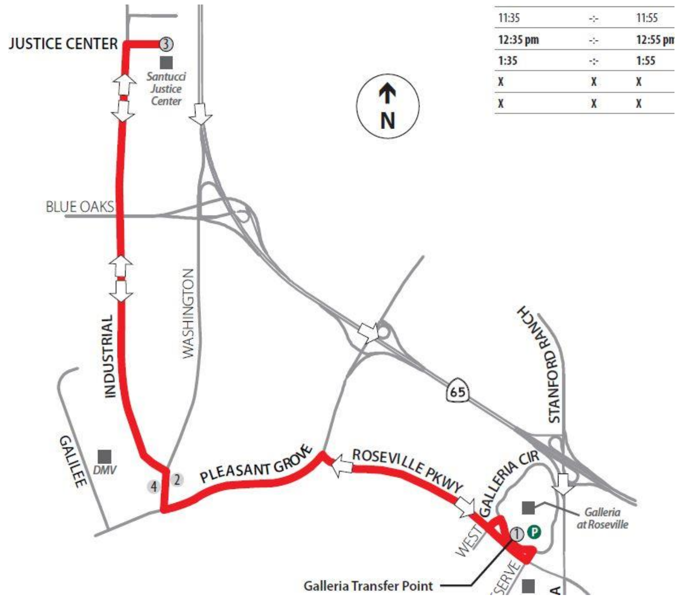
Local Route R PM Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**26.82**	0.00	**413.18**
2	**413.18**	**27.50**	0.00	**385.68**

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 35 ft.

Battery Size: 440 KWH

Hours of Service 7 AM
3 PM

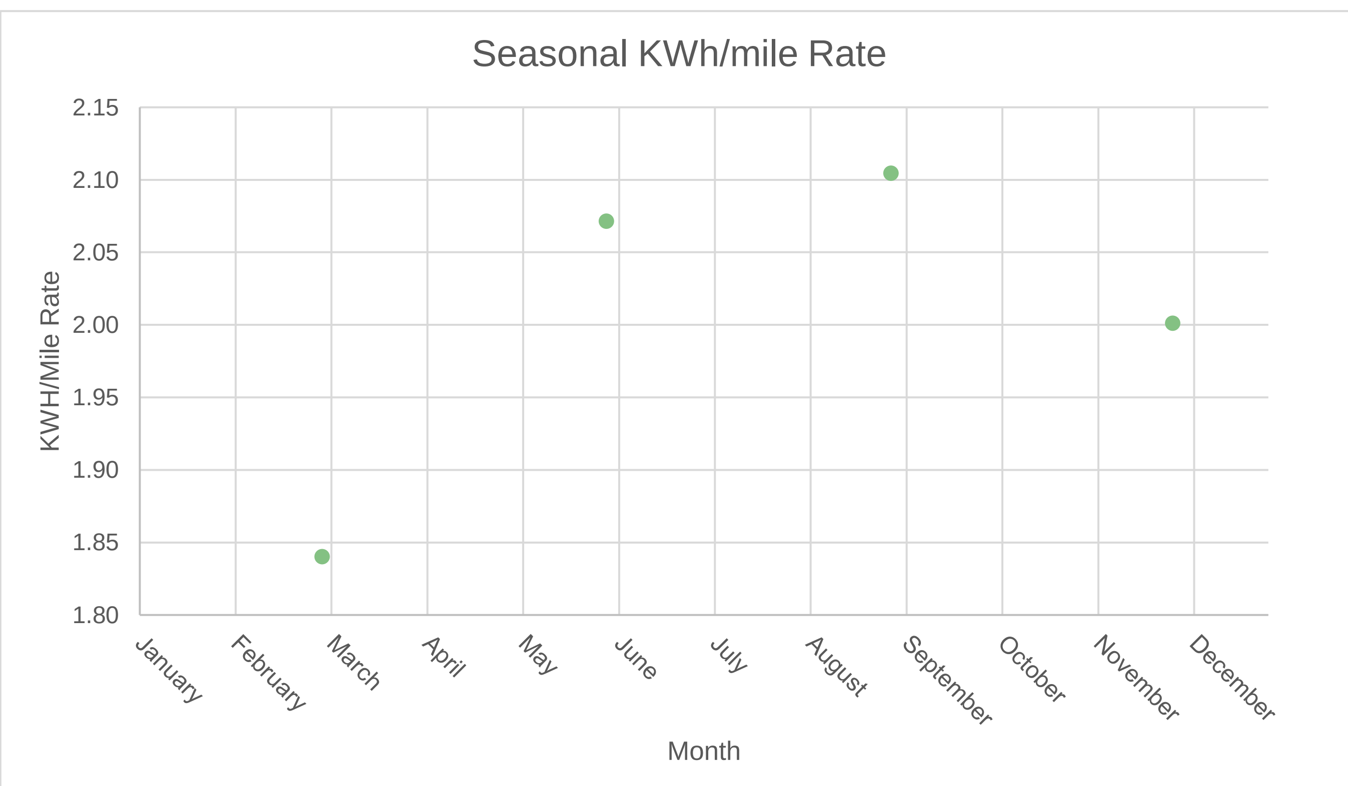
Charging Station Design

☑ Overnight Depot Charging

Charger's output: 60 KW
Time at Charger: 8 Hours

Seasonal kWh per Mile Rate

Average Winter:	Average Spring	Average Fall:	Average Summer:
2.00 kWh/mi	1.84 kWh/mi	2.10 kWh/mi	2.07 kWh/mi

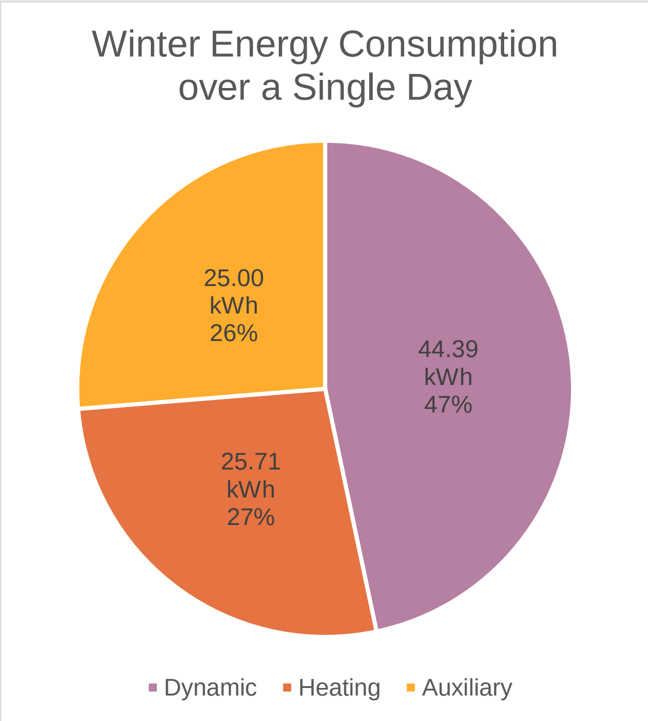


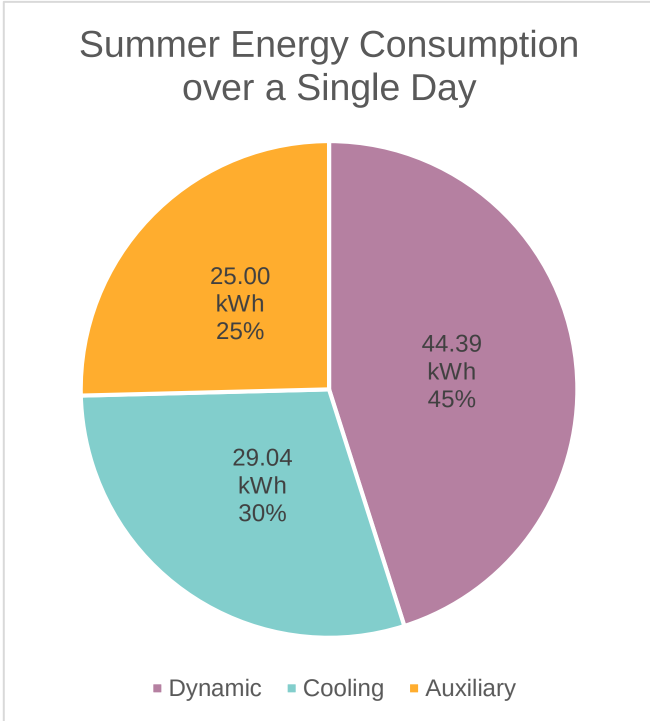
Local Route S1 Results

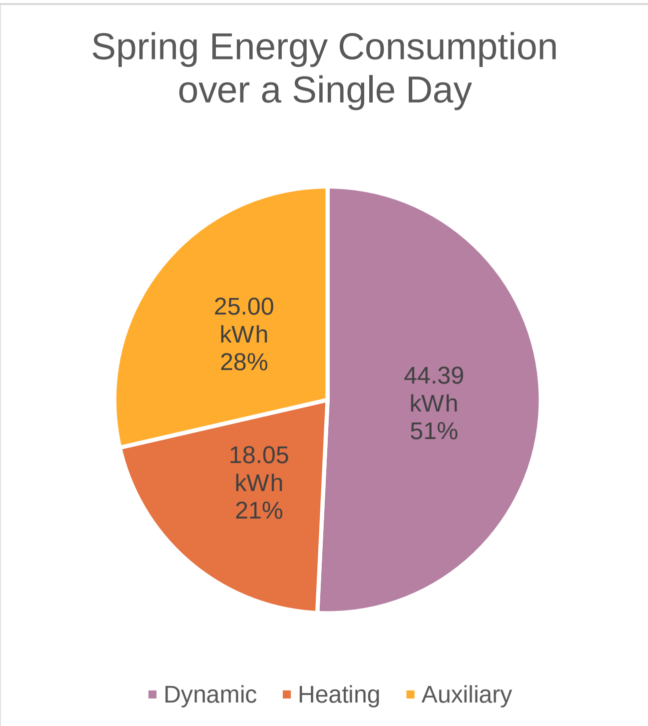
Daily Energy Consumption by Subsystem

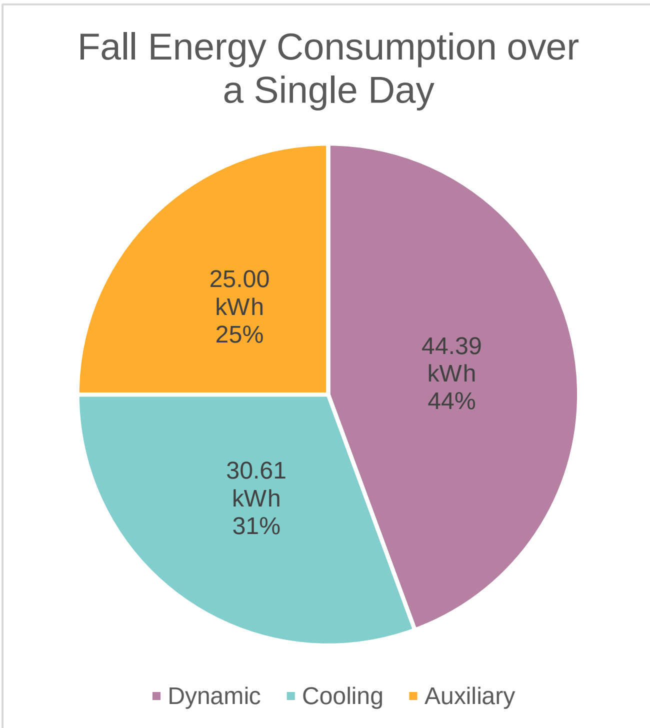
Total Daily Energy Consumption:

Summer:	98.43 KWH	Fall	100.00
Winter:	95.10 KWH	Spring	87.44









Local Route S1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**16.24**	0.00	**423.76**
2	**423.76**	**17.78**	0.00	**405.97**
3	**405.97**	**19.88**	0.00	**386.09**
4	**386.09**	**21.75**	0.00	**364.34**
5	**364.34**	**22.78**	0.00	**341.57**

Local Route S1 Results

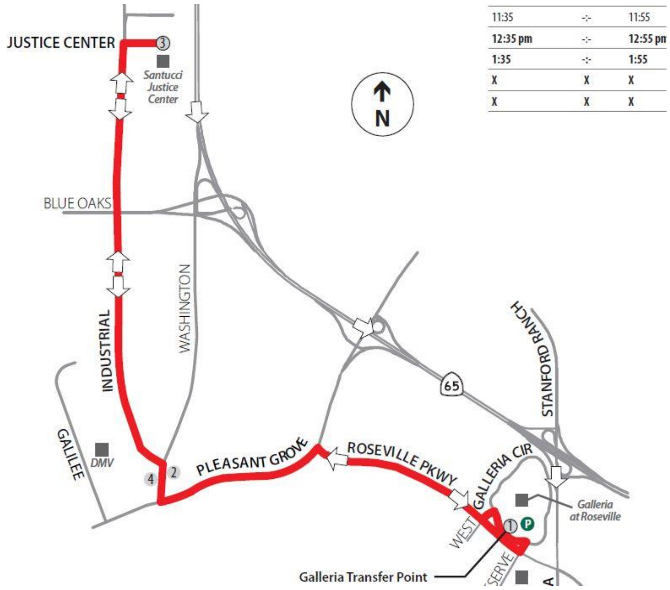
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**21.15**	0.00	**418.85**
2	**418.85**	**20.48**	0.00	**398.36**
3	**398.36**	**19.14**	0.00	**379.22**
4	**379.22**	**17.82**	0.00	**361.40**
5	**361.40**	**16.50**	0.00	**344.90**

Local Route S2 Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 35 ft.

Battery Size: 440 KWH

Hours of Service 4 PM 6 PM

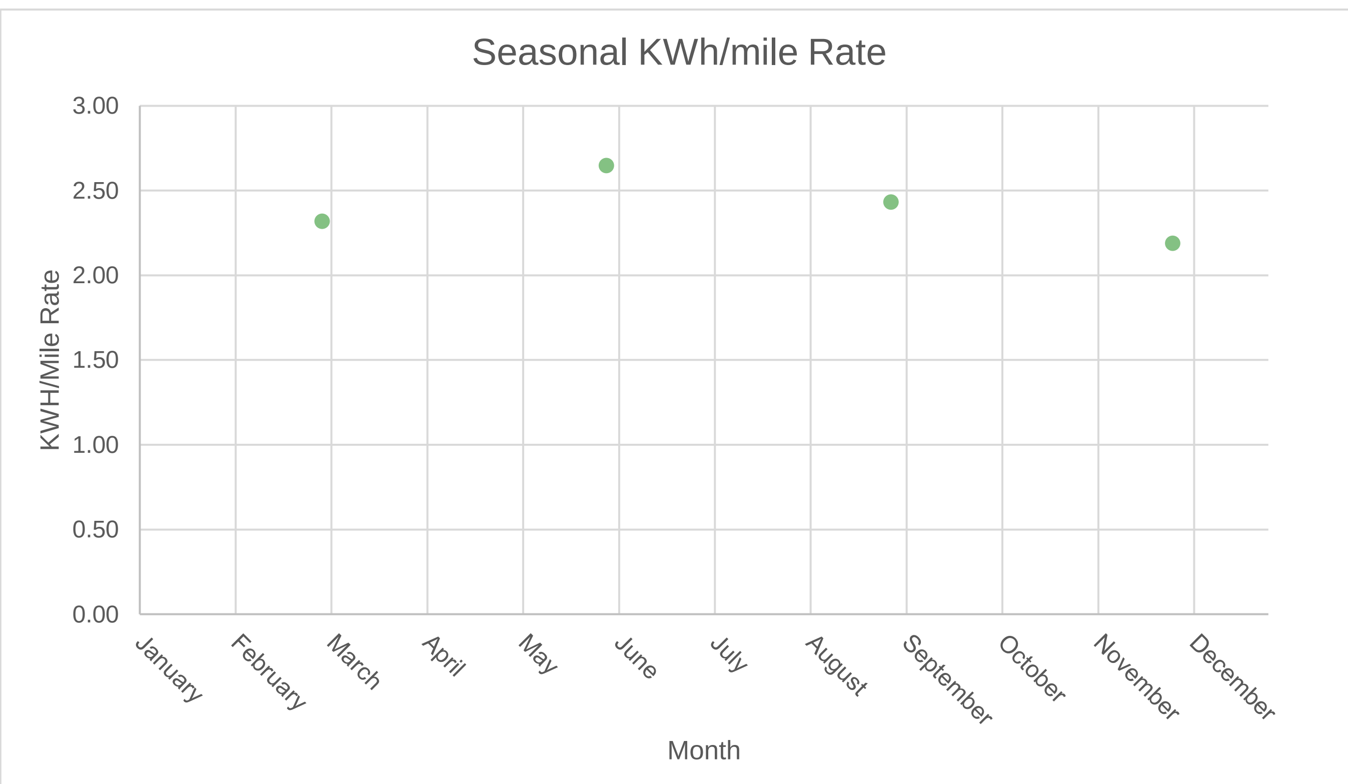
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.19 kWh/mi	2.32 kWh/mi	2.43 kWh/mi	2.65 kWh/mi

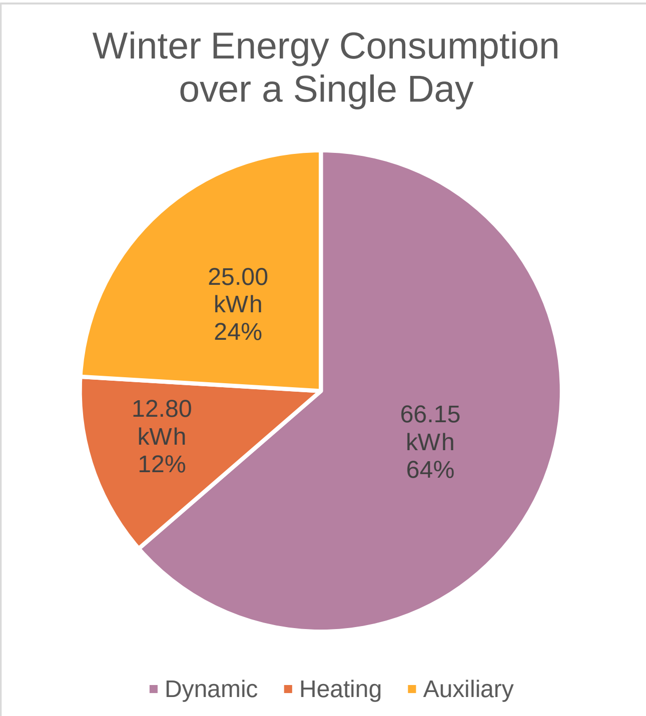


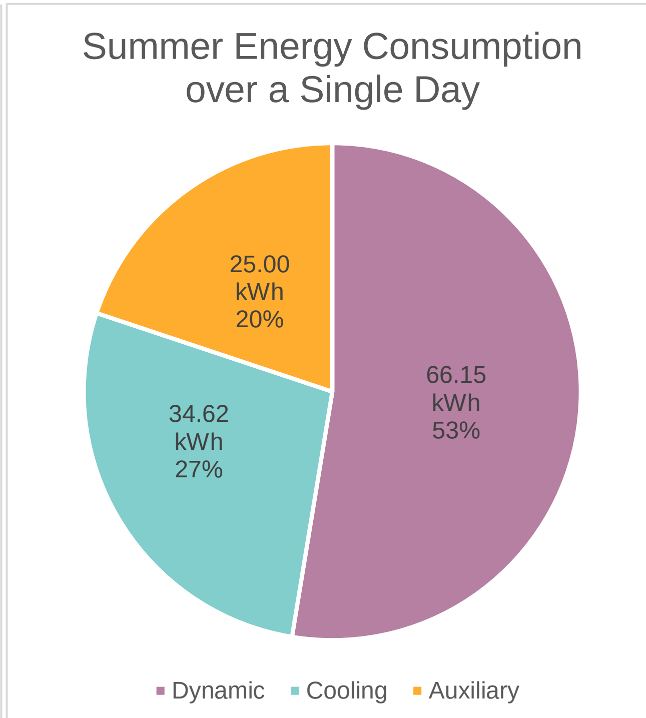
Local Route S2 Results

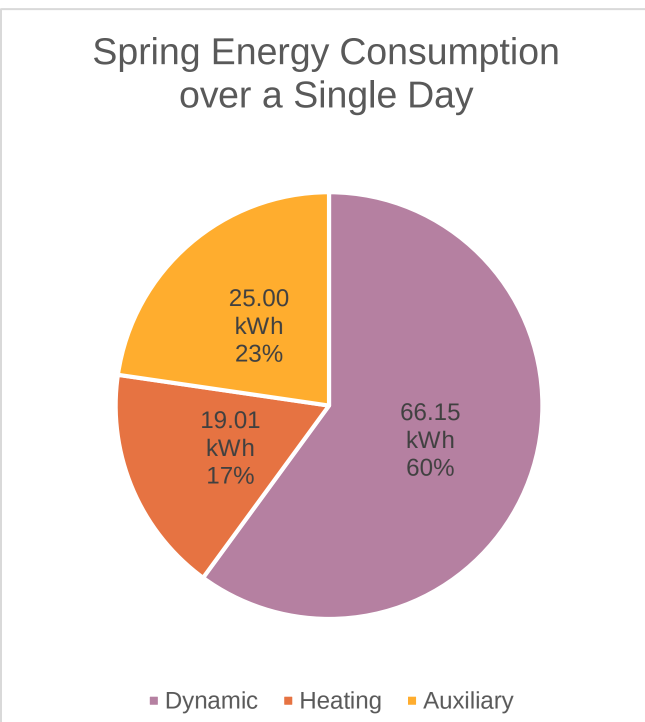
Daily Energy Consumption by Subsystem

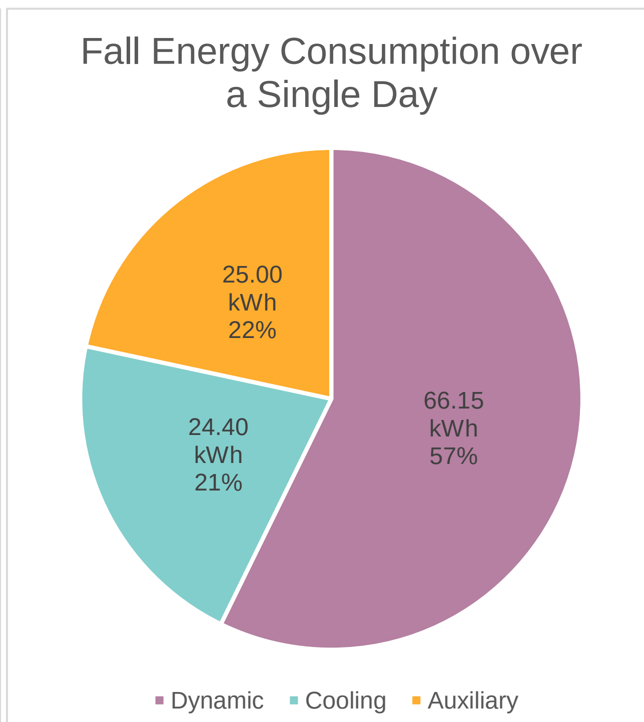
Total Daily Energy Consumption:

Summer:	125.77 KWH	Fall	115.55
Winter:	103.95 KWH	Spring	110.16









Local Route S2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**26.00**	0.00	**414.00**
2	**414.00**	**26.00**	0.00	**387.99**
3	**387.99**	**24.87**	0.00	**363.13**
4	**363.13**	**24.87**	0.00	**338.26**
5	**338.26**	**24.03**	0.00	**314.23**

Local Route S2 Results

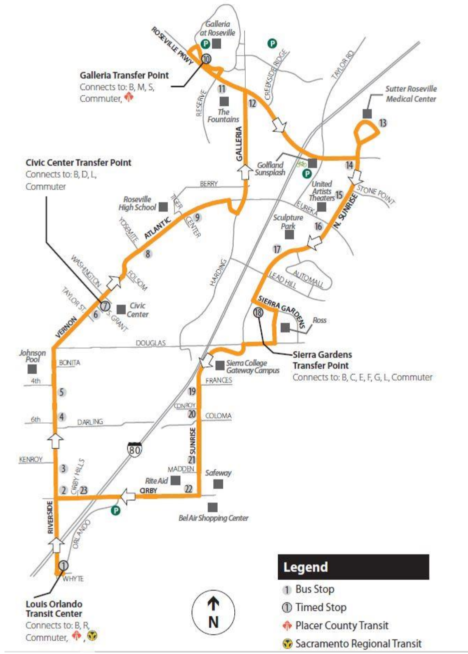
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**440.00**	**20.13**	0.00	**419.87**
2	**419.87**	**20.69**	0.00	**399.19**
3	**399.19**	**20.69**	0.00	**378.50**
4	**378.50**	**21.23**	0.00	**357.27**
5	**357.27**	**21.23**	0.00	**336.05**

Local Route A1 Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 max 40 ft.

Battery Size: 660 KWH

Hours of Service: 6 AM – 10 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

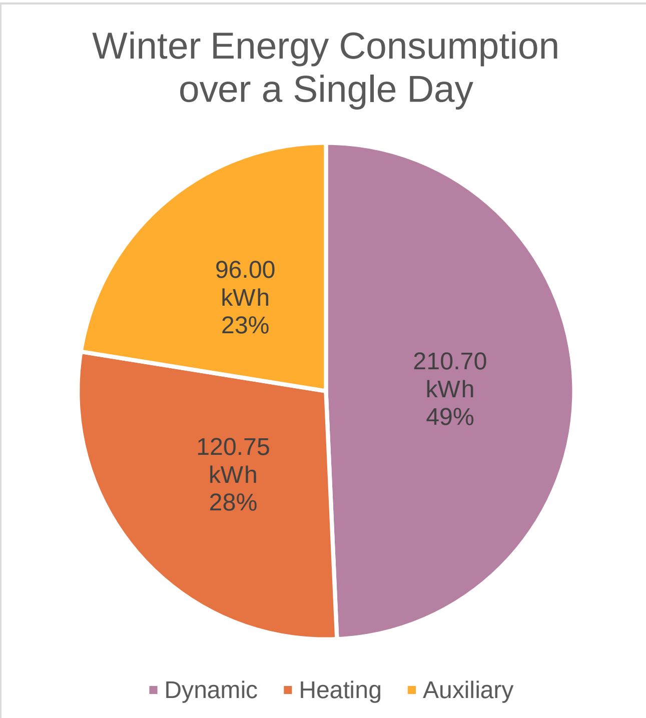
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.32 kWh/mi	2.08 kWh/mi	2.41 kWh/mi	2.50 kWh/mi

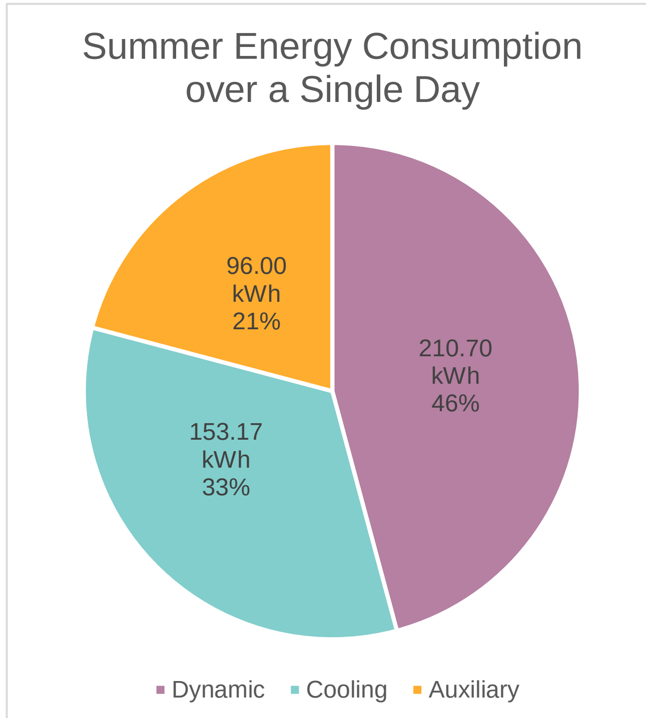
Local Route A1 Results

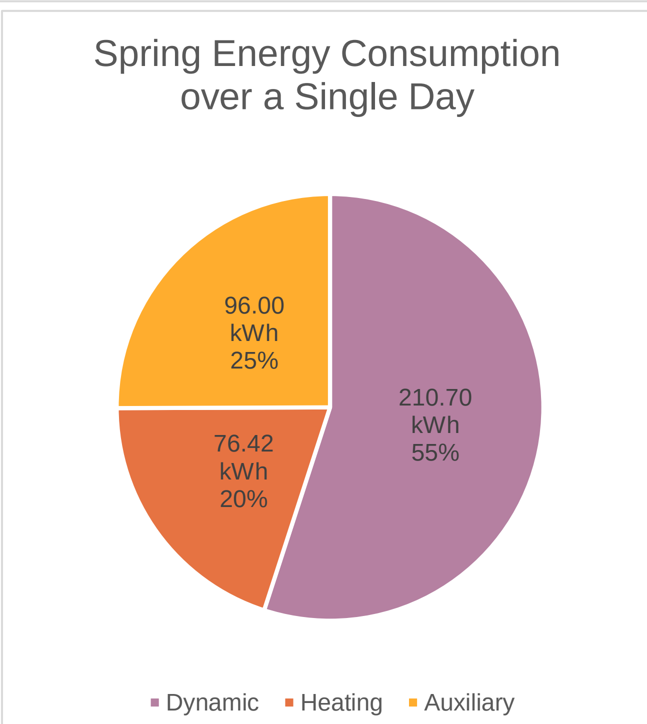
Daily Energy Consumption by Subsystem

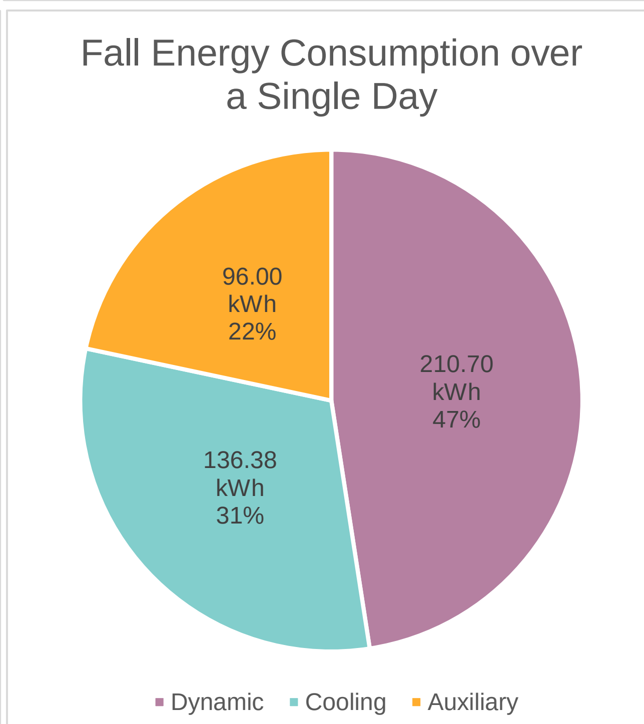
Total Daily Energy Consumption:

Summer:	459.87 KWH	Fall	443.08
Winter:	427.45 KWH	Spring	383.12









Local Route A1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**21.10**	0.00	**638.90**
2	**638.90**	**22.42**	0.00	**616.48**
3	**616.48**	**23.11**	0.00	**593.37**
4	**593.37**	**25.07**	0.00	**568.31**
5	**568.31**	**27.12**	0.00	**541.18**
6	**541.18**	**29.08**	0.00	**512.10**
7	**512.10**	**30.99**	0.00	**481.11**
8	**481.11**	**33.34**	0.00	**447.77**
9	**447.77**	**35.88**	0.00	**411.89**
10	**411.89**	**35.88**	0.00	**376.01**
11	**376.01**	**35.51**	0.00	**340.50**
12	**340.50**	**32.83**	0.00	**307.67**
13	**307.67**	**30.75**	0.00	**276.92**
14	**276.92**	**28.55**	0.00	**248.37**
15	**248.37**	**24.94**	0.00	**223.44**
16	**223.44**	**23.31**	0.00	**200.13**

Local Route A1 Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**32.30**	0.00	**627.70**
2	**627.70**	**31.21**	0.00	**596.49**
3	**596.49**	**30.12**	0.00	**566.37**
4	**566.37**	**29.03**	0.00	**537.34**
5	**537.34**	**27.96**	0.00	**509.38**
6	**509.38**	**26.89**	0.00	**482.48**
7	**482.48**	**25.84**	0.00	**456.64**
8	**456.64**	**24.81**	0.00	**431.83**
9	**431.83**	**23.73**	0.00	**408.09**
10	**408.09**	**22.44**	0.00	**385.66**
11	**385.66**	**23.43**	0.00	**362.22**
12	**362.22**	**24.34**	0.00	**337.88**
13	**337.88**	**25.13**	0.00	**312.75**
14	**312.75**	**25.92**	0.00	**286.83**
15	**286.83**	**26.73**	0.00	**260.10**
16	**260.10**	**27.55**	0.00	**232.55**

Electric Bus Corridor Model Results

Background

Bus Model:	Proterra Catalyst E2 max 40 ft.
Battery Size:	660 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

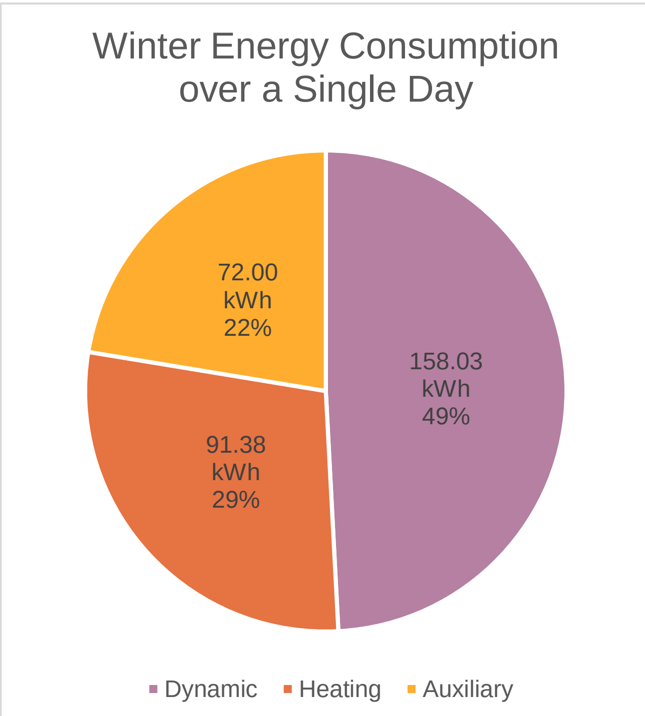
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.33 kWh/mi	2.16 kWh/mi	2.48 kWh/mi	2.57 kWh/mi

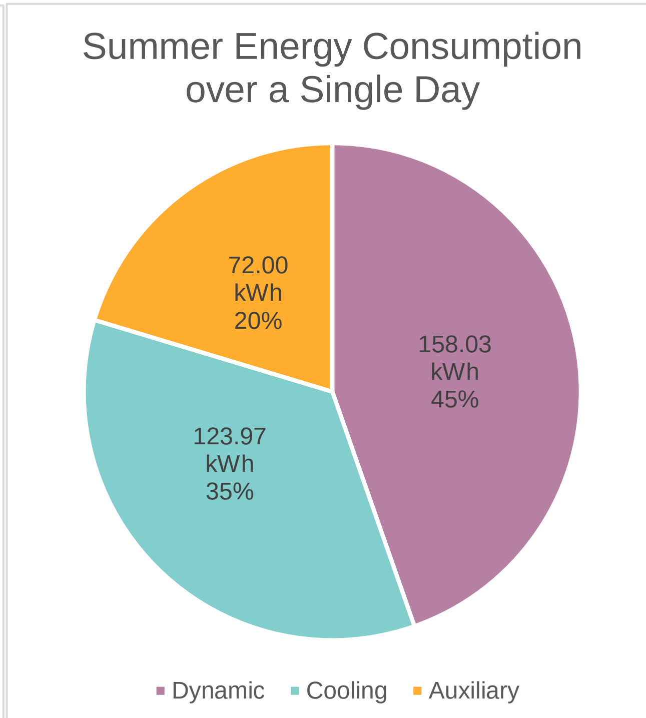
Local Route A2 Results

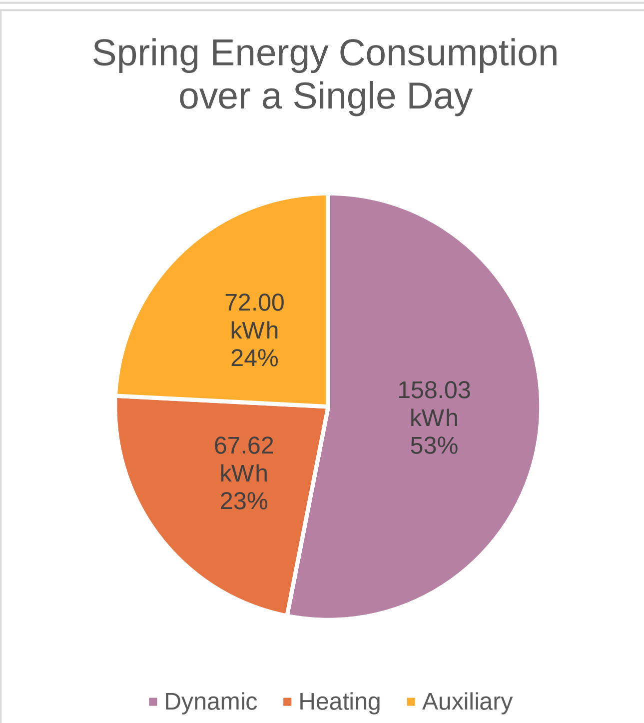
Daily Energy Consumption by Subsystem

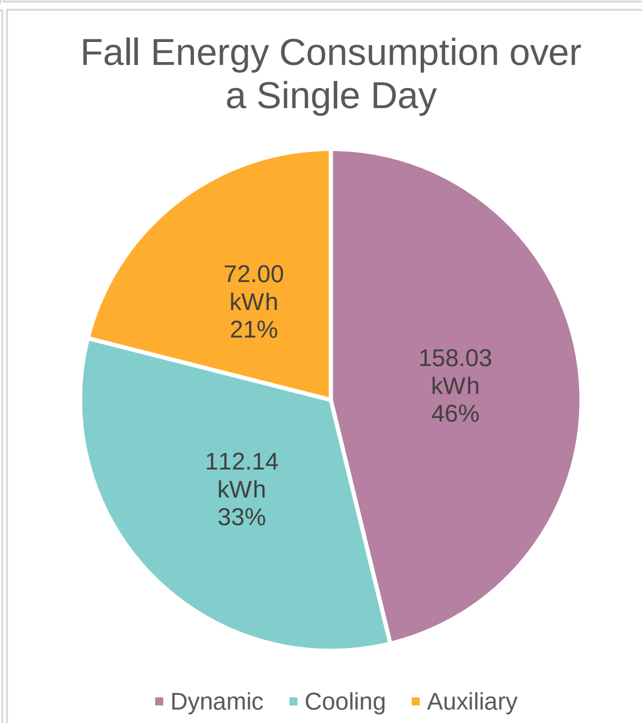
Total Daily Energy Consumption:

Summer:	354.00 KWH	Fall	342.16
Winter:	321.40 KWH	Spring	297.65









Local Route A2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**21.10**	0.00	**638.90**
2	**638.90**	**22.42**	0.00	**616.48**
3	**616.48**	**23.11**	0.00	**593.37**
4	**593.37**	**25.07**	0.00	**568.31**
5	**568.31**	**27.12**	0.00	**541.18**
6	**541.18**	**30.99**	0.00	**510.19**
7	**510.19**	**33.34**	0.00	**476.85**
8	**476.85**	**35.88**	0.00	**440.97**
9	**440.97**	**35.88**	0.00	**405.09**
10	**405.09**	**35.51**	0.00	**369.58**
11	**369.58**	**32.83**	0.00	**336.75**
12	**336.75**	**30.75**	0.00	**306.00**

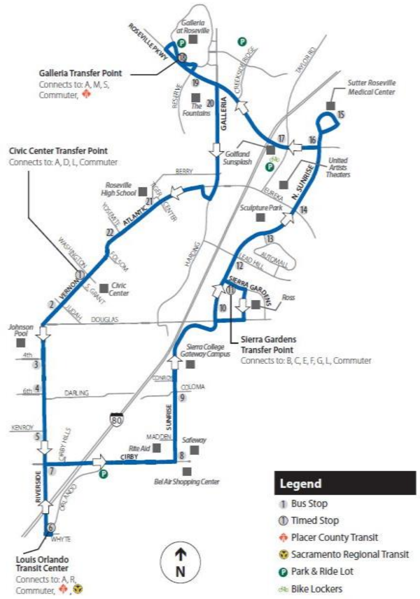
Local Route A2 Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**32.30**	0.00	**627.70**
2	**627.70**	**31.21**	0.00	**596.49**
3	**596.49**	**30.12**	0.00	**566.37**
4	**566.37**	**29.03**	0.00	**537.34**
5	**537.34**	**27.96**	0.00	**509.38**
6	**509.38**	**26.89**	0.00	**482.48**
7	**482.48**	**24.81**	0.00	**457.67**
8	**457.67**	**23.73**	0.00	**433.94**
9	**433.94**	**22.44**	0.00	**411.50**
10	**411.50**	**23.43**	0.00	**388.07**
11	**388.07**	**24.34**	0.00	**363.72**
12	**363.72**	**25.13**	0.00	**338.60**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40 ft.
Battery Size:	660 KWH
Hours of Service	6 AM 7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

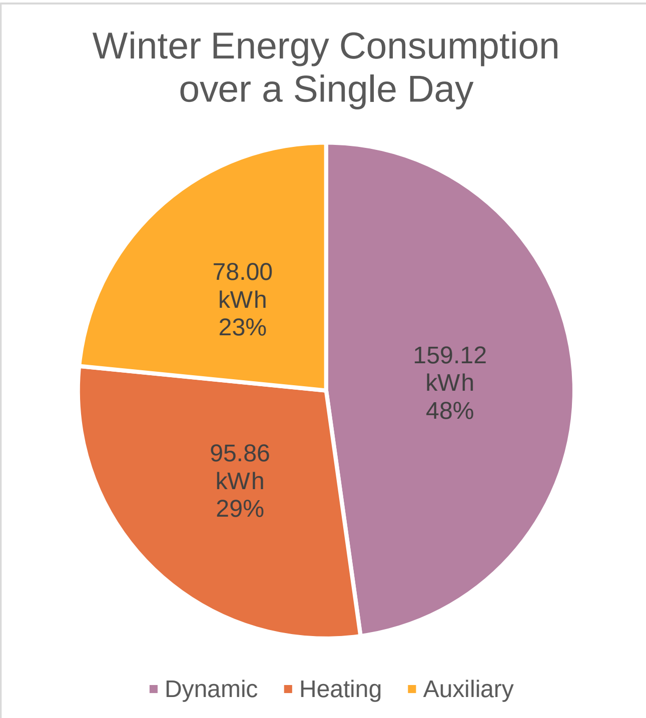
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.30 kWh/mi	2.14 kWh/mi	2.47 kWh/mi	2.54 kWh/mi

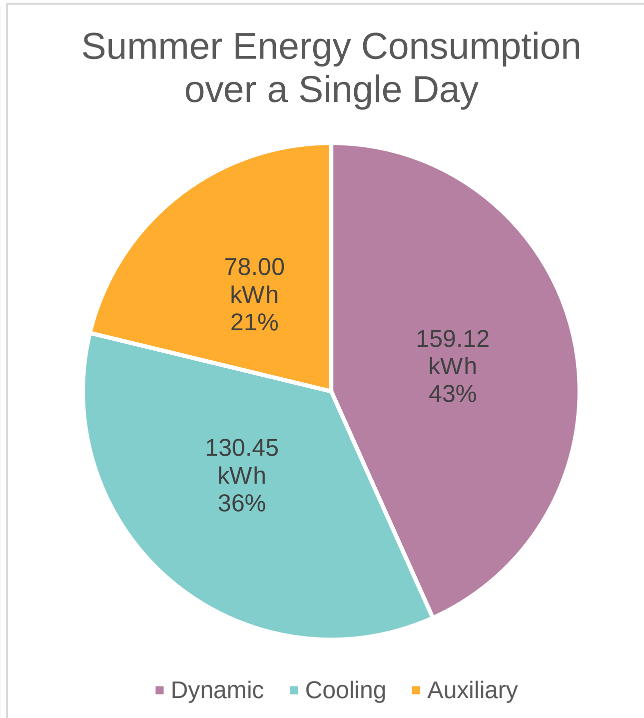
Local Route B1 Results

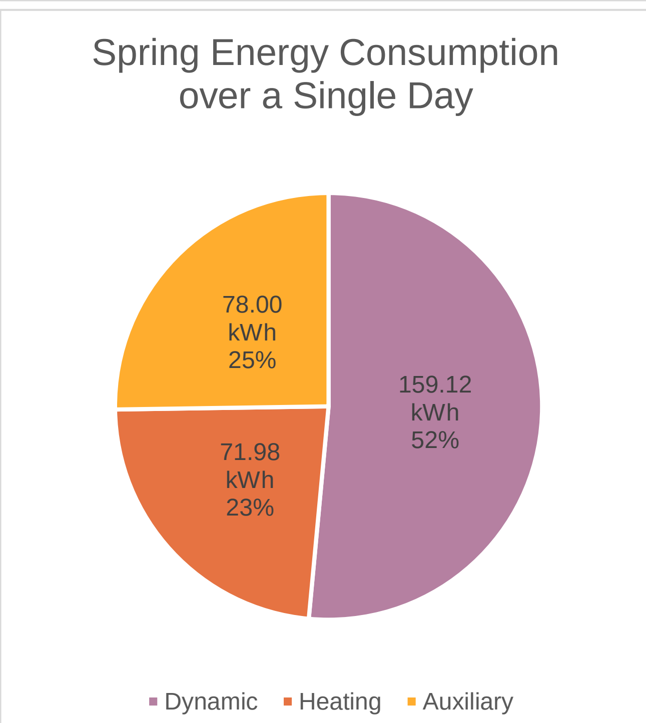
Daily Energy Consumption by Subsystem

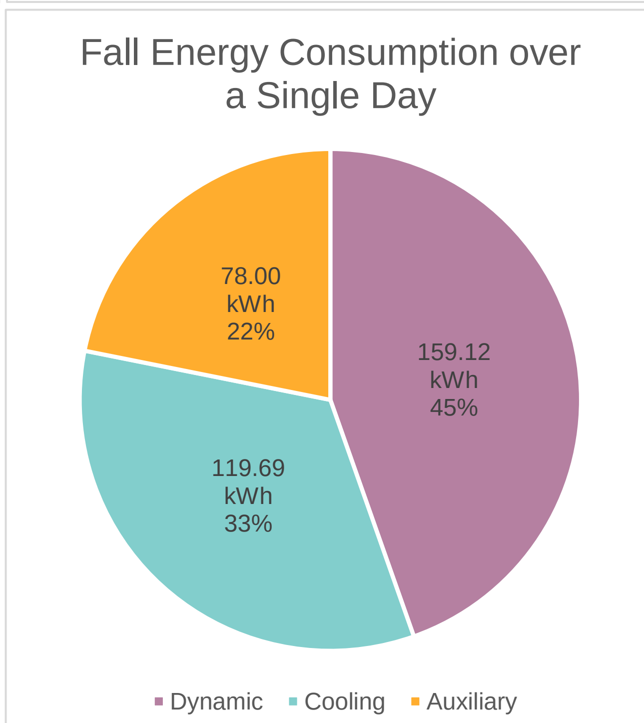
Total Daily Energy Consumption:

Summer:	367.57 KWH	Fall	356.81
Winter:	332.98 KWH	Spring	309.10









Local Route B1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**20.15**	0.00	**639.85**
2	**639.85**	**21.46**	0.00	**618.39**
3	**618.39**	**22.13**	0.00	**596.26**
4	**596.26**	**24.06**	0.00	**572.20**
5	**572.20**	**26.06**	0.00	**546.14**
6	**546.14**	**27.95**	0.00	**518.19**
7	**518.19**	**29.78**	0.00	**488.41**
8	**488.41**	**32.04**	0.00	**456.38**
9	**456.38**	**34.45**	0.00	**421.93**
10	**421.93**	**34.45**	0.00	**387.48**
11	**387.48**	**34.08**	0.00	**353.40**
12	**353.40**	**31.49**	0.00	**321.91**
13	**321.91**	**29.49**	0.00	**292.43**

Local Route B1 Results

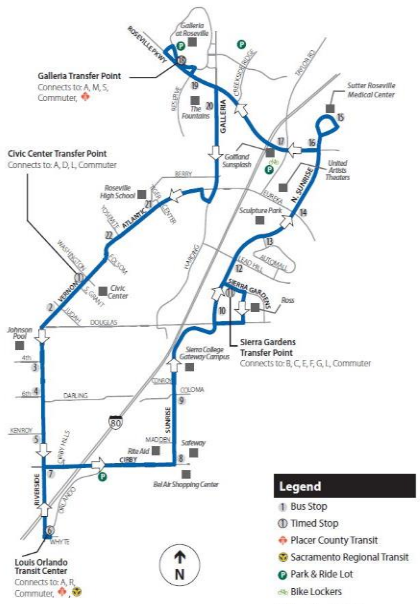
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**31.10**	0.00	**628.90**
2	**628.90**	**30.03**	0.00	**598.88**
3	**598.88**	**28.96**	0.00	**569.92**
4	**569.92**	**27.89**	0.00	**542.03**
5	**542.03**	**26.84**	0.00	**515.19**
6	**515.19**	**25.79**	0.00	**489.39**
7	**489.39**	**24.76**	0.00	**464.63**
8	**464.63**	**23.75**	0.00	**440.88**
9	**440.88**	**22.69**	0.00	**418.19**
10	**418.19**	**21.43**	0.00	**396.76**
11	**396.76**	**22.40**	0.00	**374.36**
12	**374.36**	**23.29**	0.00	**351.08**
13	**351.08**	**24.06**	0.00	**327.02**

Local Route B2 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40 ft.
Battery Size:	660 KWH
Hours of Service	6 AM
	10 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

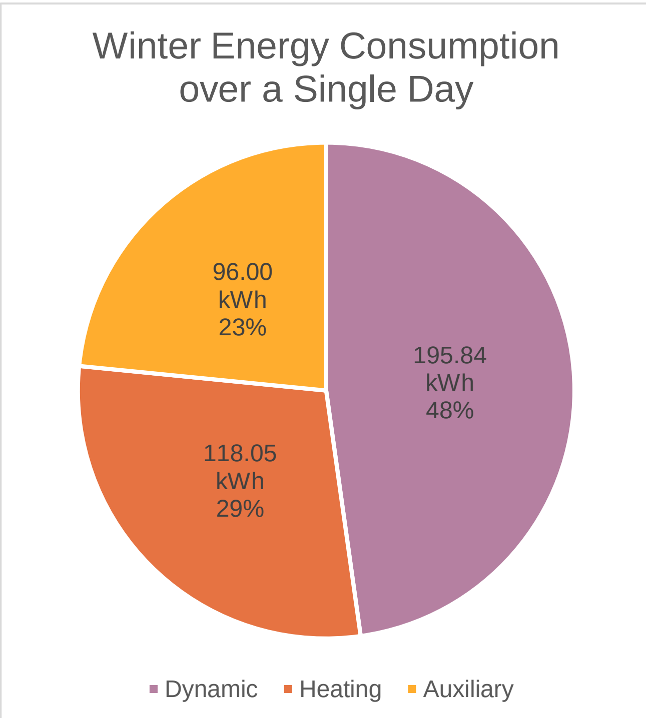
Seasonal kWh per Mile Rate

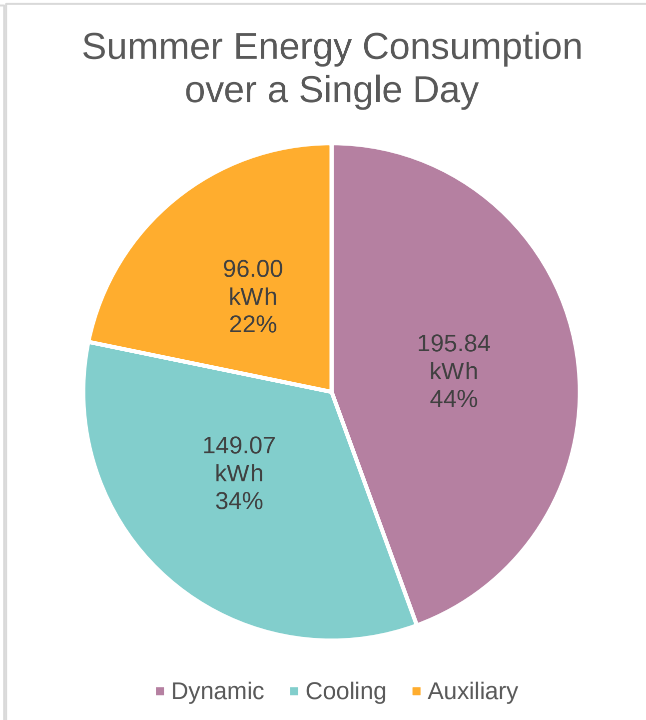
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.30 kWh/mi	2.06 kWh/mi	2.39 kWh/mi	2.48 kWh/mi

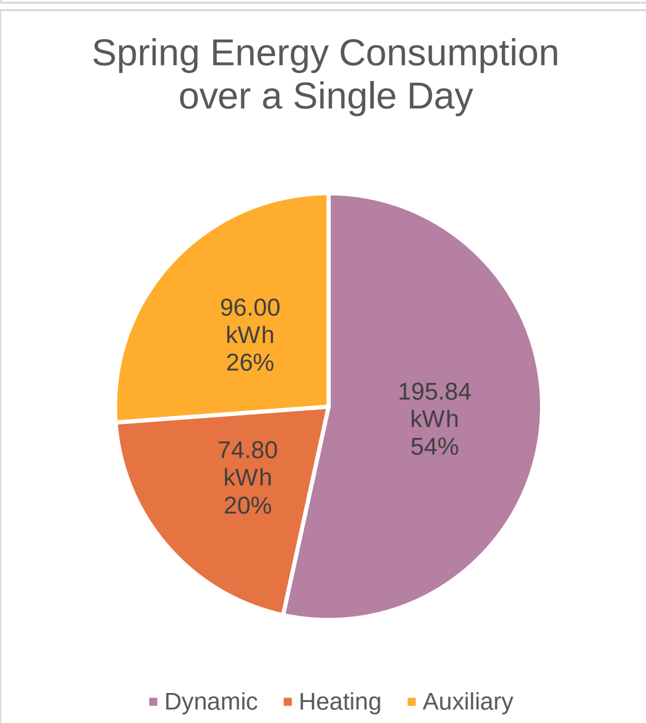
Daily Energy Consumption by Subsystem

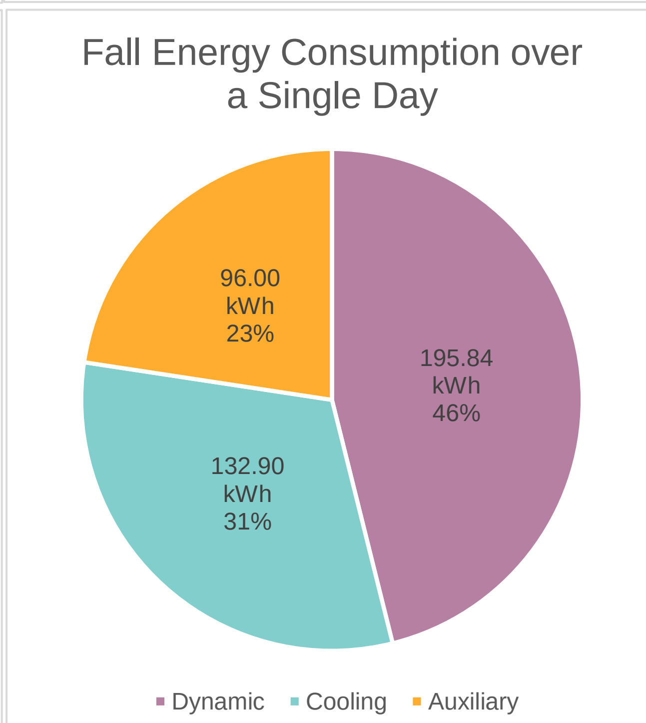
Total Daily Energy Consumption:

Summer:	440.92 KWH	Fall	424.75
Winter:	409.89 KWH	Spring	366.64









Local Route B2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**20.15**	0.00	**639.85**
2	**639.85**	**21.46**	0.00	**618.39**
3	**618.39**	**22.13**	0.00	**596.26**
4	**596.26**	**24.06**	0.00	**572.20**
5	**572.20**	**26.06**	0.00	**546.14**
6	**546.14**	**27.95**	0.00	**518.19**
7	**518.19**	**29.78**	0.00	**488.41**
8	**488.41**	**32.04**	0.00	**456.38**
9	**456.38**	**34.45**	0.00	**421.93**
10	**421.93**	**34.45**	0.00	**387.48**
11	**387.48**	**34.08**	0.00	**353.40**
12	**353.40**	**31.49**	0.00	**321.91**
13	**321.91**	**29.49**	0.00	**292.43**
14	**292.43**	**27.35**	0.00	**265.08**
15	**265.08**	**23.79**	0.00	**241.29**
16	**241.29**	**22.21**	0.00	**219.08**

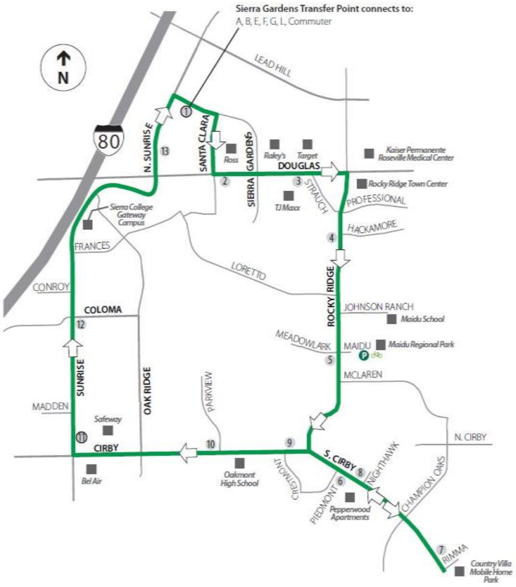
Local Route B2 Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**31.10**	0.00	**628.90**
2	**628.90**	**30.03**	0.00	**598.88**
3	**598.88**	**28.96**	0.00	**569.92**
4	**569.92**	**27.89**	0.00	**542.03**
5	**542.03**	**26.84**	0.00	**515.19**
6	**515.19**	**25.79**	0.00	**489.39**
7	**489.39**	**24.76**	0.00	**464.63**
8	**464.63**	**23.75**	0.00	**440.88**
9	**440.88**	**22.69**	0.00	**418.19**
10	**418.19**	**21.43**	0.00	**396.76**
11	**396.76**	**22.40**	0.00	**374.36**
12	**374.36**	**23.29**	0.00	**351.08**
13	**351.08**	**24.06**	0.00	**327.02**
14	**327.02**	**24.84**	0.00	**302.18**
15	**302.18**	**25.63**	0.00	**276.54**
16	**276.54**	**26.43**	0.00	**250.11**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40
Battery Size:	660 KWH
Hours of Service	6 AM
	7 PM

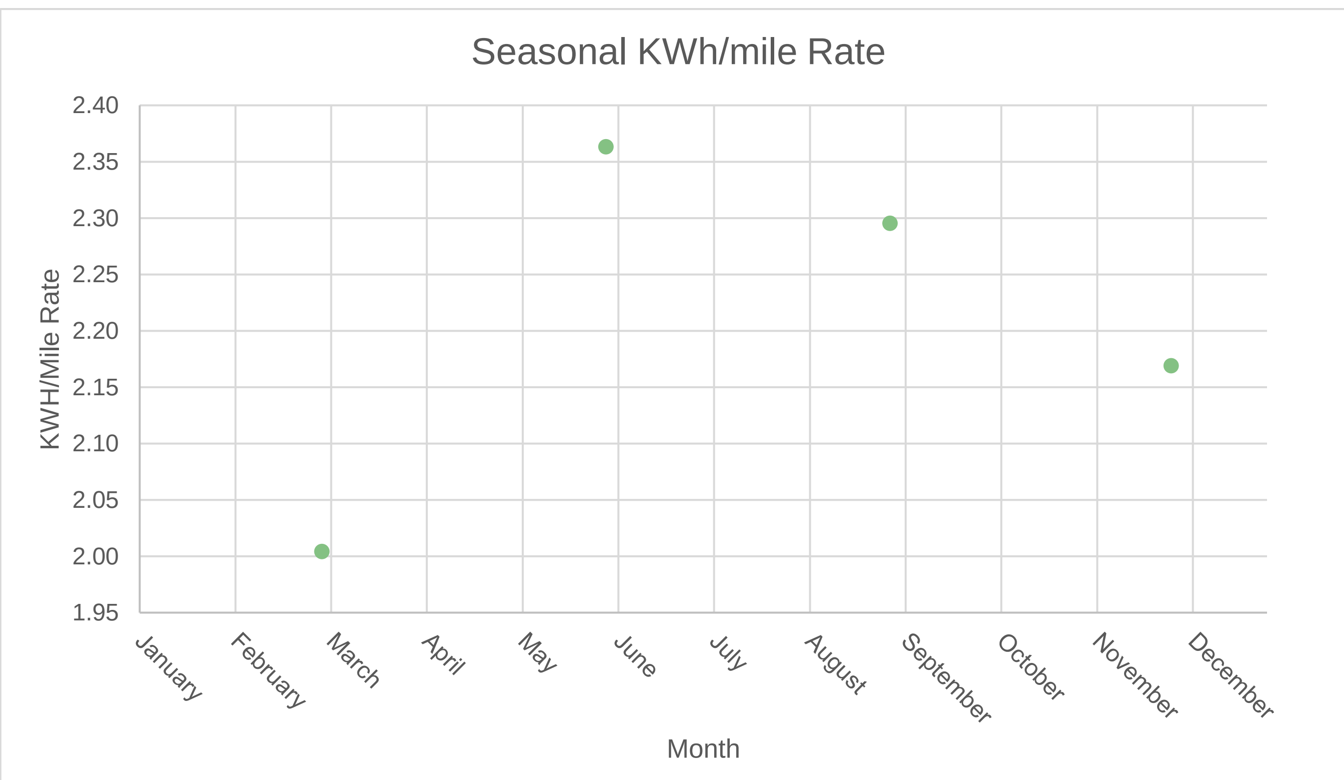
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.17 kWh/mi	2.00 kWh/mi	2.30 kWh/mi	2.36 kWh/mi

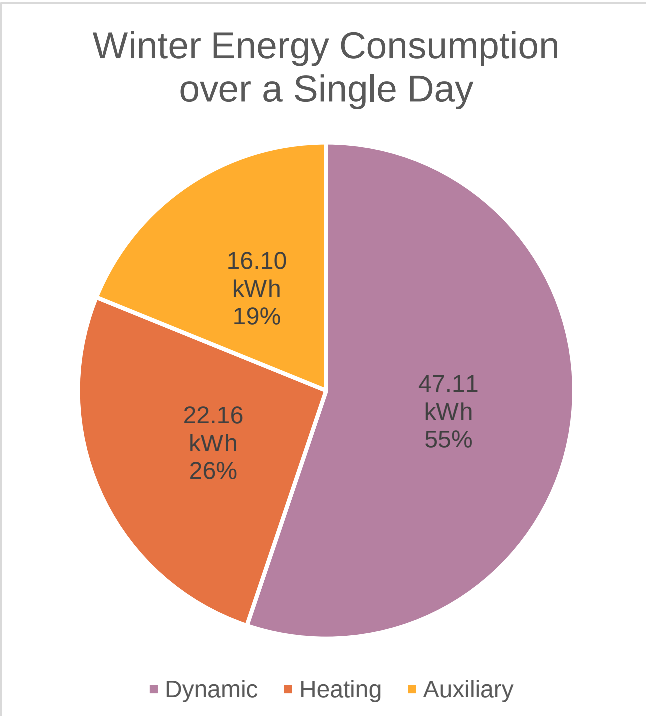


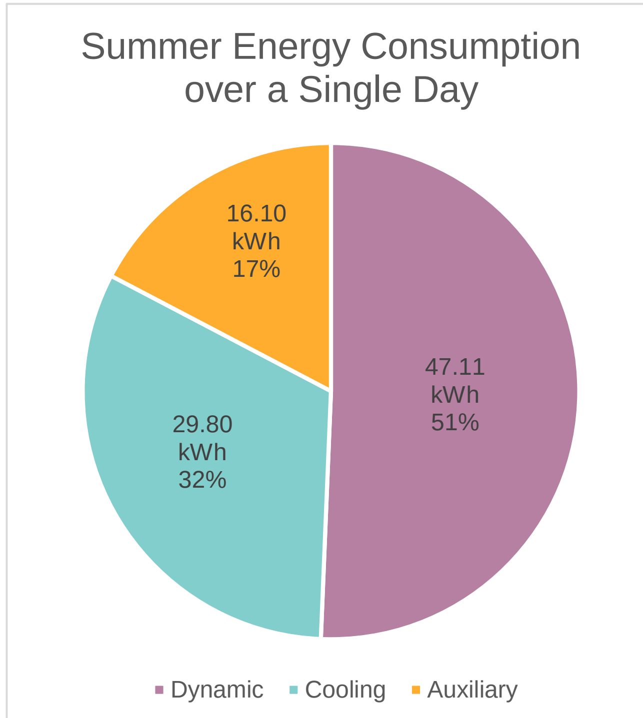
Local Route C Results

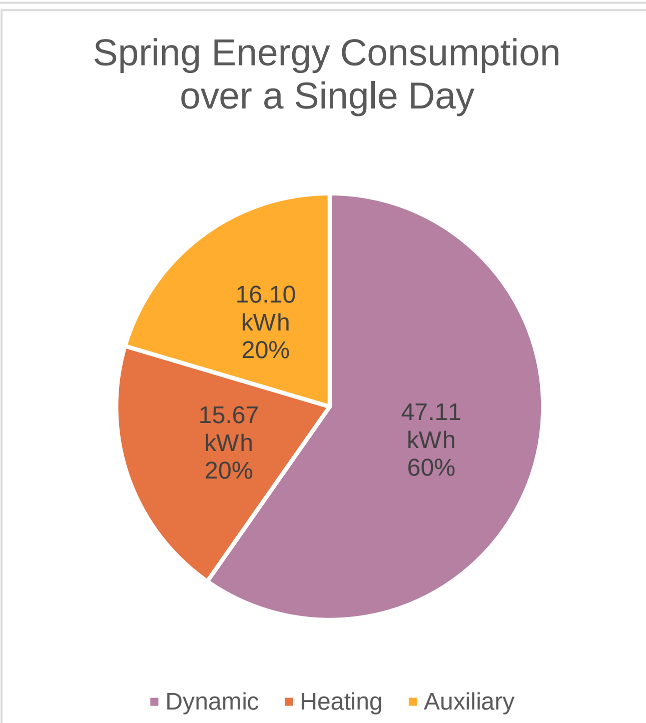
Daily Energy Consumption by Subsystem

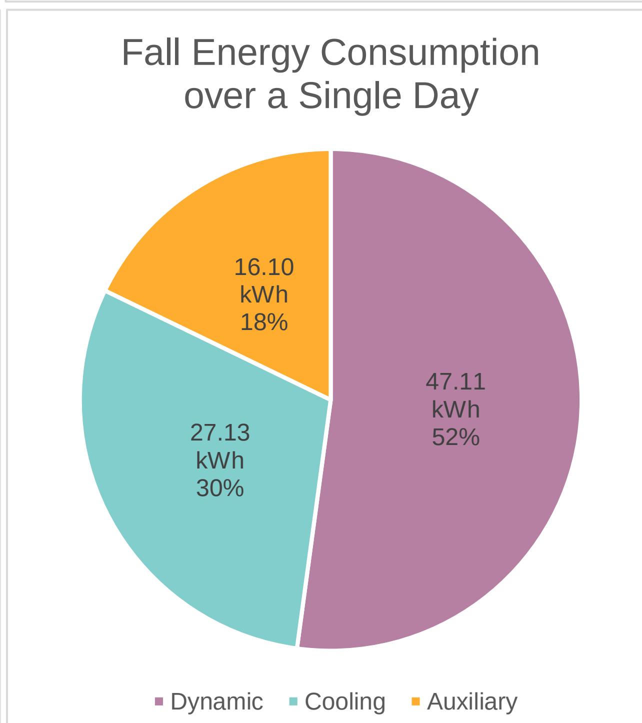
Total Daily Energy Consumption:

Summer:	93.00 KWH	Fall	90.33
Winter:	85.37 KWH	Spring	78.88









Local Route C Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**10.11**	0.00	**649.89**
2	**649.89**	**11.15**	0.00	**638.73**
3	**638.73**	**12.76**	0.00	**625.97**
4	**625.97**	**14.50**	0.00	**611.47**
5	**611.47**	**15.55**	0.00	**595.92**
6	**595.92**	**15.42**	0.00	**580.50**
7	**580.50**	**13.50**	0.00	**567.00**

Local Route C Results

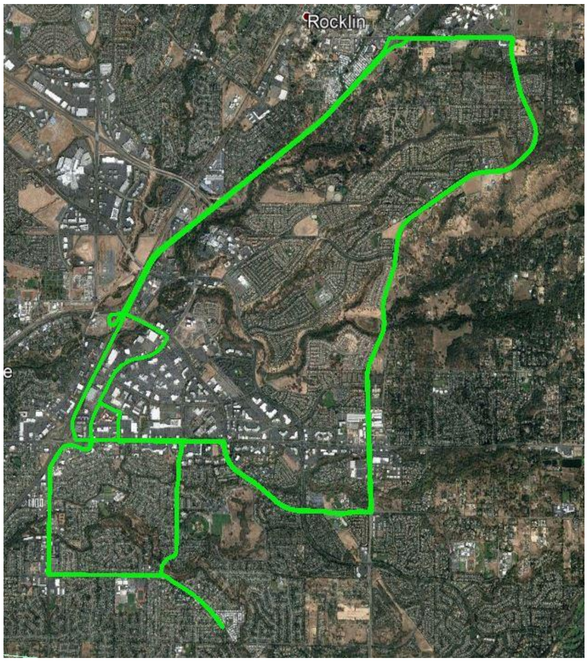
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**14.29**	0.00	**645.71**
2	**645.71**	**13.42**	0.00	**632.29**
3	**632.29**	**12.55**	0.00	**619.74**
4	**619.74**	**11.71**	0.00	**608.03**
5	**608.03**	**10.87**	0.00	**597.17**
6	**597.17**	**11.11**	0.00	**586.06**
7	**586.06**	**11.42**	0.00	**574.63**

Local Route C, G, F, E Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40 ft.
Battery Size:	660 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

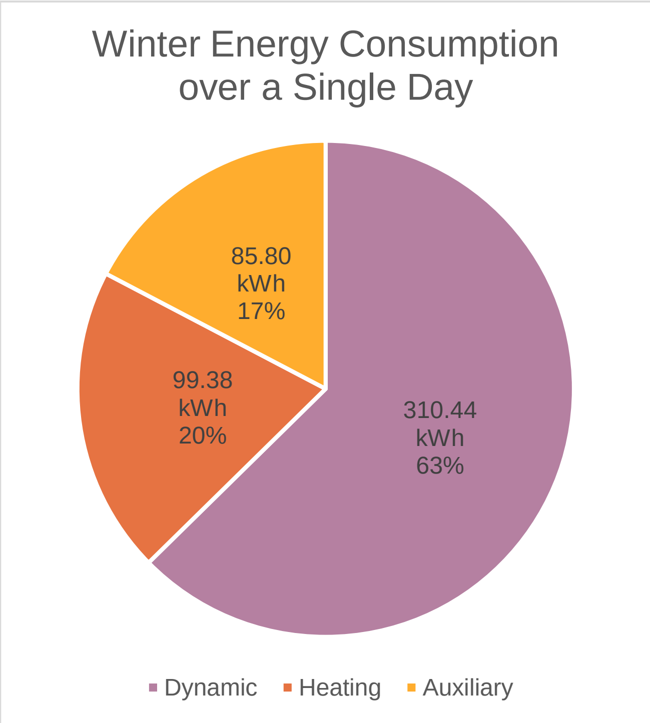
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.71 kWh/mi	2.56 kWh/mi	2.80 kWh/mi	2.84 kWh/mi

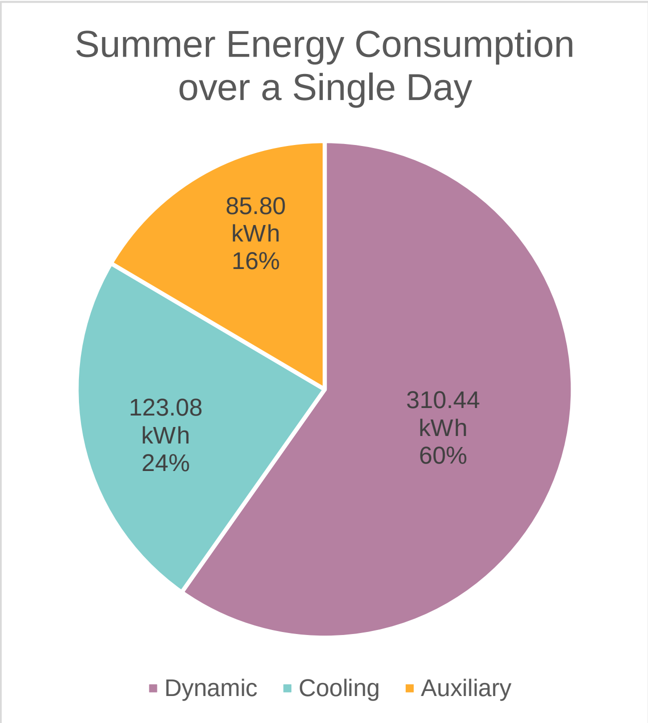
Local Route C, G, F, E Results

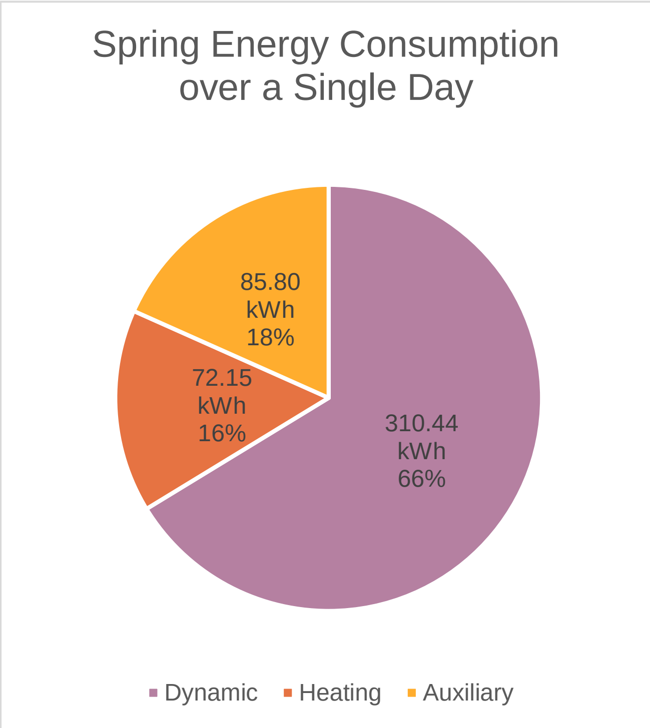
Daily Energy Consumption by Subsystem

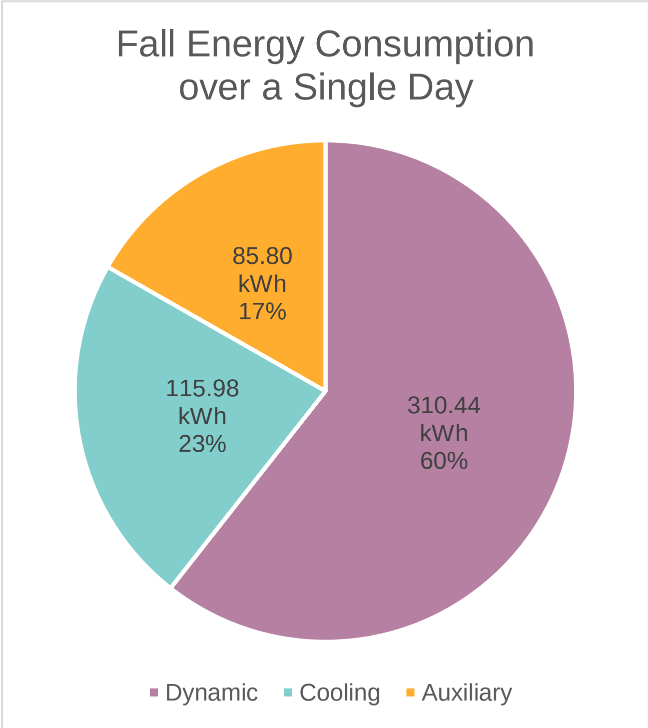
Total Daily Energy Consumption:

Summer:	519.32 KWH	Fall	512.23
Winter:	495.62 KWH	Spring	468.39









Local Route C, G, F, E Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**72.87**	0.00	**587.13**
2	**587.13**	**77.89**	0.00	**509.24**
3	**509.24**	**87.98**	0.00	**421.27**
4	**421.27**	**95.26**	0.00	**326.01**
5	**326.01**	**95.26**	0.00	**230.75**
6	**230.75**	**90.08**	0.00	**140.68**

Local Route C, G, F, E Results

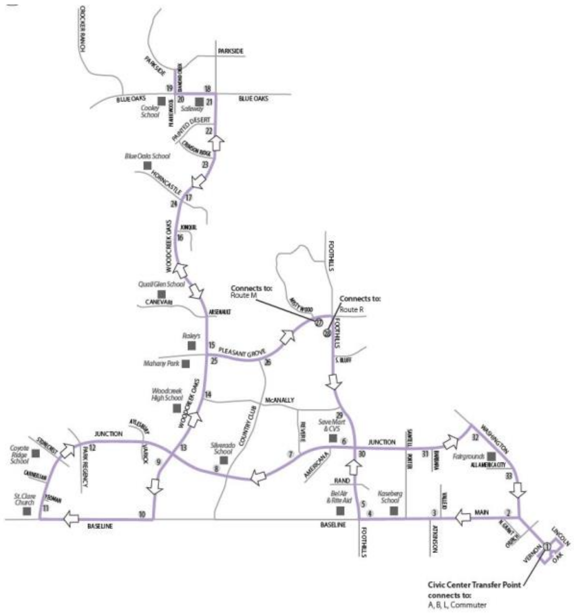
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**93.20**	0.00	**566.80**
2	**566.80**	**88.61**	0.00	**478.18**
3	**478.18**	**84.05**	0.00	**394.13**
4	**394.13**	**77.31**	0.00	**316.82**
5	**316.82**	**74.45**	0.00	**242.37**
6	**242.37**	**77.99**	0.00	**164.38**

Local Route D Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40 ft.
Battery Size:	660 KWH
Hours of Service	6 AM
	7 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

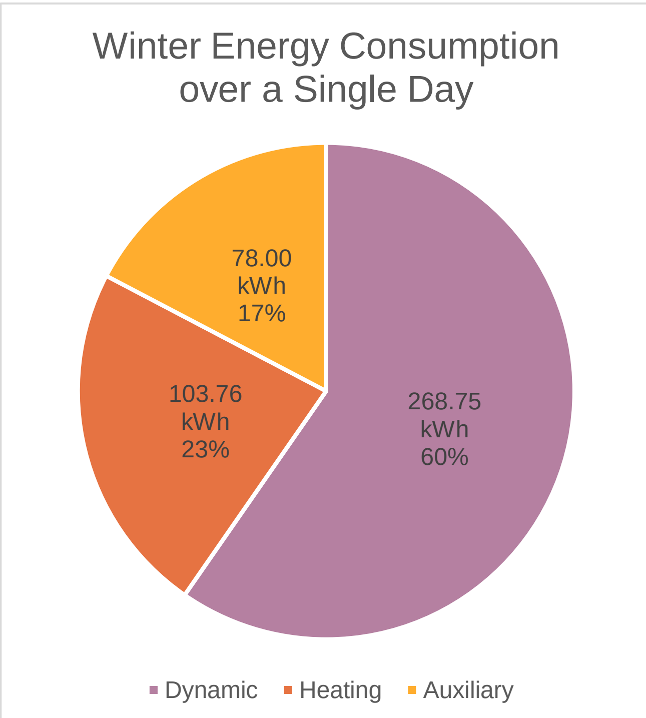
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.13 kWh/mi	1.97 kWh/mi	2.22 kWh/mi	2.27 kWh/mi

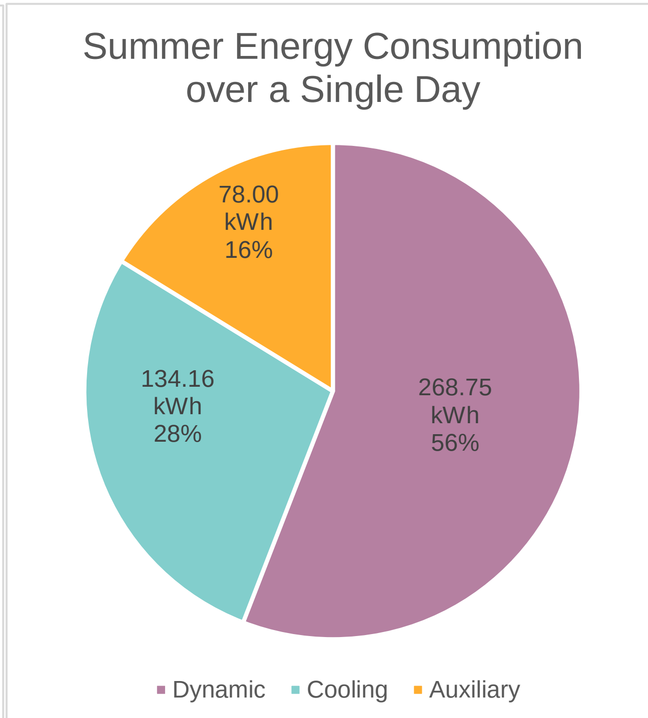
Local Route D Results

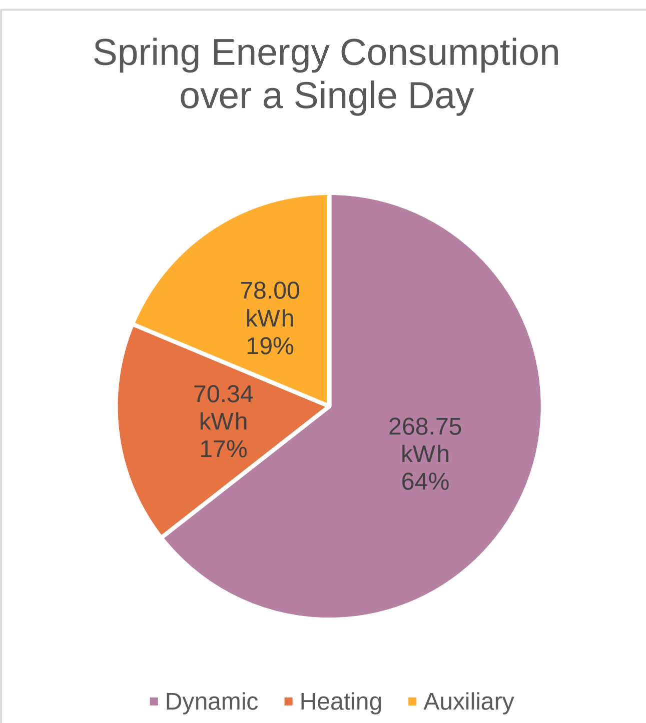
Daily Energy Consumption by Subsystem

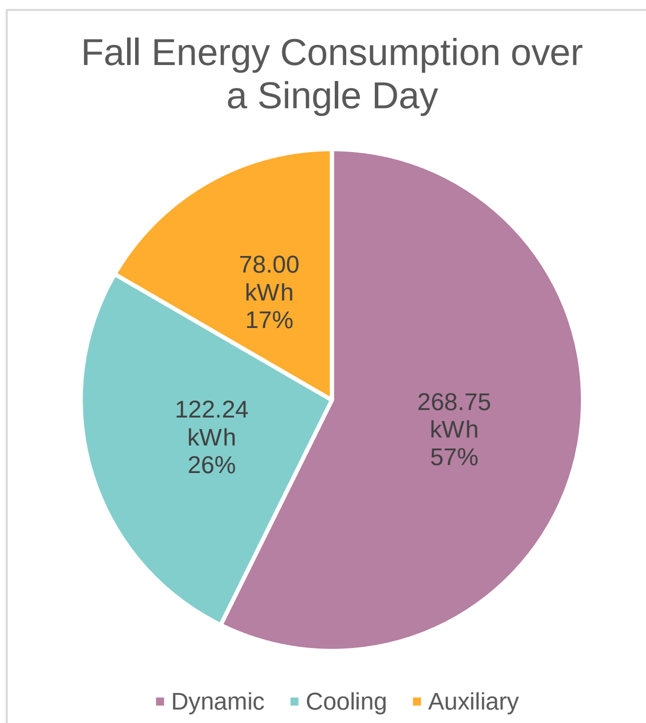
Total Daily Energy Consumption:

Summer:	480.91 KWH	Fall	468.99
Winter:	450.51 KWH	Spring	417.09









Local Route D Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**28.23**	0.00	**631.77**
2	**631.77**	**29.52**	0.00	**602.25**
3	**602.25**	**30.23**	0.00	**572.02**
4	**572.02**	**32.24**	0.00	**539.79**
5	**539.79**	**34.38**	0.00	**505.41**
6	**505.41**	**36.46**	0.00	**468.95**
7	**468.95**	**38.52**	0.00	**430.43**
8	**430.43**	**41.06**	0.00	**389.37**
9	**389.37**	**43.83**	0.00	**345.54**
10	**345.54**	**43.83**	0.00	**301.70**
11	**301.70**	**43.49**	0.00	**258.22**
12	**258.22**	**40.66**	0.00	**217.55**
13	**217.55**	**38.46**	0.00	**179.09**

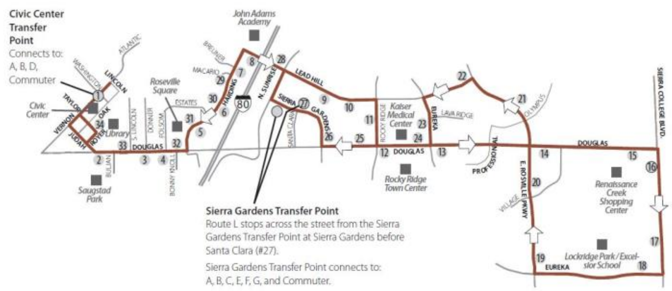
Local Route D Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**40.55**	0.00	**619.45**
2	**619.45**	**39.40**	0.00	**580.05**
3	**580.05**	**38.25**	0.00	**541.81**
4	**541.81**	**37.10**	0.00	**504.71**
5	**504.71**	**35.97**	0.00	**468.74**
6	**468.74**	**34.85**	0.00	**433.89**
7	**433.89**	**33.74**	0.00	**400.15**
8	**400.15**	**32.66**	0.00	**367.50**
9	**367.50**	**31.52**	0.00	**335.98**
10	**335.98**	**30.14**	0.00	**305.84**
11	**305.84**	**31.20**	0.00	**274.64**
12	**274.64**	**32.16**	0.00	**242.48**
13	**242.48**	**32.99**	0.00	**209.49**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40
Battery Size:	660 KWH
Hours of Service	6 AM
	6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

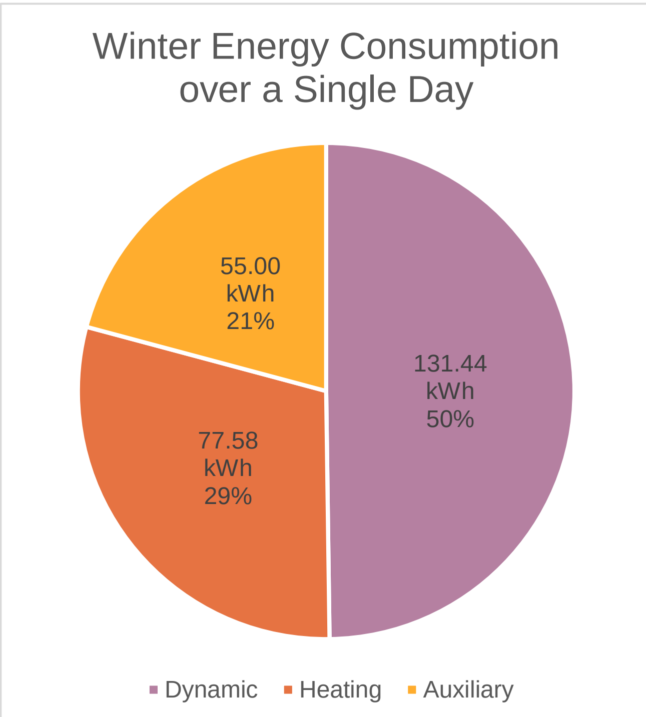
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.29 kWh/mi	2.07 kWh/mi	2.40 kWh/mi	2.47 kWh/mi

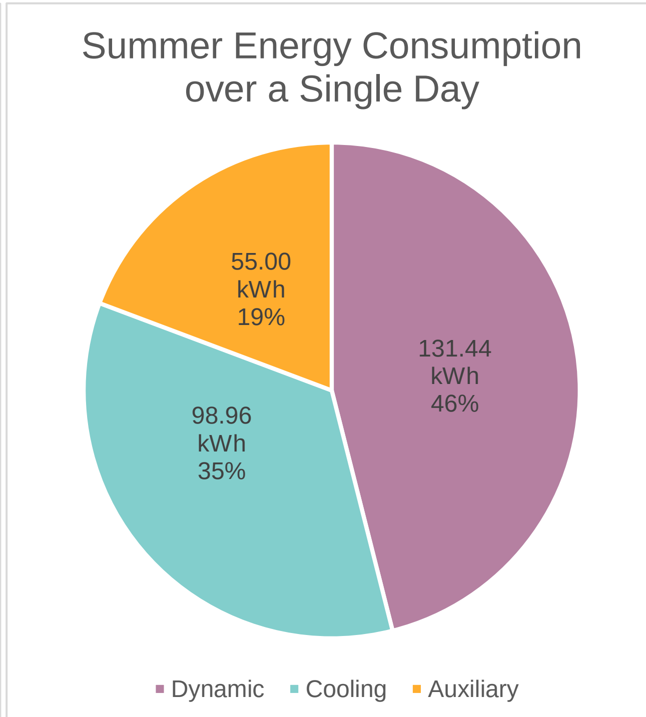
Local Route L Results

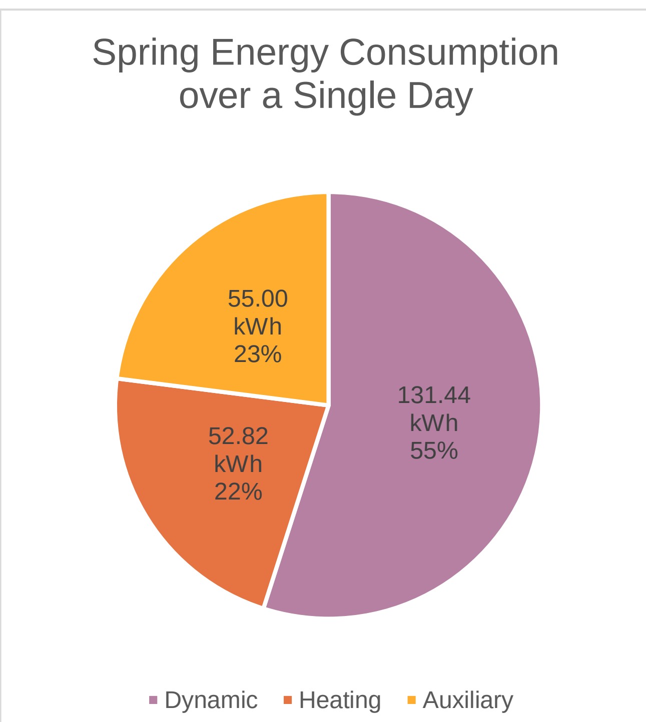
Daily Energy Consumption by Subsystem

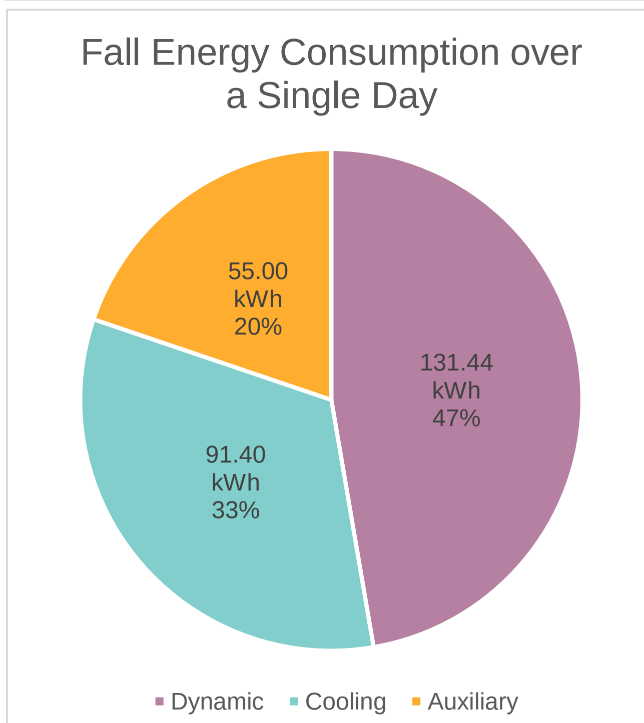
Total Daily Energy Consumption:

Summer:	285.40 KWH	Fall	277.84
Winter:	264.02 KWH	Spring	239.26









Local Route L Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**18.17**	0.00	**641.83**
2	**641.83**	**19.32**	0.00	**622.51**
3	**622.51**	**19.97**	0.00	**602.54**
4	**602.54**	**21.72**	0.00	**580.82**
5	**580.82**	**23.62**	0.00	**557.20**
6	**557.20**	**27.35**	0.00	**529.86**
7	**529.86**	**29.65**	0.00	**500.20**
8	**500.20**	**32.19**	0.00	**468.01**
9	**468.01**	**32.19**	0.00	**435.82**
10	**435.82**	**31.89**	0.00	**403.93**
11	**403.93**	**29.33**	0.00	**374.60**

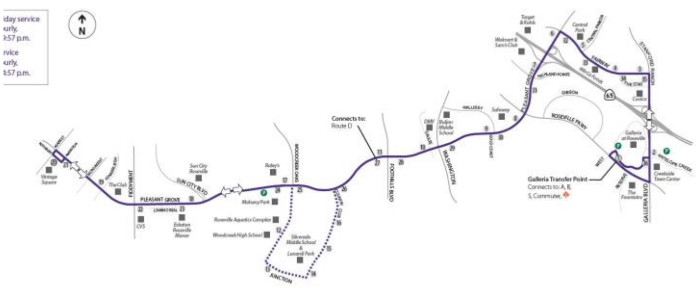
Local Route L Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**28.82**	0.00	**631.18**
2	**631.18**	**27.84**	0.00	**603.34**
3	**603.34**	**26.85**	0.00	**576.49**
4	**576.49**	**25.88**	0.00	**550.61**
5	**550.61**	**24.92**	0.00	**525.69**
6	**525.69**	**23.96**	0.00	**501.73**
7	**501.73**	**22.11**	0.00	**479.62**
8	**479.62**	**21.14**	0.00	**458.48**
9	**458.48**	**19.95**	0.00	**438.53**
10	**438.53**	**20.86**	0.00	**417.67**
11	**417.67**	**21.69**	0.00	**395.98**

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40 ft.	
Battery Size:	660	KWH
Hours of Service	5	AM
	10	PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

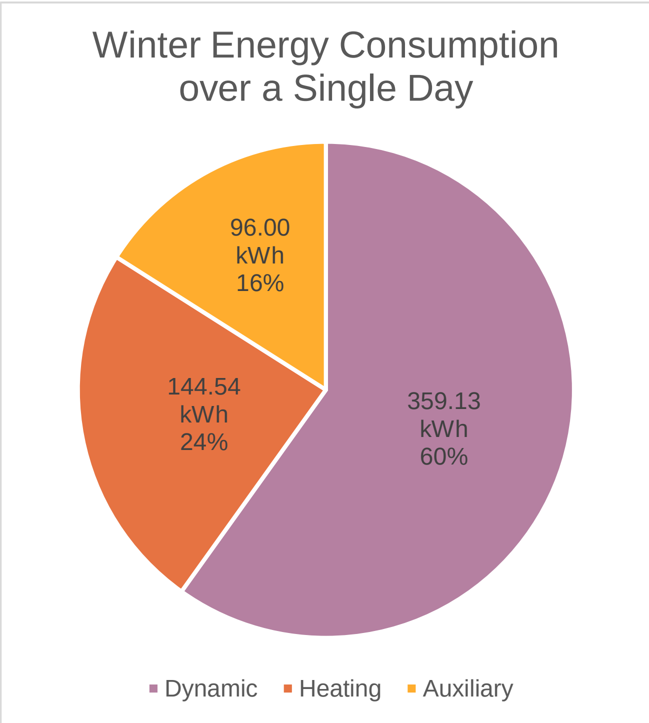
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.26 kWh/mi	1.98 kWh/mi	2.22 kWh/mi	2.29 kWh/mi

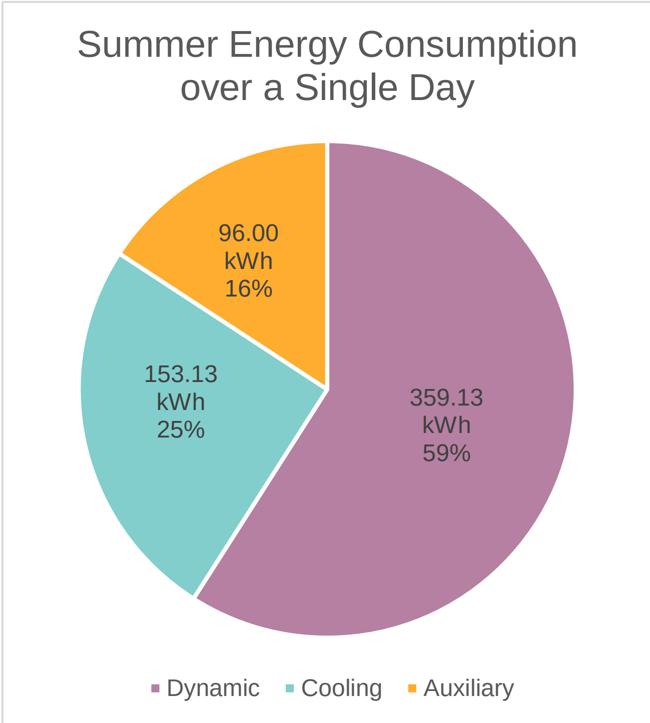
Local Route M Results

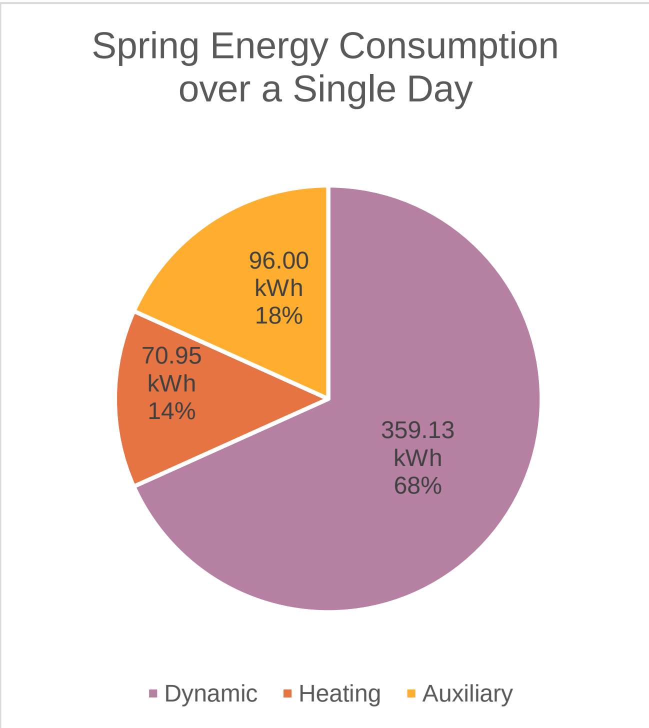
Daily Energy Consumption by Subsystem

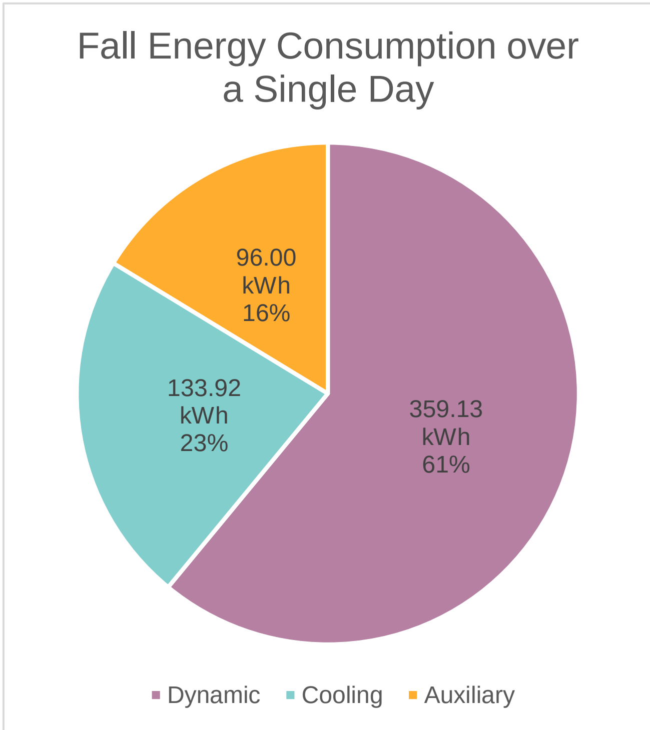
Total Daily Energy Consumption:

Summer:	608.27 KWH	Fall	589.06
Winter:	599.67 KWH	Spring	526.08









Local Route M Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**28.07**	0.00	**631.93**
2	**631.93**	**30.08**	0.00	**601.85**
3	**601.85**	**31.42**	0.00	**570.43**
4	**570.43**	**32.20**	0.00	**538.23**
5	**538.23**	**34.31**	0.00	**503.92**
6	**503.92**	**36.60**	0.00	**467.32**
7	**467.32**	**38.87**	0.00	**428.45**
8	**428.45**	**44.00**	0.00	**384.45**
9	**384.45**	**47.13**	0.00	**337.32**
10	**337.32**	**47.13**	0.00	**290.20**
11	**290.20**	**46.78**	0.00	**243.41**
12	**243.41**	**43.68**	0.00	**199.73**
13	**199.73**	**41.24**	0.00	**158.49**
14	**158.49**	**38.74**	0.00	**119.75**
15	**119.75**	**34.94**	0.00	**84.81**
16	**84.81**	**33.08**	0.00	**51.73**

Local Route M Results

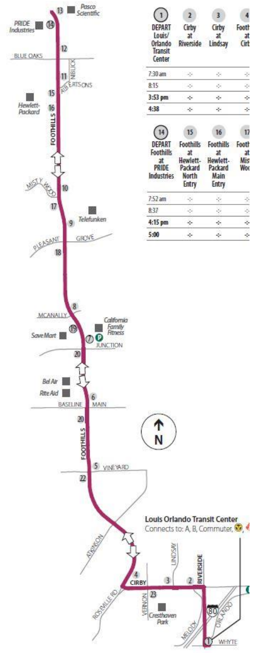
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**44.28**	0.00	**615.72**
2	**615.72**	**43.06**	0.00	**572.66**
3	**572.66**	**41.85**	0.00	**530.82**
4	**530.82**	**40.64**	0.00	**490.17**
5	**490.17**	**39.44**	0.00	**450.73**
6	**450.73**	**38.25**	0.00	**412.48**
7	**412.48**	**37.08**	0.00	**375.40**
8	**375.40**	**35.93**	0.00	**339.47**
9	**339.47**	**33.60**	0.00	**305.87**
10	**305.87**	**32.13**	0.00	**273.73**
11	**273.73**	**33.26**	0.00	**240.47**
12	**240.47**	**34.28**	0.00	**206.19**
13	**206.19**	**35.14**	0.00	**171.05**
14	**171.05**	**36.02**	0.00	**135.03**
15	**135.03**	**36.90**	0.00	**98.13**
16	**98.13**	**37.80**	0.00	**60.33**

Local Route R AM Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 max 40
Battery Size: 660 KWH
Hours of Service 7 AM
9 AM
Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

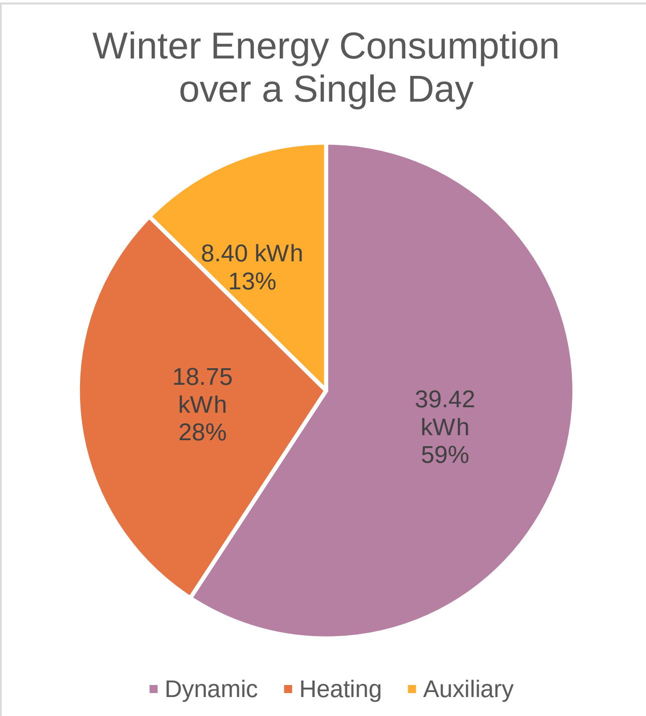
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.52 kWh/mi	1.83 kWh/mi	2.04 kWh/mi	2.00 kWh/mi

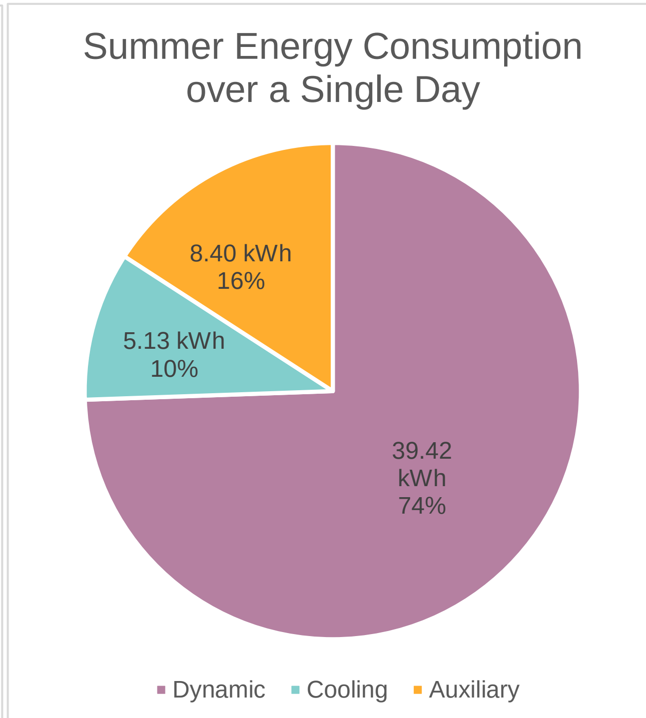
Local Route R AM Results

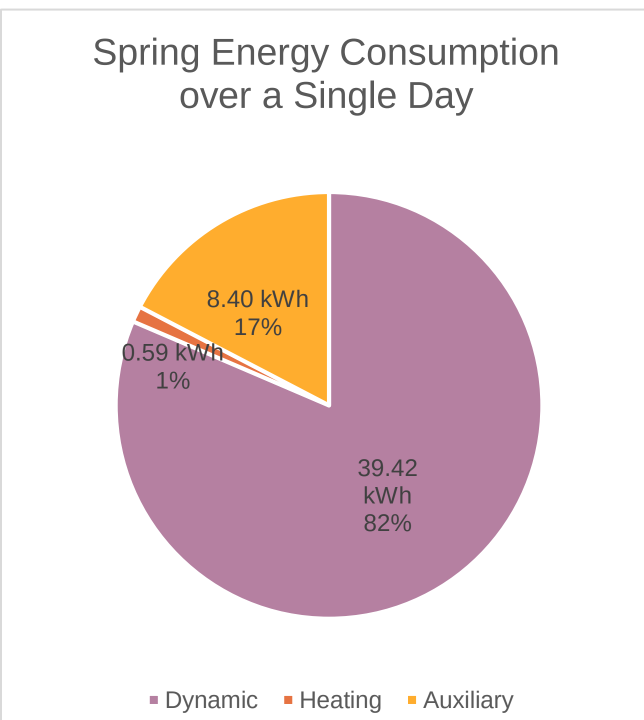
Daily Energy Consumption by Subsystem

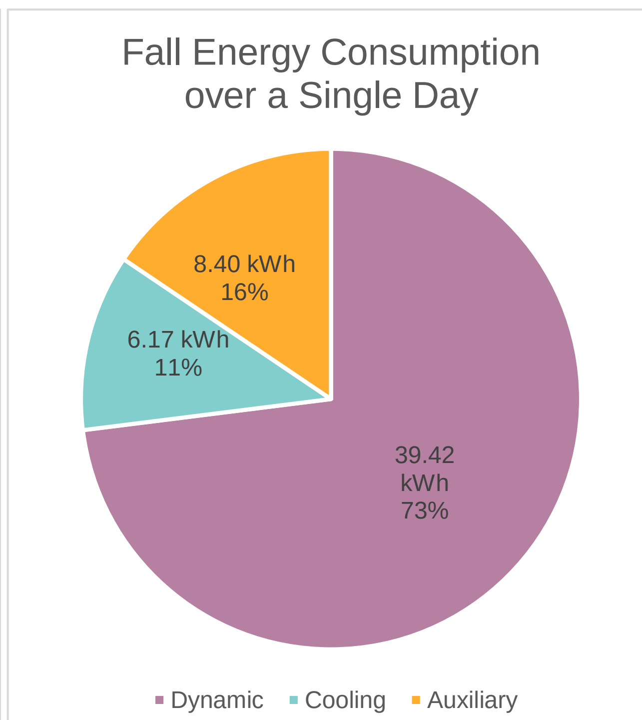
Total Daily Energy Consumption:

Summer:	52.96 KWH	Fall	53.99
Winter:	66.57 KWH	Spring	48.41









Local Route R AM Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**26.19**	0.00	**633.81**
2	**633.81**	**26.77**	0.00	**607.04**

Local Route R AM Results

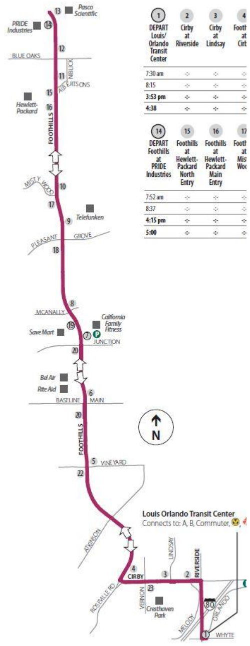
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**33.73**	0.00	**626.27**
2	**626.27**	**32.85**	0.00	**593.43**

Local Route R PM Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 max 40

Battery Size: 660 KWH

Hours of Service 4 PM

6 PM

Charging Station Design

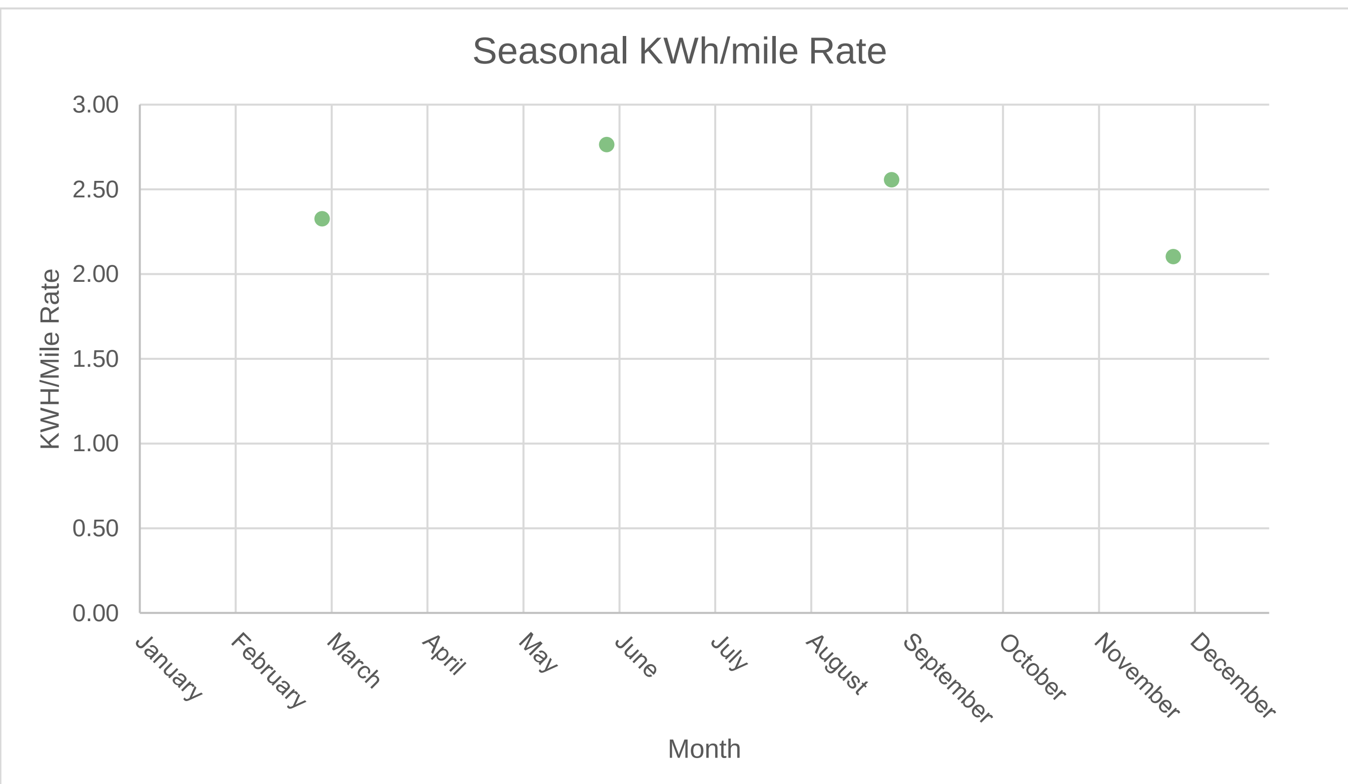
☑ Overnight Depot Charging

Charger's output: 60 KW

Time at Charger: 8 Hours

Seasonal kWh per Mile Rate

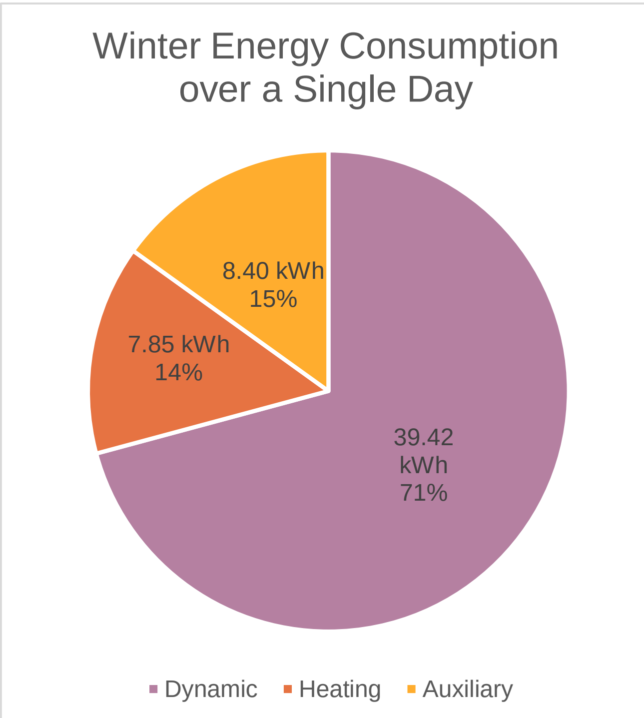
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.10 kWh/mi	2.33 kWh/mi	2.56 kWh/mi	2.76 kWh/mi

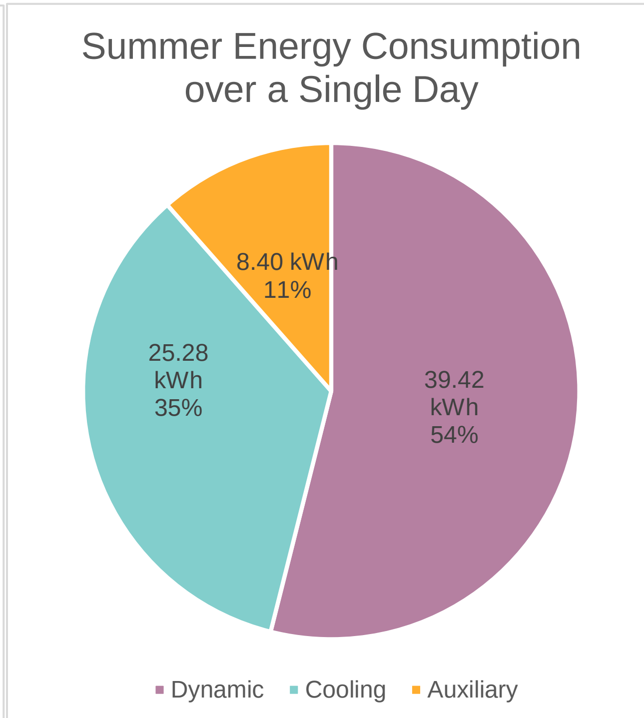


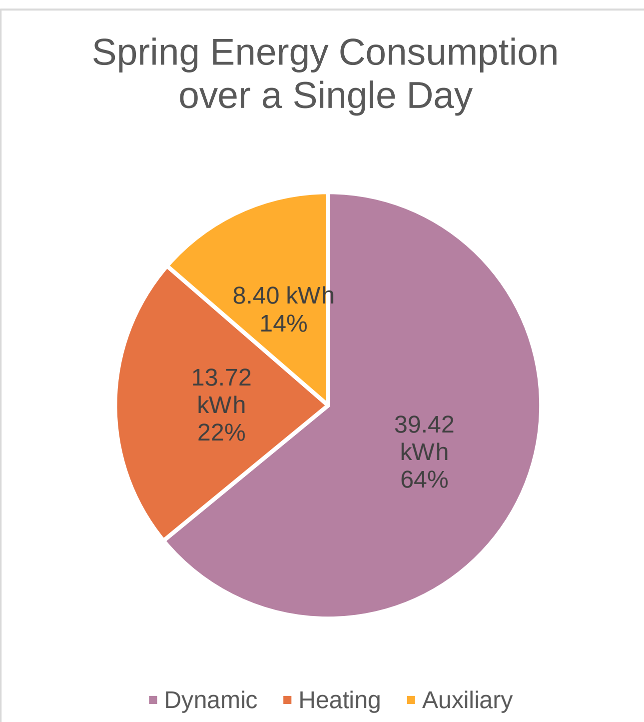
Daily Energy Consumption by Subsystem

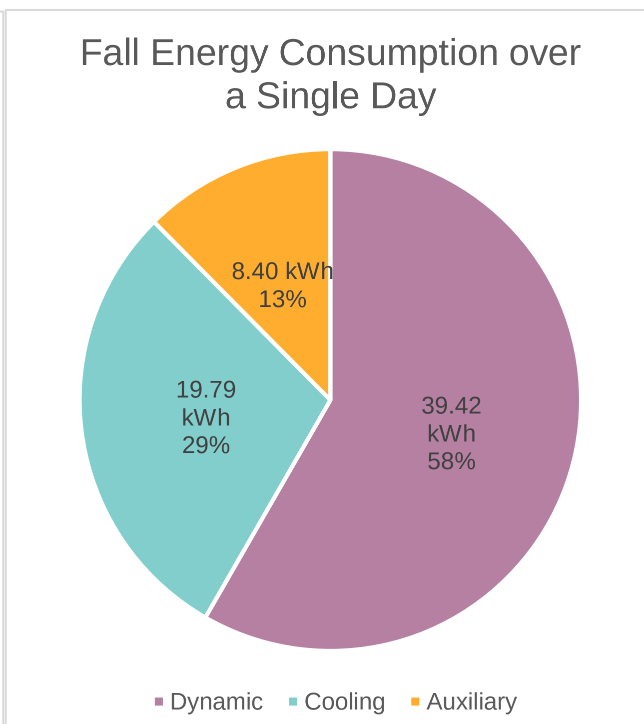
Total Daily Energy Consumption:

Summer:	73.10 KWH	Fall	67.61
Winter:	55.67 KWH	Spring	61.55









Local Route R PM Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**37.71**	0.00	**622.29**
2	**622.29**	**35.39**	0.00	**586.90**

Local Route R PM Results

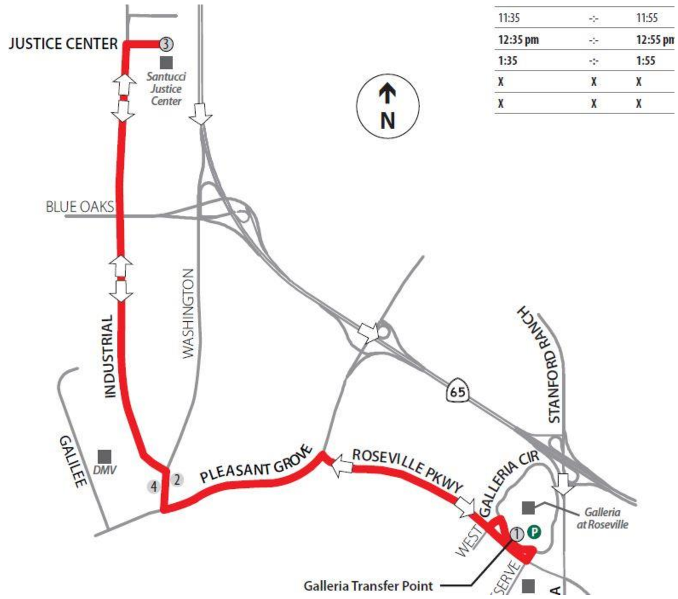
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**27.46**	0.00	**632.54**
2	**632.54**	**28.21**	0.00	**604.33**

Local Route S1 Results

Electric Bus Corridor Model Results



Background

Bus Model:	Proterra Catalyst E2 max 40
Battery Size:	660 KWH
Hours of Service	7 AM 3 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

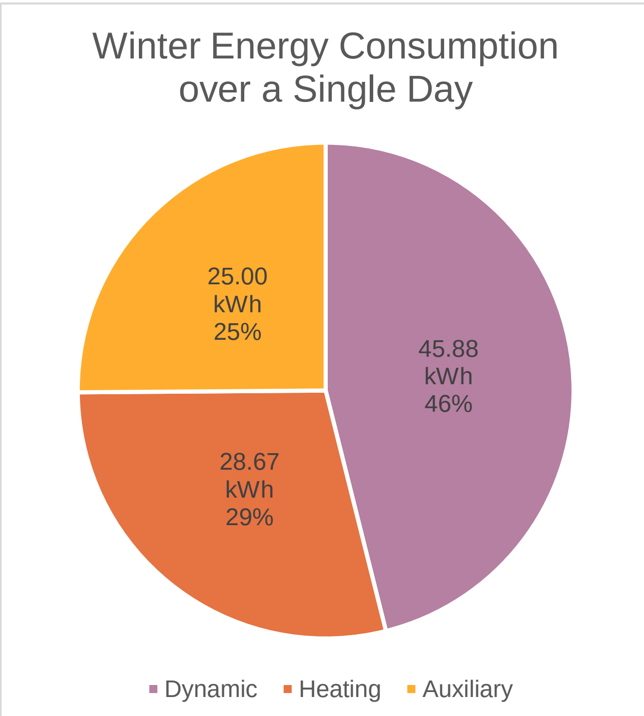
Average Winter:	**Average Spring**	**Average Fall:**	**Average Summer:**
2.09 kWh/mi	1.91 kWh/mi	2.21 kWh/mi	2.17 kWh/mi

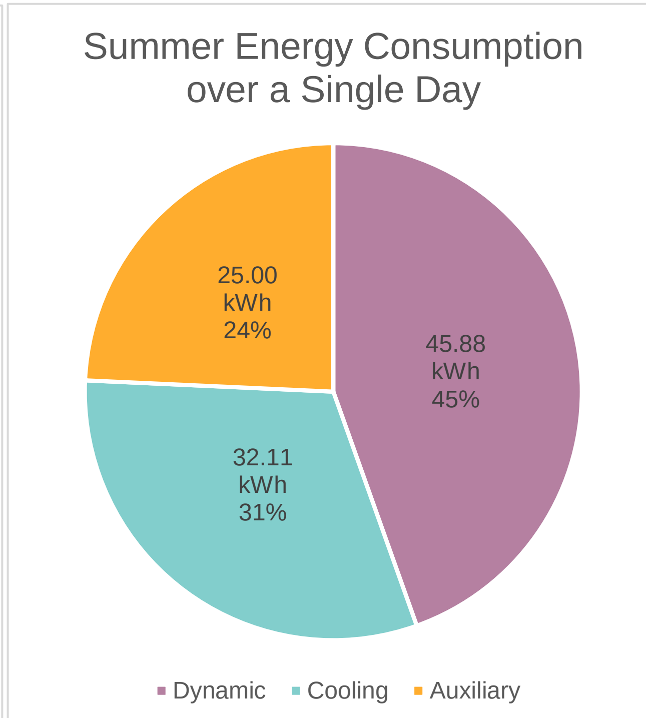
Local Route S1 Results

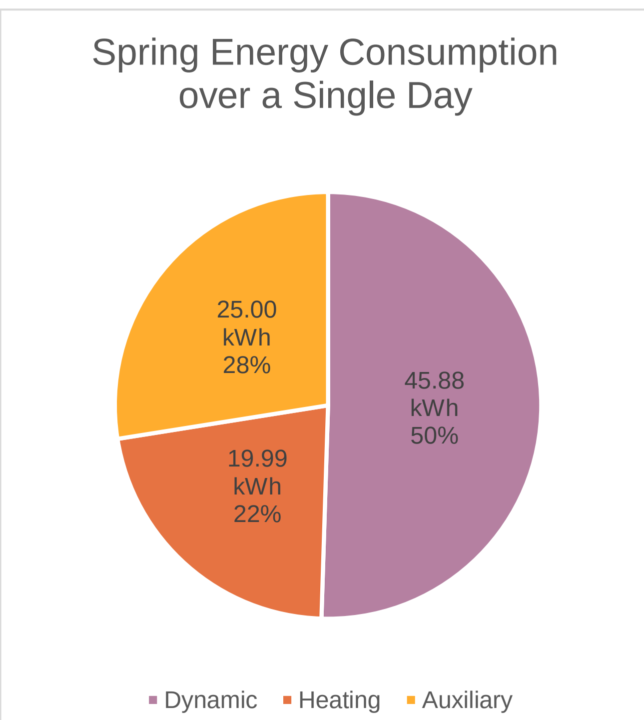
Daily Energy Consumption by Subsystem

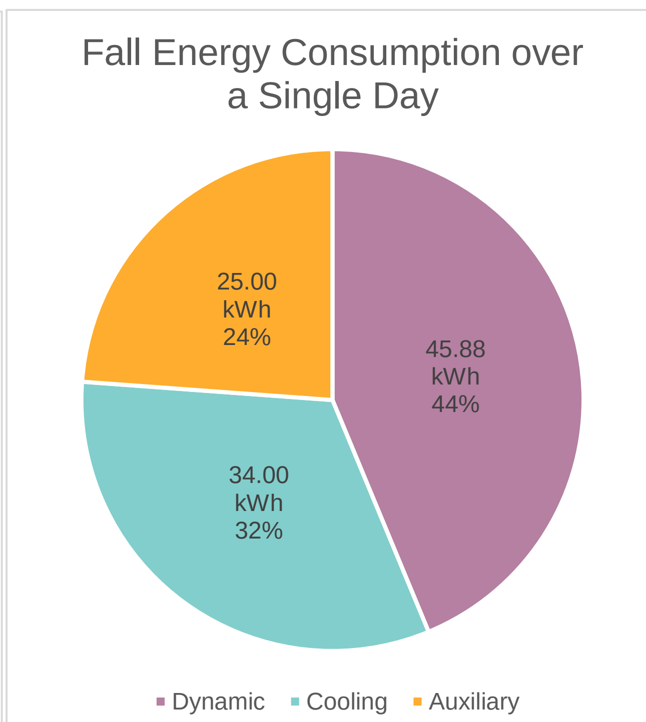
Total Daily Energy Consumption:

Summer:	102.99 KWH	Fall	104.89
Winter:	99.55 KWH	Spring	90.87









Local Route S1 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**16.77**	0.00	**643.23**
2	**643.23**	**18.49**	0.00	**624.74**
3	**624.74**	**20.84**	0.00	**603.90**
4	**603.90**	**22.90**	0.00	**581.00**
5	**581.00**	**23.99**	0.00	**557.01**

Local Route S1 Results

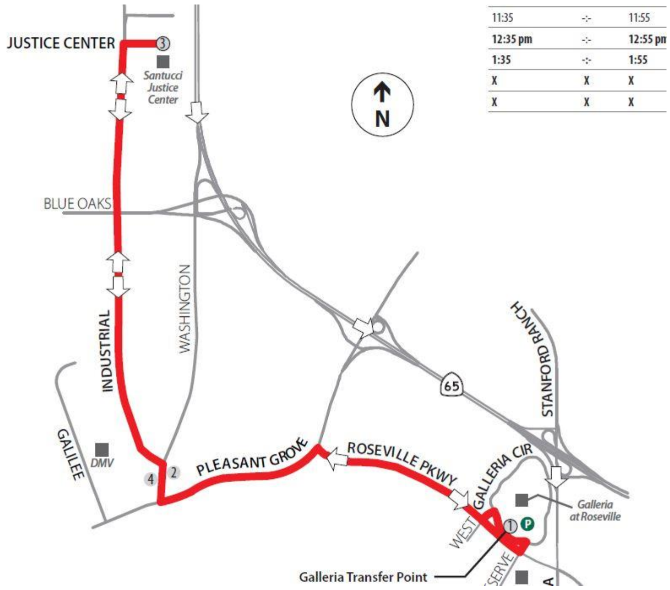
Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**22.29**	0.00	**637.71**
2	**637.71**	**21.54**	0.00	**616.16**
3	**616.16**	**20.05**	0.00	**596.11**
4	**596.11**	**18.57**	0.00	**577.54**
5	**577.54**	**17.09**	0.00	**560.45**

Local Route S2 Results

Electric Bus Corridor Model Results



Background

Bus Model: Proterra Catalyst E2 max 40

Battery Size: 660 KWH

Hours of Service 4 PM

6 PM

Charging Station Design

☑ Overnight Depot Charging

Charger's output:	60	KW
Time at Charger:	8	Hours

Seasonal kWh per Mile Rate

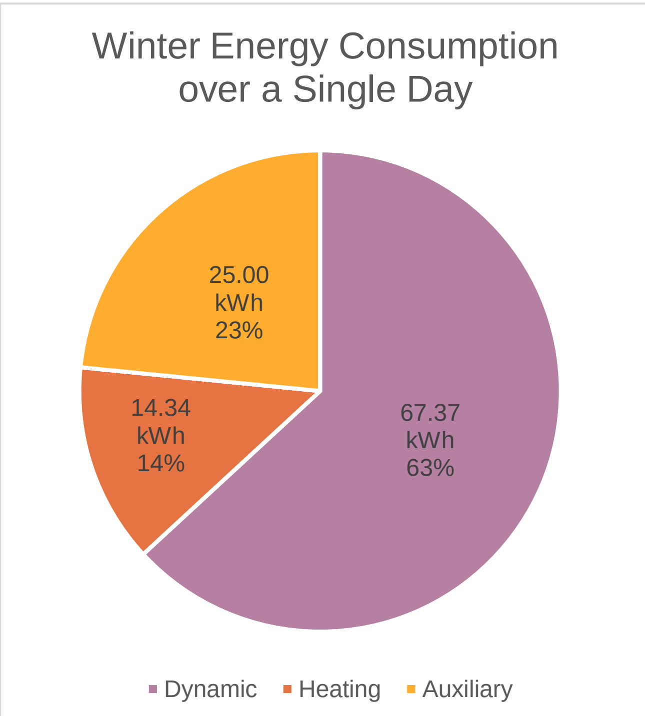
Average Winter:	Average Spring	Average Fall:	Average Summer:
2.25 kWh/mi	2.39 kWh/mi	2.51 kWh/mi	2.75 kWh/mi

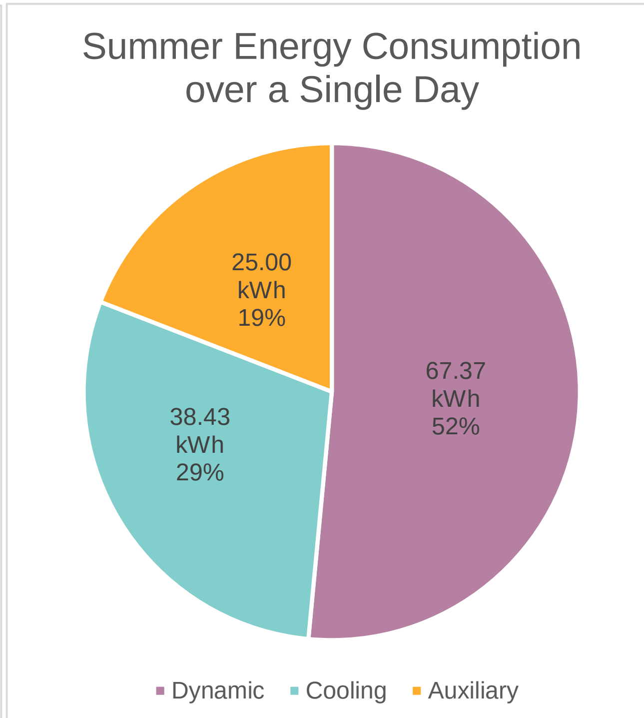
Local Route S2 Results

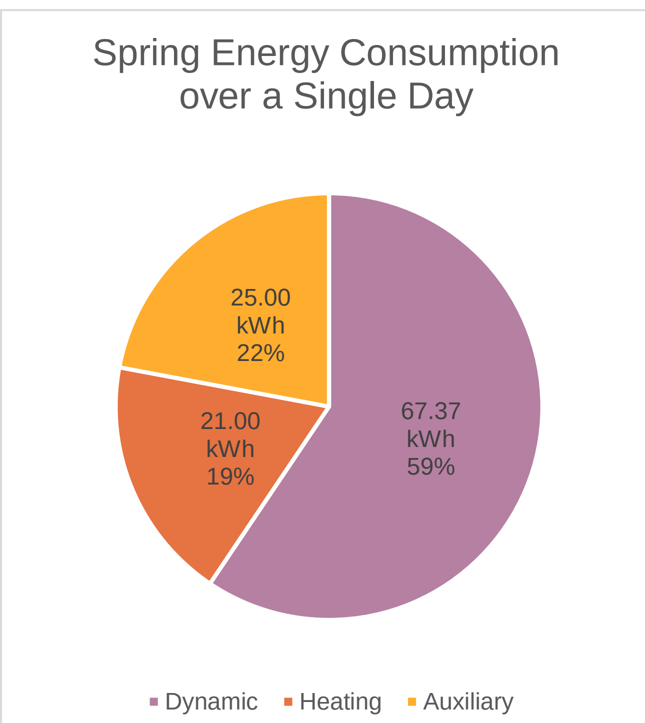
Daily Energy Consumption by Subsystem

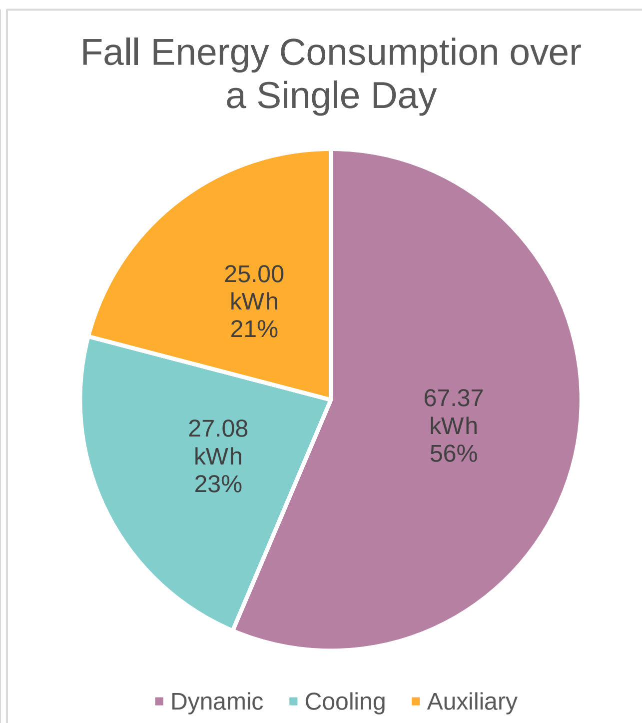
Total Daily Energy Consumption:

Summer:	130.80 KWH	Fall	119.45
Winter:	106.71 KWH	Spring	113.37









Local Route S2 Results

Daily State of Charge

Summer

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**27.11**	0.00	**632.89**
2	**632.89**	**27.11**	0.00	**605.78**
3	**605.78**	**25.83**	0.00	**579.94**
4	**579.94**	**25.83**	0.00	**554.11**
5	**554.11**	**24.91**	0.00	**529.20**

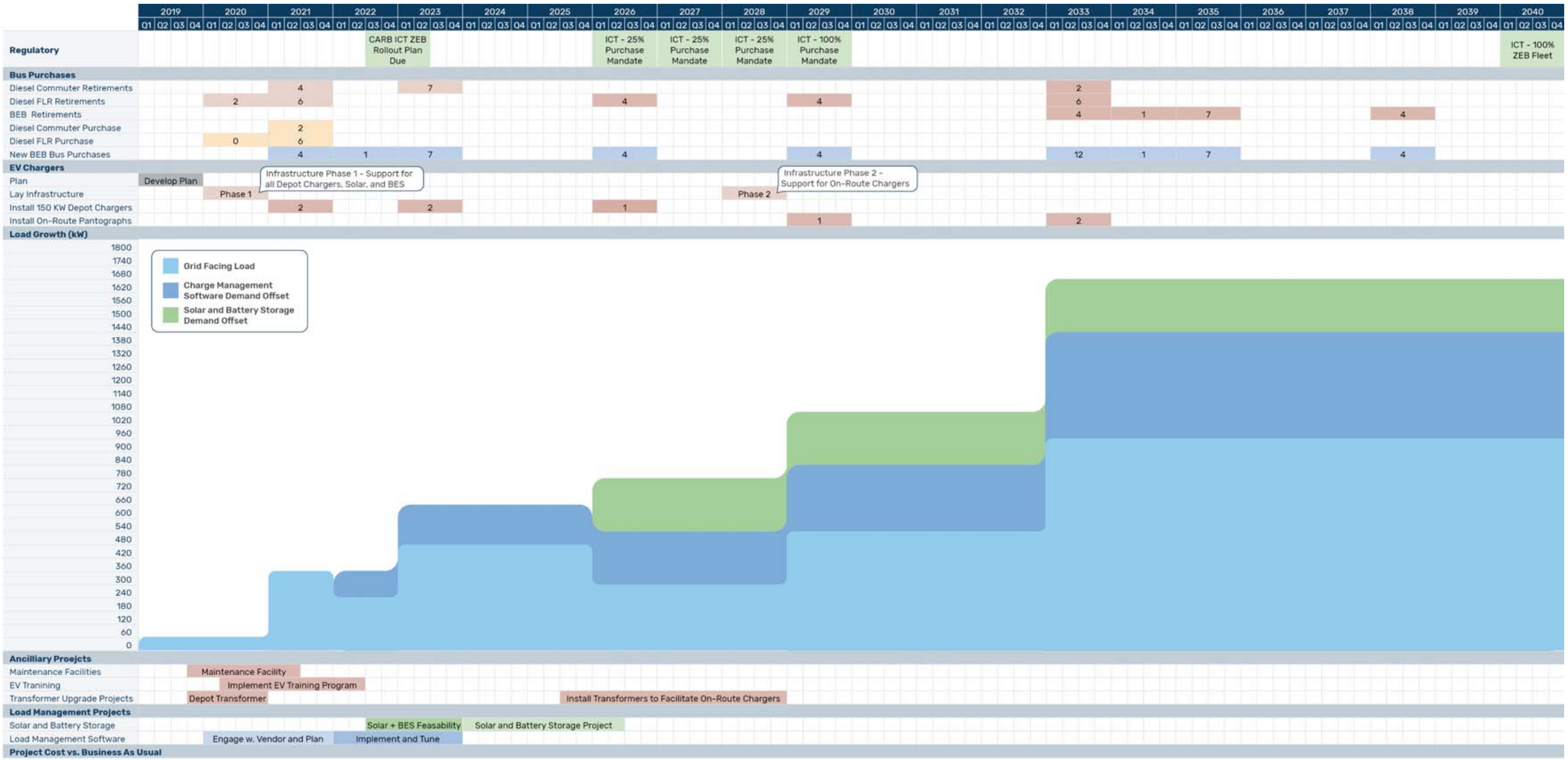
Local Route S2 Results

Daily State of Charge

Winter

Partial Recharge Gained		SOC is below the lower bound		
Trip No.	**Initial SOC**	**Consume**	**Recharge**	**Final SOC**
1	**660.00**	**20.60**	0.00	**639.40**
2	**639.40**	**21.22**	0.00	**618.18**
3	**618.18**	**21.22**	0.00	**596.95**
4	**596.95**	**21.83**	0.00	**575.12**
5	**575.12**	**21.83**	0.00	**553.29**

Appendix B – ZEB Fleet Conversion Project Plan



Appendix C – Conceptual Plan