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Westbrook - CT

Energy Consumption Analysis

Introduction

Middletown Energy Consumption Analysis

1. Project: Assisting Westbrook’s transition to an electric bus fleet.
2. Goal: Develop a functional, efficient, and sustainable EV operational strategy
3. Project Overview: Developed Fleet Mileage & Scheduling Strategies, Evaluated Electrification Options for High-Mileage Routes, Formulated Mixed Fleet & Transit-Only Bus Scenarios
4. Presenation Outline: Optimized Fleet Charging Strategy Model, Electric Bus Fleet Analysis, Charging Hours, Scenario Introduction, Modeling Assumptions, Xendee Data Presentation, Key Takeaways, and Next steps.

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Key Technical Assumptions

- Route and mileage data, vehicle type selections by route, and assumed mileage efficiencies were provided by CTDOT for modeling purposes
- A/B fleet modeling does not account for any necessary deadheading miles in direct calculations that may be necessary for midday recharging strategy at the Westbrook depot
- The A/B recharging strategy may require additional time
- No Time-of-day demand charges are present from the utility, so we are incentivized to keep the peak as low as possible for all times of the day and not avoid any specific hours

Optimized Fleet Charging Strategy Model

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Practical Operation with Mixed Vehicle Fleet – Direct Fleet Conversion

Vehicle ID	Depot Departure Time	Depot Arrival Time	Total Route Mileage (mi)	Energy Consumption Rate (kWh/mi)	Energy Required for Route Completion (kWh)	Usable Battery Capacity (kWh)	Number of Buses Serving Route	Daily Energy Need per Bus (kWh)	Number of Midday Recharges	Fleet Service Strategy
Clinton Trolley	12:00 PM	9:00 PM	117	4.1	480	540	1	480	0	One Bus
Clinton Trolley	11:00 AM	6:00 PM	91	4.1	373	540	1	373	0	
641 (route 1)	6:00 AM	7:00 PM	242	4.1	992	540	2	496	0	A/B
641 (route 2)	6:00 AM	7:00 PM	227	4.1	931	540	2	465	0	
Madison Shuttle	9:00 AM	6:00 PM	165	2	330	144	2	165	1	A/B
640	7:00 AM	7:00 PM	95	2	190	144	2	95	0	A/B
642	6:00 AM	8:00 PM	190	2	380	144	2	190	1	A/B
643	7:00 AM	6:00 PM	292	2	584	144	2	292	3	A/B
644	6:00 AM	7:00 PM	445	2	890	144	2	445	5	A/B
645	6:00 AM	6:00 PM	405	2	810	144	2	405	4	A/B

These 3 routes are very high mileage and require several battery charges per bus to complete current routes, and present significant operational challenges to effectively implement with Minibuses

All Routes Covered by Transit Buses

Vehicle ID	Depot Departure Time	Depot Arrival Time	Total Route Mileage (mi)	Energy Consumption Rate (kWh/mi)	Energy Required for Route Completion (kWh)	Usable Battery Capacity (kWh)	Number of Buses Serving Route	Daily Energy Need per Bus (kWh)	Number of Midday Recharges	Fleet Service Strategy
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641 (route 2)	6:00 AM	7:00 PM	227	4.1	931	540	2	465	0	A/B
Madison Shuttle	9:00 AM	6:00 PM	165	4.1	677	540	2	338	0	A/B
640	7:00 AM	7:00 PM	95	4.1	390	540	1	390	0	One Bus
642	6:00 AM	8:00 PM	190	4.1	779	540	2	390	0	A/B
643	7:00 AM	6:00 PM	292	4.1	1197	540	2	599	1	A/B
644	6:00 AM	7:00 PM	445	4.1	1825	540	2	912	2	A/B
645	6:00 AM	6:00 PM	405	4.1	1661	540	2	830	2	A/B

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Electric Bus Fleet Analysis

Charging Strategies & Feasibility

1. **Mixed Vehicle Fleet Operations:** Examines energy needs and operational hours of a diverse fleet, highlighting route feasibility for various bus types and sizes.
2. **A/B Fleet Configuration Scenarios:** Explores the employment of two separate buses (A and B) for each route to minimize midday recharging and enhance operational efficiency.
3. **Detailed Charging Methods:** Provides critical insights into daily energy requirements, charging durations, and the necessary infrastructure for overnight and midday recharging.

Practical Operation with Mixed Vehicle Fleet

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645	6:00 AM	6:00 PM	405	2	810	144	2	405	4	A/B

Explanation of Charging Hours

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- Entirety of fleet available for charging at depot from 9PM to 6AM
- Remainder of overnight charging occurs for specific vehicles around these hours depending on availability
- Midday charging is crucial to serving very high mileage routes
- Transit buses can technically be used to simplify operations, but can provide other operational challenges

Scenario Introduction

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- Vehicles always leave the depot fully charged
- Subject to Eversource Utility rate 56

Technical Feasibility

- Evaluated the infrastructure needs assuming all charging occurs overnight
- Assesses the worst-case scenario for charging needs to ensure the fleet can operate daily routes

Mixed Vehicle Fleet

- Implements A/B topology with midday charging
- Considers practical operations of combining 22-foot minibuses and transit buses in the fleet
- High frequency of short midday recharges presents operational complexity

All Transit Fleet

- Implements A/B topology with midday charging
- Utilizes A/B topology, focusing solely on larger transit buses
- Aims to reduce the number of midday recharging windows, streamlining operations

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Modeling Assumptions

Westbrook Energy Consumption Analysis

Mixed Fleet Scenario, min # vehicles*	All Transit Scenario, min # vehicles*	Bus Type	Energy Consumption	Listed Range (miles)	Battery Capacity	Charging method
5	12	40’ Transit Buses	4.1 kWh/mile	230	675 kWh	Overnight plug-in, DC Fast (180 kW nominal) 480V@200A
12	0	22’ Minibuses	2.0 kWh/mile	150	180 kWh	Overnight plug-in, DC Fast (180 kW nominal) 480V@200A

*Additional vehicles may be required depending on deadheading and charging strategy to provide operational flexibility if desired

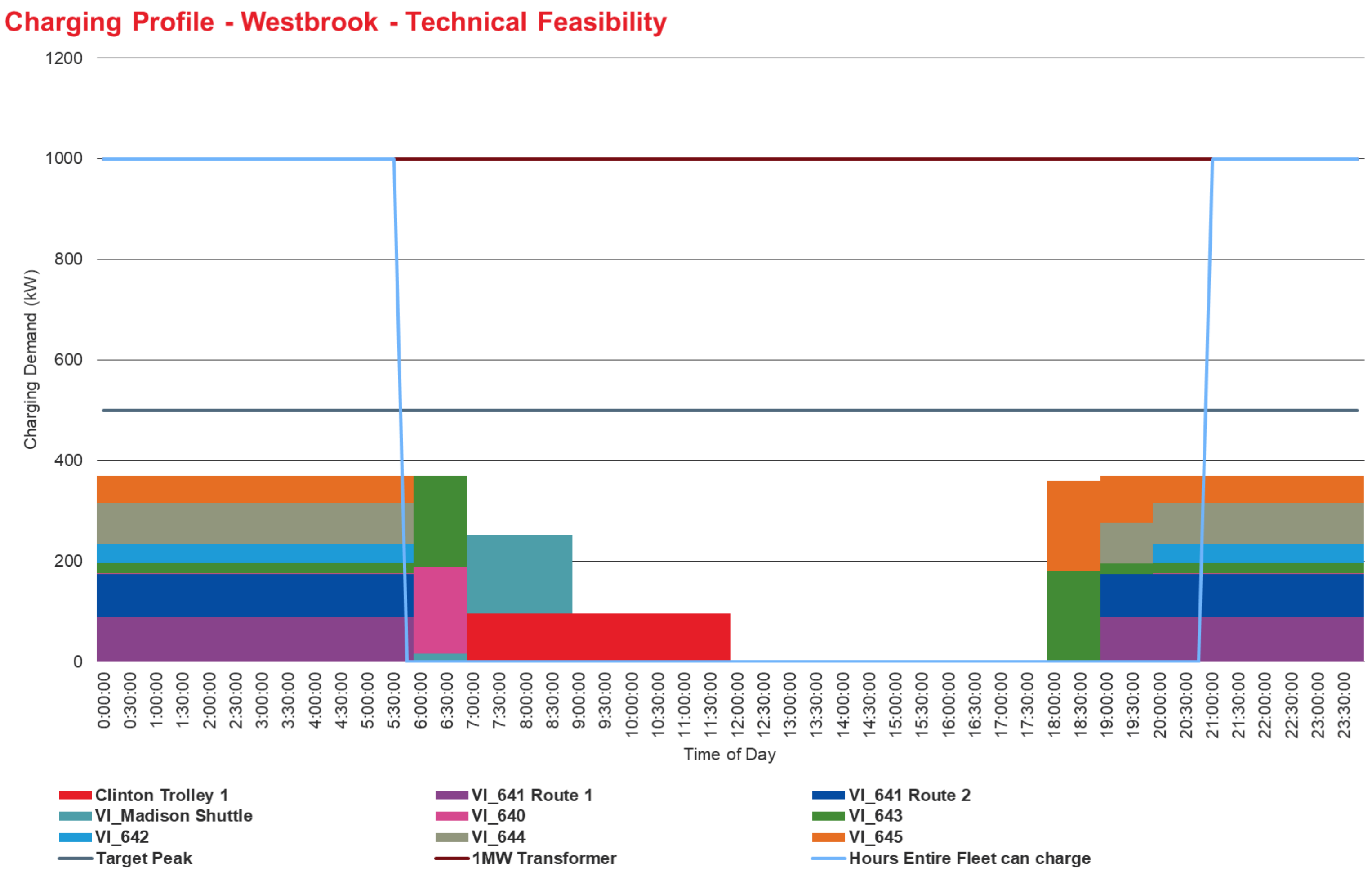
Scenarios

Energy Modeling results

Technical Feasibility Scenario

Xendee Data

- Based on our analysis, a peak demand of 500kW is identified as a reasonable requirement for charging operations.
- A 1 MW transformer is sufficient, providing ample headroom for DC fast charging capabilities.
- The optimized charging profile focuses on providing all energy during overnight deadheading to highlight the worst case scenario for electrical infrastructure sizing.



* Graph serves as a visual explanation of how charging is managed

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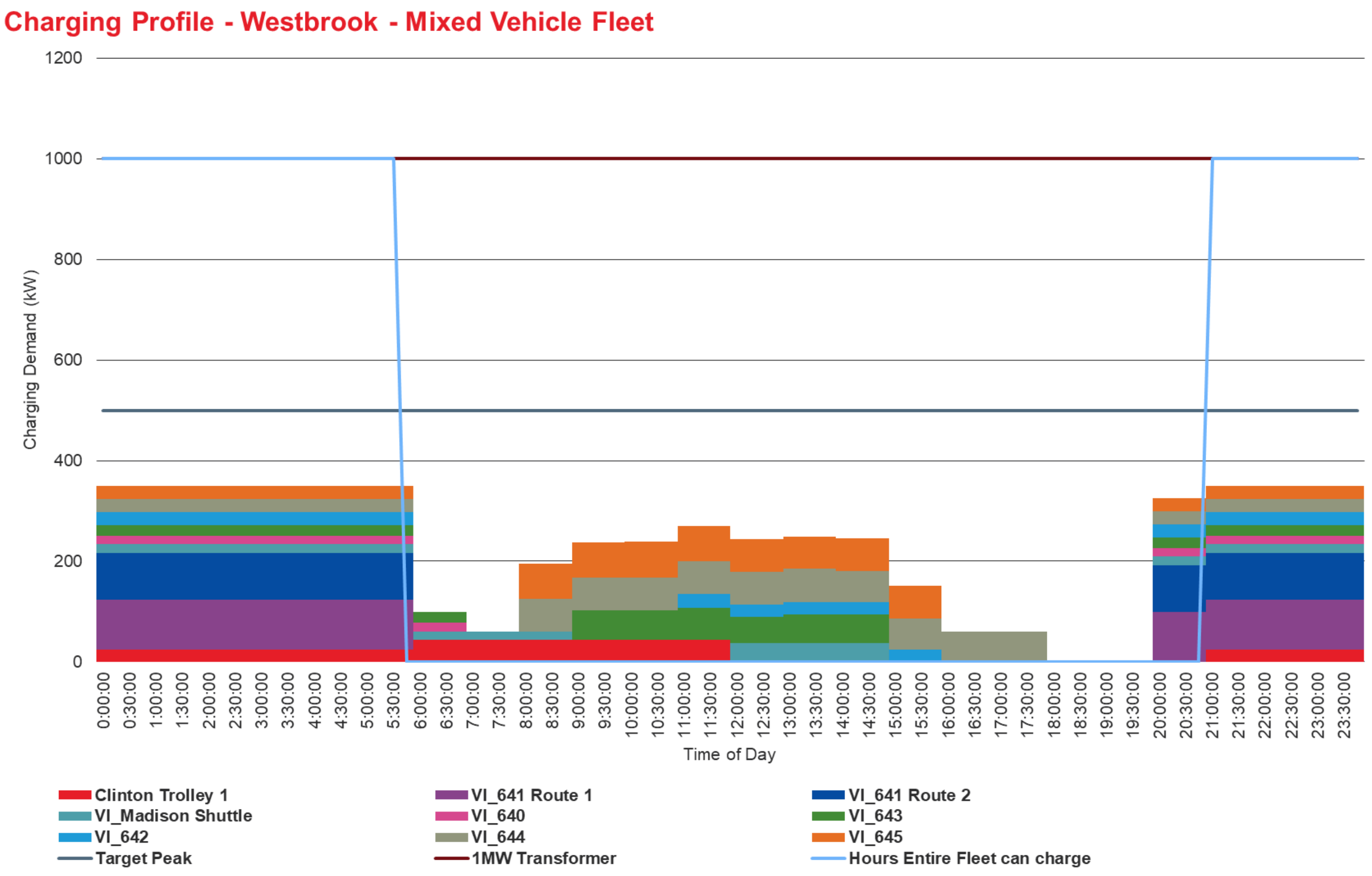
Mixed Vehicle Fleet Scenario

Xendee Data

- Aligns with CTDOT's current mixed vehicle fleet, utilizing a combination of transit buses and 22-foot minibuses.
- Requires a complex charging schedule due to significant midday recharging needs, stemming from high-mileage routes, vehicles with low battery capacity, and A/B vehicle operations for routes.
- A peak demand of 500kW is a reasonable requirement based on our analysis, and a 1 MW transformer is sufficient, providing headroom for DC fast charging capabilities.



* Graph serves as a visual explanation of how charging is managed. Refer to slide 13 for additional explanation of A/B vehicle blocking for individual routes

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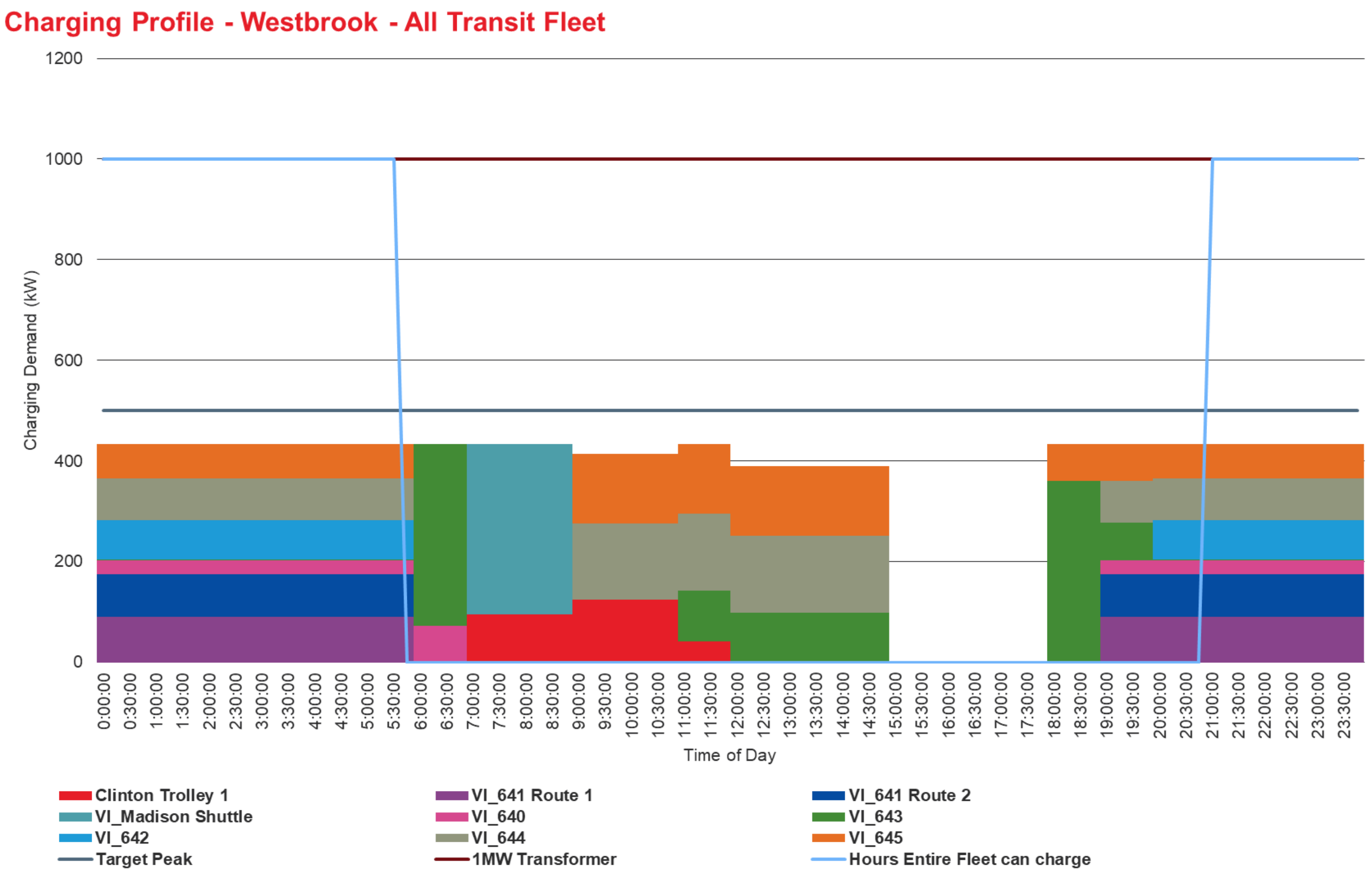
All Transit Fleet Scenario

Xendee Data

- Simplifies logistics with higher battery capacity, reducing the need for midday recharging and thus streamlining operations.
- Buses in this scenario are less energy-efficient per mile compared to a mixed fleet, but their higher capacity allows for extended range.
- A peak demand of 500kW is a reasonable requirement based on our analysis, and a 1 MW transformer is sufficient, providing headroom for DC fast charging capabilities.



* Graph serves as a visual explanation of how charging is managed. Refer to slide 13 for additional explanation of A/B vehicle blocking for individual routes

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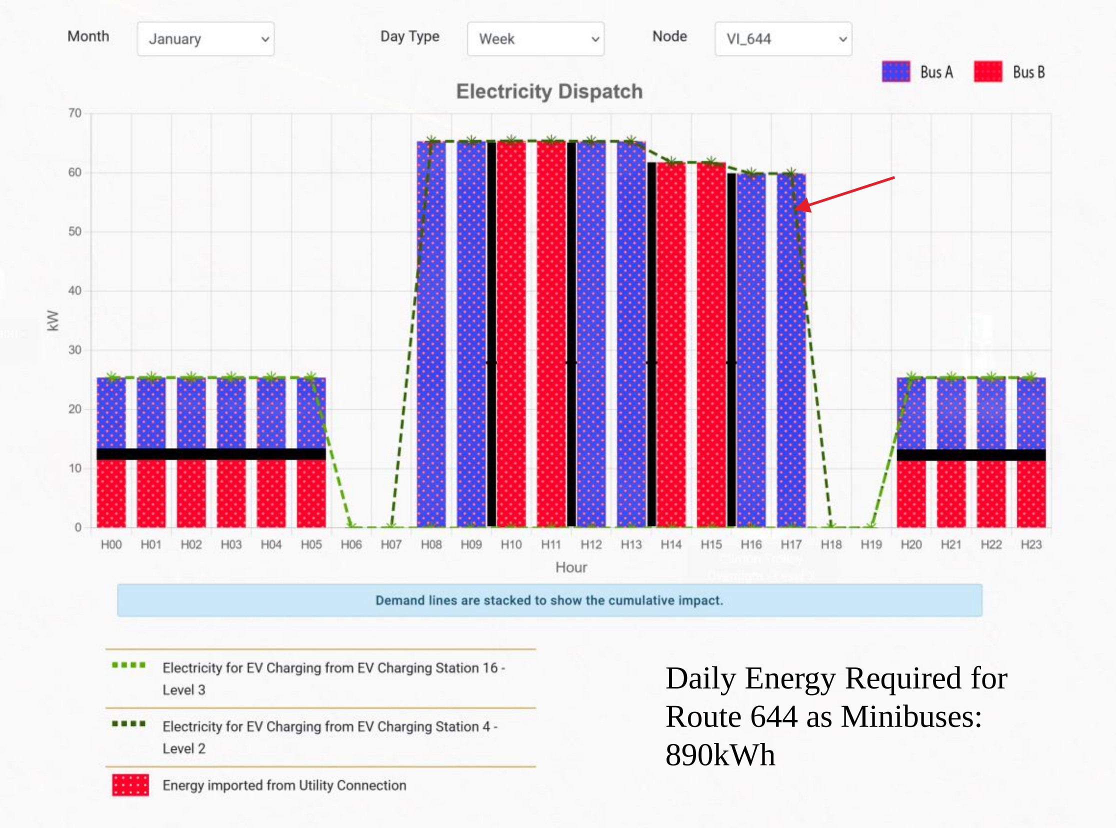
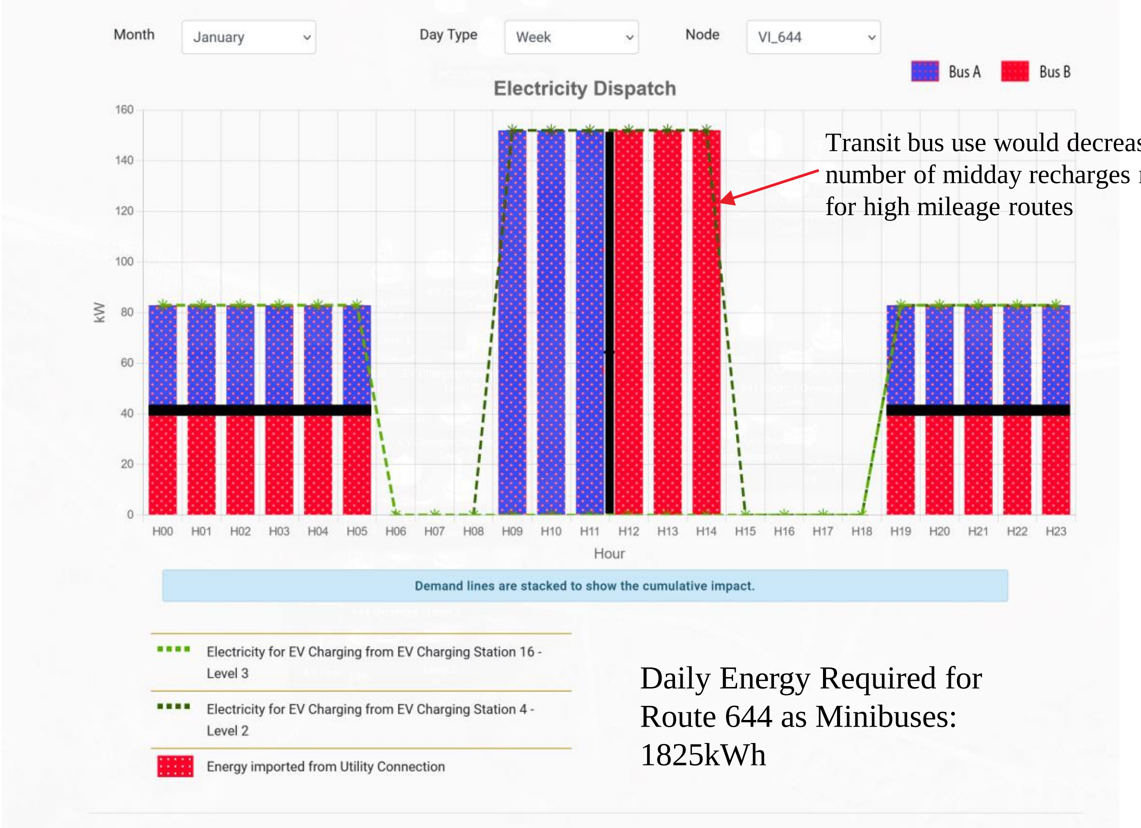
Example A/B Charging for Route 644

Mixed Fleet Scenario



Daily Energy Required for Route 644 as Minibuses: 890kWh

All Transit Scenario



Transit bus use would decrease the number of midday recharges needed for high mileage routes

Daily Energy Required for Route 644 as Minibuses: 1825kWh

- By utilizing transit buses for higher mileage routes, the frequency and number of midday recharges decreases, which offers simplified operations at the expense of less efficient vehicles

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Key Takeaways

1. Transitioning the fleet with equivalent or similar vehicle types is operationally challenging due to small battery capacities and high mileage routes, necessitating frequent mid-day recharging and vehicle swapping.
2. Electrifying the entire fleet with transit buses would reduce the frequency of mid-day recharging due to their larger energy capacity, simplifying operations but at the cost of increased overall energy demand and vehicle purchases for a 1:1 electrification of current routes.
3. Given the high mileage and current vehicle battery capacity limitations, implementing an A/B fleet strategy with recharging is required to provide sufficient energy to the buses, however this comes with a significant operational challenge.
4. There is no 'silver bullet' solution to electrifying the fleet to match its current blocking; a combination of re-routing, selective fleet conversion, and exploring additional on-route charging sites will be necessary to strike a balance between cost, technical, and operational considerations.

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Next Steps

1. If fast charging stations are considered at the main depot, BESS should be considered to mitigate peak demand charges.
2. Arup recommends conducting a detailed route and blocking study to reconfigure routes for lower mileage where 22-foot buses can be used effectively and develop a strategic plan to convert only the highest mileage routes to 40-foot transit buses where route shortening is not feasible.
3. Identify and assess potential sites along the routes where additional charging infrastructure could be installed, extending bus range during operations and potentially eliminating the need for midday recharging at the depot, or the need for A/B fleets on certain routes.

Questions