Milwaukee County Transit System

Milwaukee County Transit System Battery Electric Bus Analysis

Milwaukee County Transportation
Public Works and Transit Committee

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DRAYTON Consulting

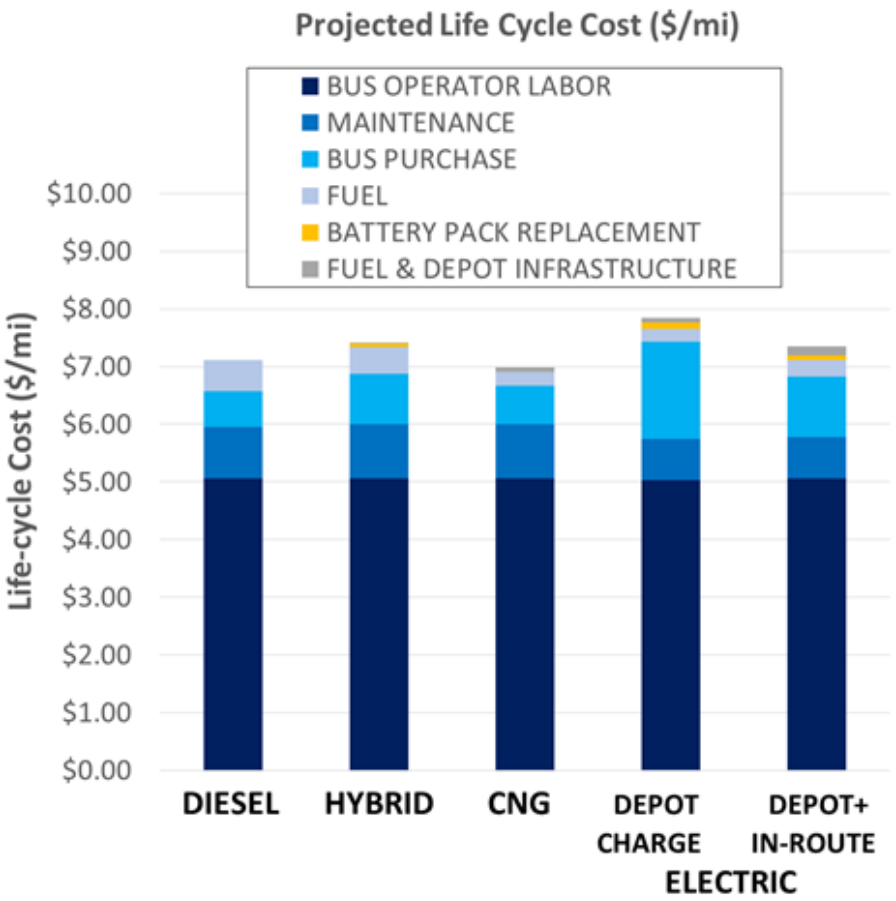
IBC ENGINEERING SERVICES, INC.

Project Purpose

Help MCTS prepare for *potential* electrification of the bus fleet:

- Evaluate and compare available battery bus options
- Determine infrastructure requirements for battery bus charging
- Project capital and operating costs associated with fleet conversion
- Identify potential funding opportunities for fleet conversion
- Identify necessary changes to maintenance and operations to accommodate electric buses
- Develop a *Fleet Electrification Business Plan*
- Develop Technical Specifications

2016 MCTS Alternative Fuel Bus Analysis

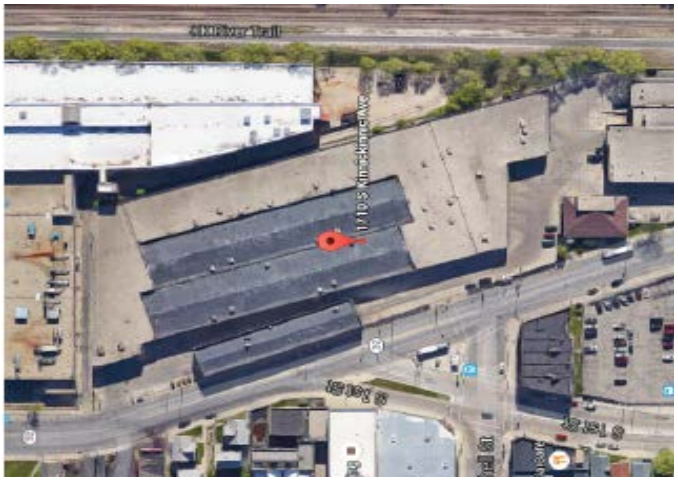


- 2016 Alternative Fuel Bus Analysis evaluated electric buses for use on the new BRT route
- A lot has changed, just in the last 3 years
- This project will build on the 2016 analysis, but will update and refine many assumptions – especially related to charging infrastructure

MCTS Fleet and Facilities

Fond du Lac Garage

Kinnickinnic Garage



Fiebrantz Garage

No longer in use

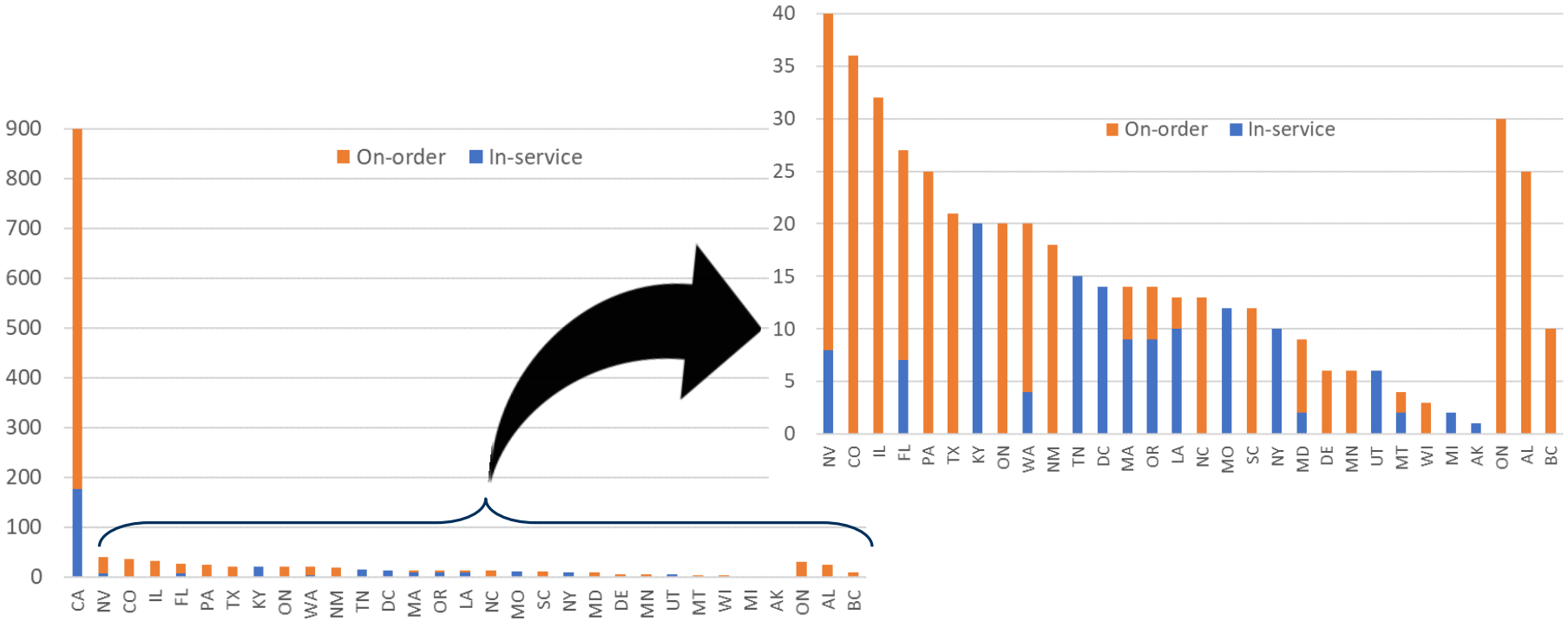
Bus Garage	Facility Size			Bus Parking Capacity	Maintenanance Area			Assigned Buses
	Maint Bldg [SF]	Bus Storage [SF]	Total [SF]	[Buses]	Hoists	Pits	Total	
Fond du Lac	48,808	160,749	209,557	229	10	12	22	216
Kinnickinnic	47,472	126,697	174,169	177	9	9	19	175
Fleet Maint	204,578	0	204,578	0	31	11	42	NA
Fiebrantz	28,819	58,001	86,820	100	3	8	11	NA
TOTAL	**329,677**	**345,447**	**675,124**	**506**	**53**	**40**	**94**	**391**

U.S. Electric Transit Buses

Status & Trends

Current North American Electric Bus Market

- BEBs in service (~**600)** and on order (~**1,200)** total ~**1,800 (2% of fleet)**
- ~50 transit agencies with ZEBs already in service and ~125 agencies who have ordered ZEBs (6% of agencies)
- Proterra and BYD are the dominant ZEB manufacturers with approximately 550 and 540 ZEBs sold, respectively (~40% of market each)



Notable Recent Electric Bus Orders

- LA Metro — 105 buses (BYD)
- LA DOT — 118 buses (BYD, Proterra)
- Antelope Valley — 89 buses (BYD)
- Foothill Transit — 50 buses (Proterra)
- AC Transit — 50 buses (Proterra)
- KC Metro — 73 buses (Proterra)
- Toronto — 60 buses (BYD / New Flyer / Proterra)
- Montreal — 40 buses (Nova)
- MN Metro — 27 buses (New Flyer)
- CTA — 20 buses
- SEPTA — 10 buses

Formal commitments for zero emission transition (outside of California): NYCT, KC Metro, MN Metro, Toronto, TransLink

Climate Concerns are Driving the Market….

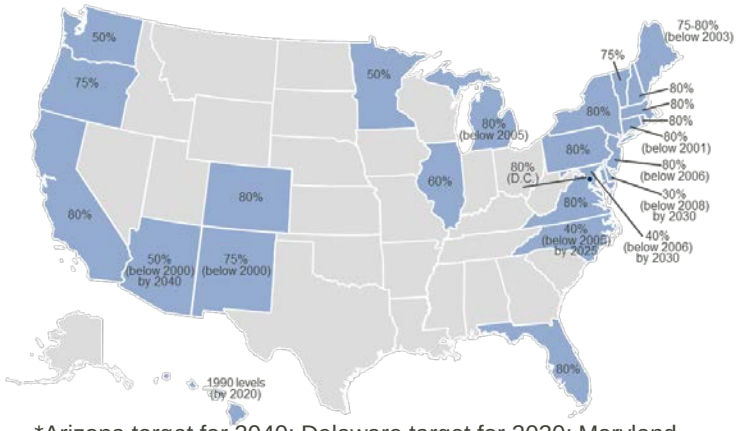
REUTERS

WORLD NEWS

AUGUST 4, 2017 / 5:25 PM / A YEAR AGO

U.S. submits formal notice of withdrawal from Paris climate pact

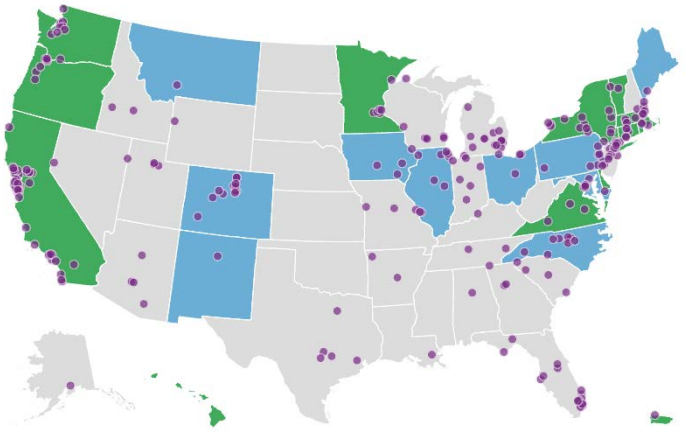
2050 GHG Reduction Targets



*Arizona target for 2040; Delaware target for 2030; Maryland target for 2030, North Carolina target for 2025

Note: GHG reduction targets from different baseline years; though most are 1990

Climate Commitments



12 member states: U.S. Climate Alliance

10 supporting states: Paris Agreement

274 member cities: Mayors National Climate Action Agenda

California "Innovative Clean Transit Regulation"

- Adopted by CARB in December 2014
- Mandates ALL CA transit buses "zero emission" by 2040
- Supported by significant state subsidies

… but U.S. policy is driven by states & Cities

Considerations for Electric Bus Implementation

40-ft Electric Bus Models

Manuf	Model	Battery Capacity (kWh)	Effective Range (mi) [1]	Maximum Passenger Capacity [2]
PROTERRA	XR	220	77	113
	XR+	330	116	102
	E2	440	155	92
	E2+	550	193	81
	E2 max	660	232	70
BYD	K9	324	114	76
	K9	500	176	61
New Flyer	XE40	150	53	93
	XE40	200	70	83
	XE40	388	136	80
	XE40	466	164	71
Nova	LFSe	150	53	80+

Intended for in-route charging only

[1] At bus mid-life in MTS service, with fuel heating [2] Based on manufacturer GVWR

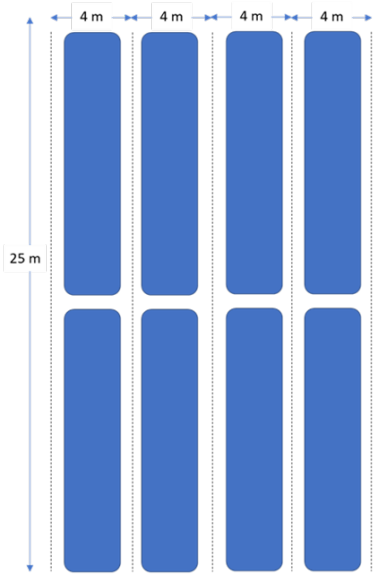
Charging Scenarios

SCENARIO	DEPOT CHARGING	IN-ROUTE CHARGING
CONCEPT	All energy added "overnight", using 50-100 kW chargers located at each Transit Centre	All energy added "in-route", using 350-600 kW chargers located throughout service area
COST TRADE-OFFS	• Very large battery required on bus, **high bus cost** • Practical limitation on battery size limits range – in the near term **additional buses will be required** • Large number of chargers required – space claim at Depots	• Smaller battery required on bus, **lower bus cost** • Smaller number of chargers required, **but much higher cost/charger** • Siting in-route chargers could be difficult

Depot vs In-route Charging

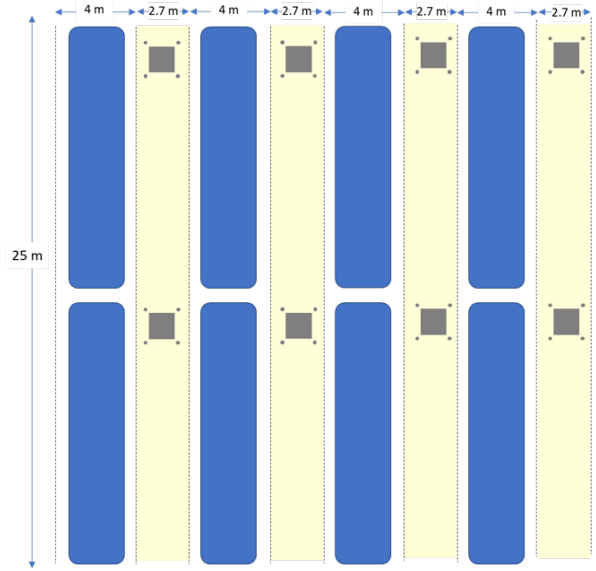
	DEPOT CHARGING	IN-ROUTE CHARGING
PROS (+)	• More direct control over infrastructure • Lower infrastructure costs • Lower electricity cost • Potentially less expensive in the long run	• Less expensive now • Do not need to shorten daily bus assignments • No loss of depot parking capacity • Greater resiliency/reliability –a few chargers out of commission won't affect bus operations • Lower cost bus
CONS (-)	• Space claim for chargers reduces parking capacity • Must re-configure daily bus assignments to shorten them; increased dead-head time • Difficult/costly to provide back-up power to entire depot • Higher cost bus	• Time and effort for site acquisition and permitting of charger sites • Less control over infrastructure • Higher infrastructure costs • Higher electricity cost • Higher cost/difficulty of charger maintenance • Additional time in schedules to accommodate charging

Depot Charger Space Claim



CURRENT BUS PARKING

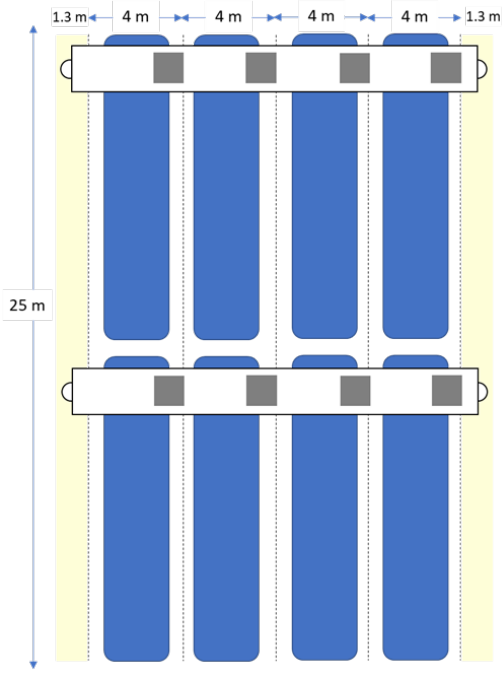
~50 m^2/12-m bus
not including circulation space



GROUND-MOUNTED CHARGERS

~79 m^2/12-m bus
not including circulation space

Up to 40% loss in parking capacity for full depot conversion
To minimize space loss, would need charge ports on both sides of bus

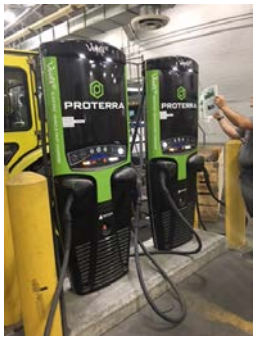


OVERHEAD CHARGERS

~55 m^2/12-m bus
not including circulation space

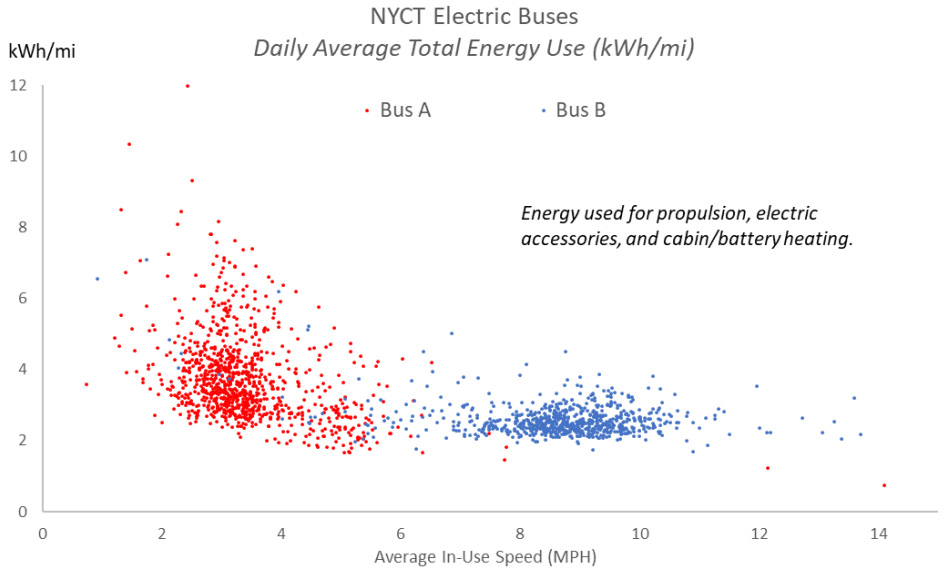
As little as10% loss in parking capacity for full depot conversion.

Additional cost for over-head structure, but also less trenching required for conduit runs

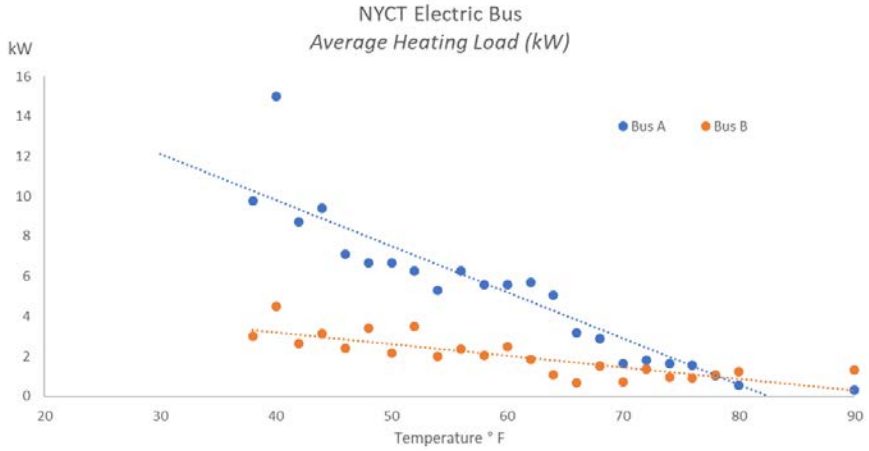


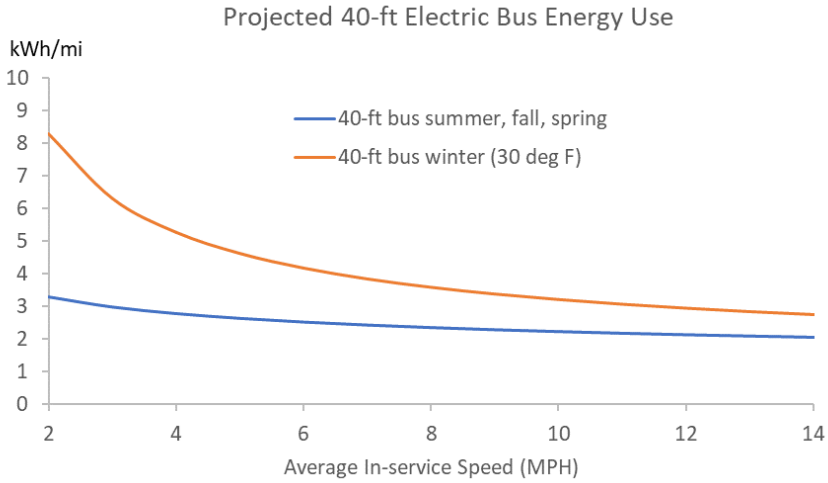
In-route Chargers

Electric Bus Energy Use

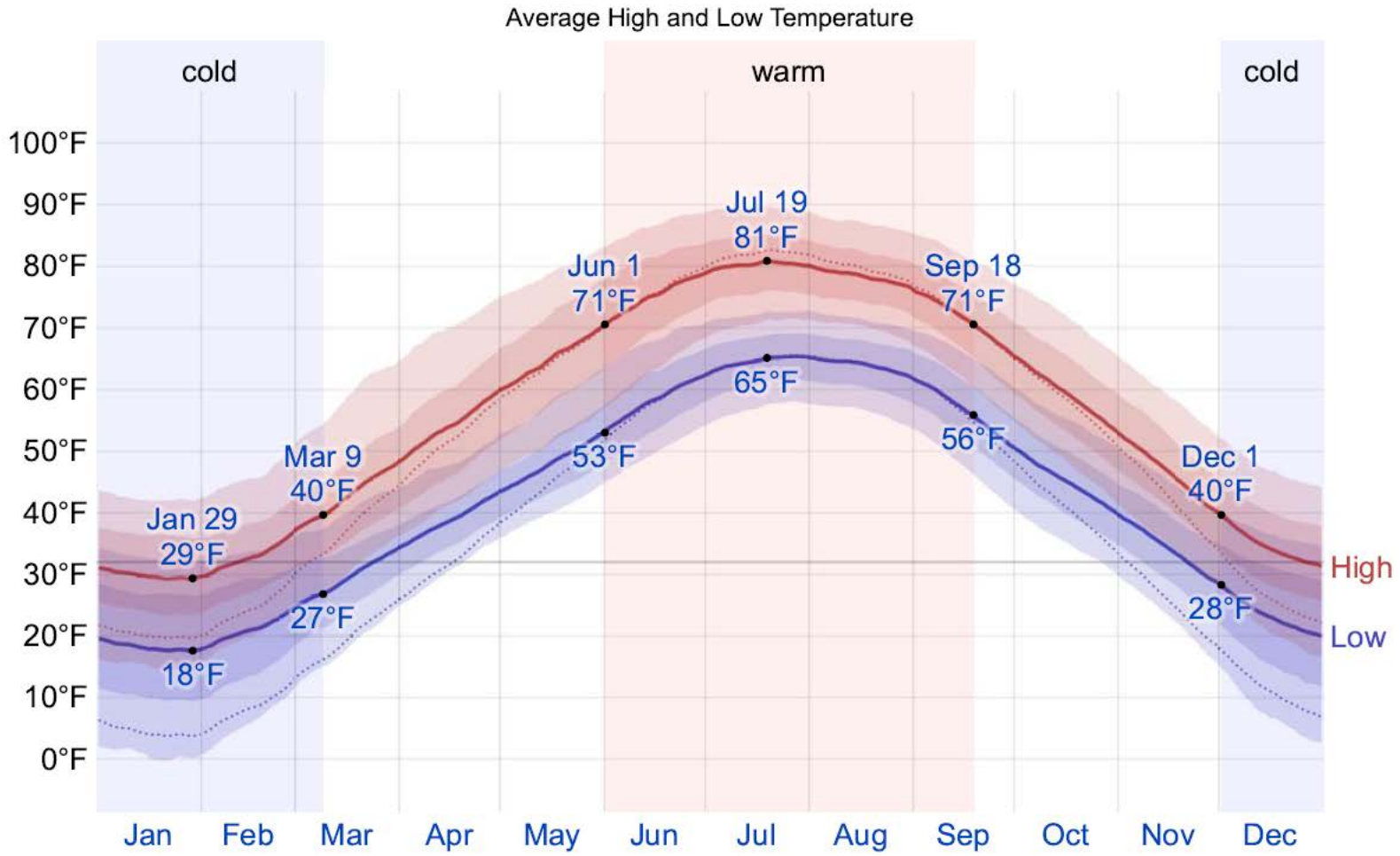


- Propulsion energy use varies by duty cycle (MPH)
- Energy for cabin heating varies with ambient temperature
- On very cold days total energy use (kWh/mi) can more than double compared to energy use on warm days, especially on low-speed routes





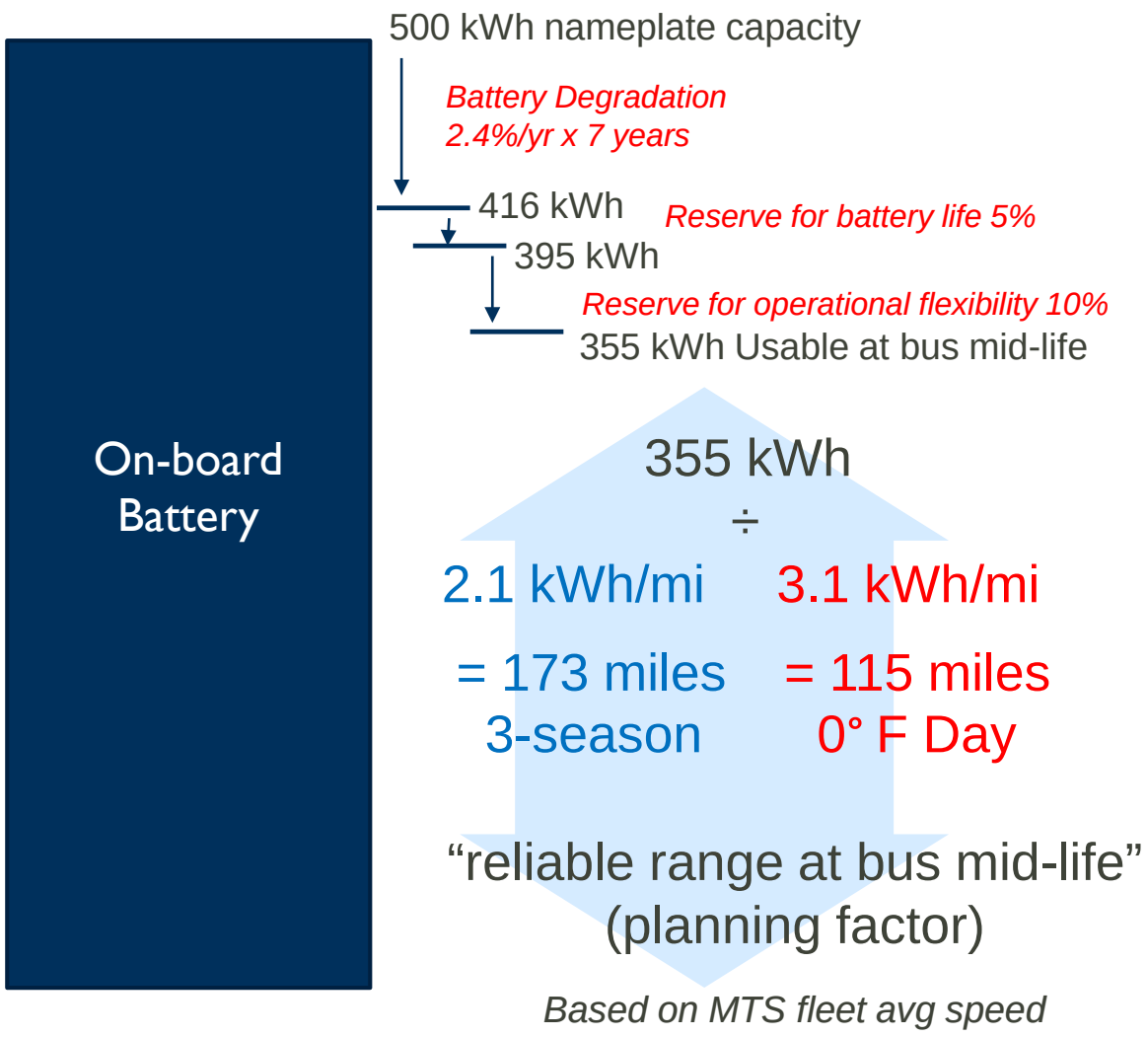
Milwaukee Weather



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

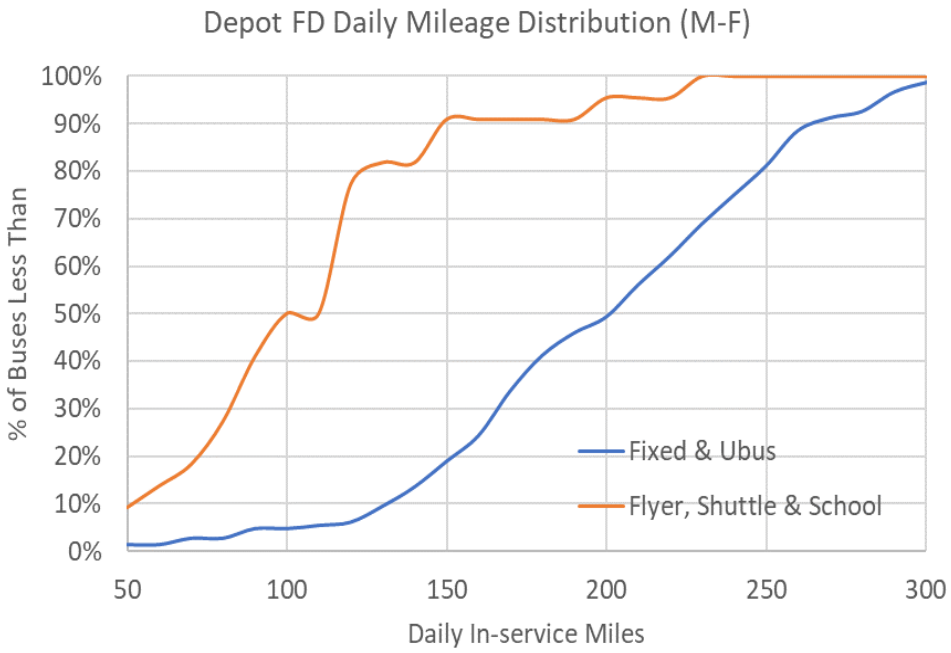
https://weatherspark.com/y/14288/Average-Weather-in-Milwaukee-Wisconsin-United-States-Year-Round

Electric Bus Range per Charge



- Batteries degrade over time, losing effective capacity
- Most battery manufacturers don't recommend bringing batteries all the way down to zero state of charge every day – maintain a reserve of 5% - 20%
- Daily energy use can vary from the average by 10% or more on a given day
- Electric bus planning should be based on a "reliable" range per charge that accounts for these factors – not on name plate range of a new battery and average energy use

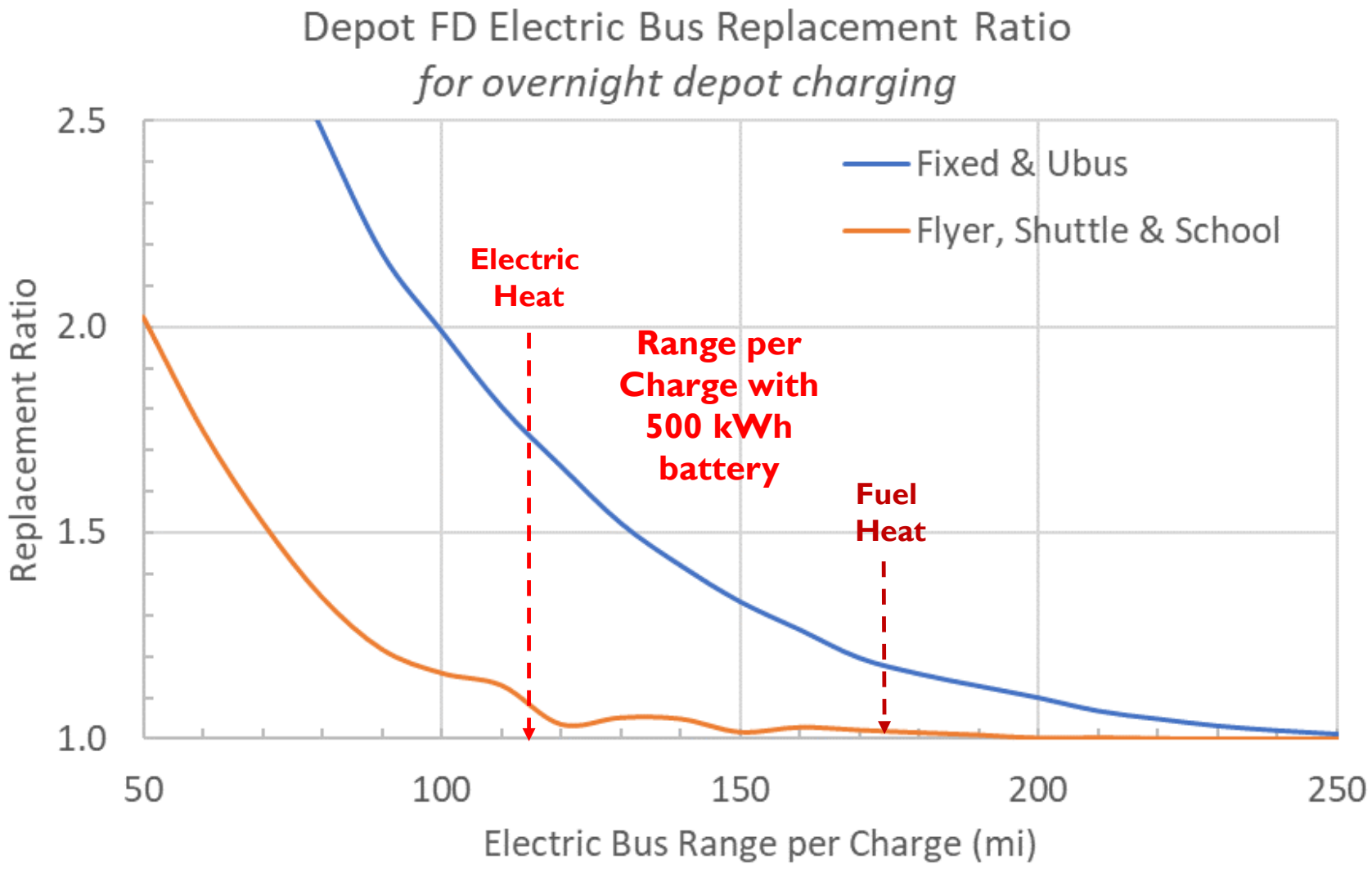
Bus Scheduling – Miles per Day



- Due to limitations on battery size and range, when using depot-charged electric buses, long route assignments will need to be shortened – which will INCREASE peak bus requirements

- MTS operates two types of routes:
  - ✓ Fixed – *operate all day*
  - ✓ Flyer, Shuttle, Ubus, School – *operate only during AM and PM peak*
- Buses on fixed routes average ~200 miles per day, but some buses travel 300+ miles per day
- Buses on Flyer, Shuttle & school routes average 72 mi/day at Kinnickinnic and 121 mi/day at Fond du Lac, but some buses go over 200 mi/day
- This is NOT a function of how "long" routes are (end-to end miles), but rather of how buses are scheduled

Electric Bus Replacement Ratio



Electric Bus Economics

- Electric buses are significantly more expensive than diesel and hybrid buses
- Charging infrastructure is expensive – but less so than incremental cost of buses
- Batteries will (likely) need to be replaced at mid-life

CAPITAL

- Electricity is cheaper than diesel
- Potential for modest maintenance cost savings

OPERATING

CAPITAL / OPERATING COST TRADE-OFFS

“BREAK EVEN” (vs Diesel) VARIES BY LOCATION BASED ON ELECTRICITY COST

THERE ARE OTHER COST & OPERATIONAL TRADE-OFFS BASED ON CHARGING STRATEGY

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