Battery Electric Buses (BEB's)

Lessons Learned

October 6th, 2021 Presentation

MINNESOTA
WISCONSIN
PUBLIC
TRANSPORTATION
RESILIENT AND STRONG
2021

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Battery Electric Buses (BEB's)
Lessons Learned

Agenda

- BEB Overview
- Battery Considerations
- Charger Considerations
- Case Study – Greater Bridgeport Transit (GBT)
- Questions

Some of our Transit Clients

Metro Transit

ALEXANDRIA TRANSIT COMPANY DASH

HART

MTA New York City Transit

SW SouthWest Transit

M metro

marta

GTA The Way To Move

CAT CHATHAM AREA TRANSIT

VALLEY METRO

ART arlington transit

gbt GREATER BRIDGEPORT TRANSIT

GRTC TRANSIT SYSTEM

PRTC Potomac and Rappahannock Transportation Commission

NFTA Niagara Frontier Transportation Authority

GLTC

Augusta GEORGIA

GET bus GOLDEN EMPIRE TRANSIT DISTRICT

CT transit

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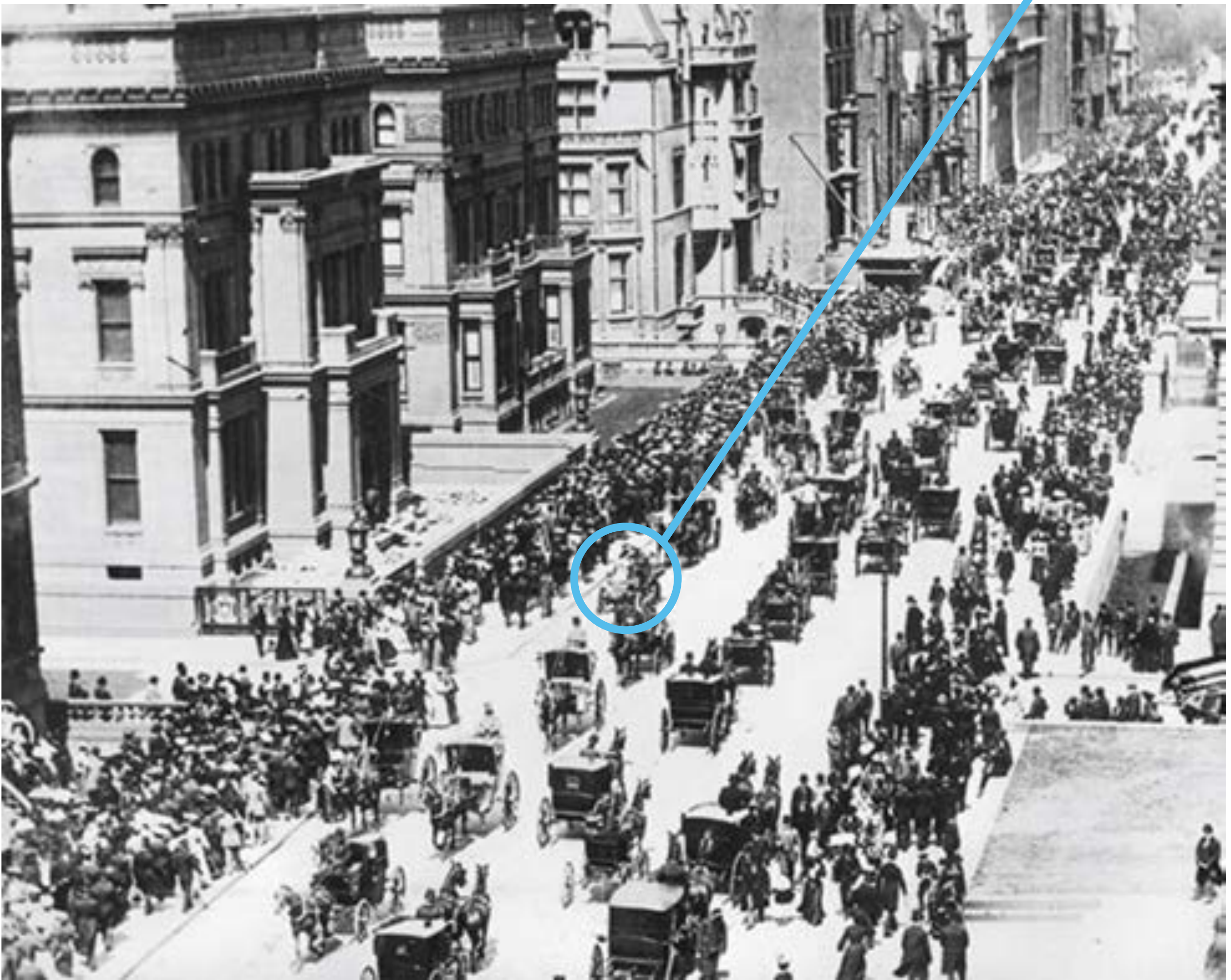
[Image and Content Source: Tony Seba, Clean Disruption of Energy and Transportation]

A Sign of the Times

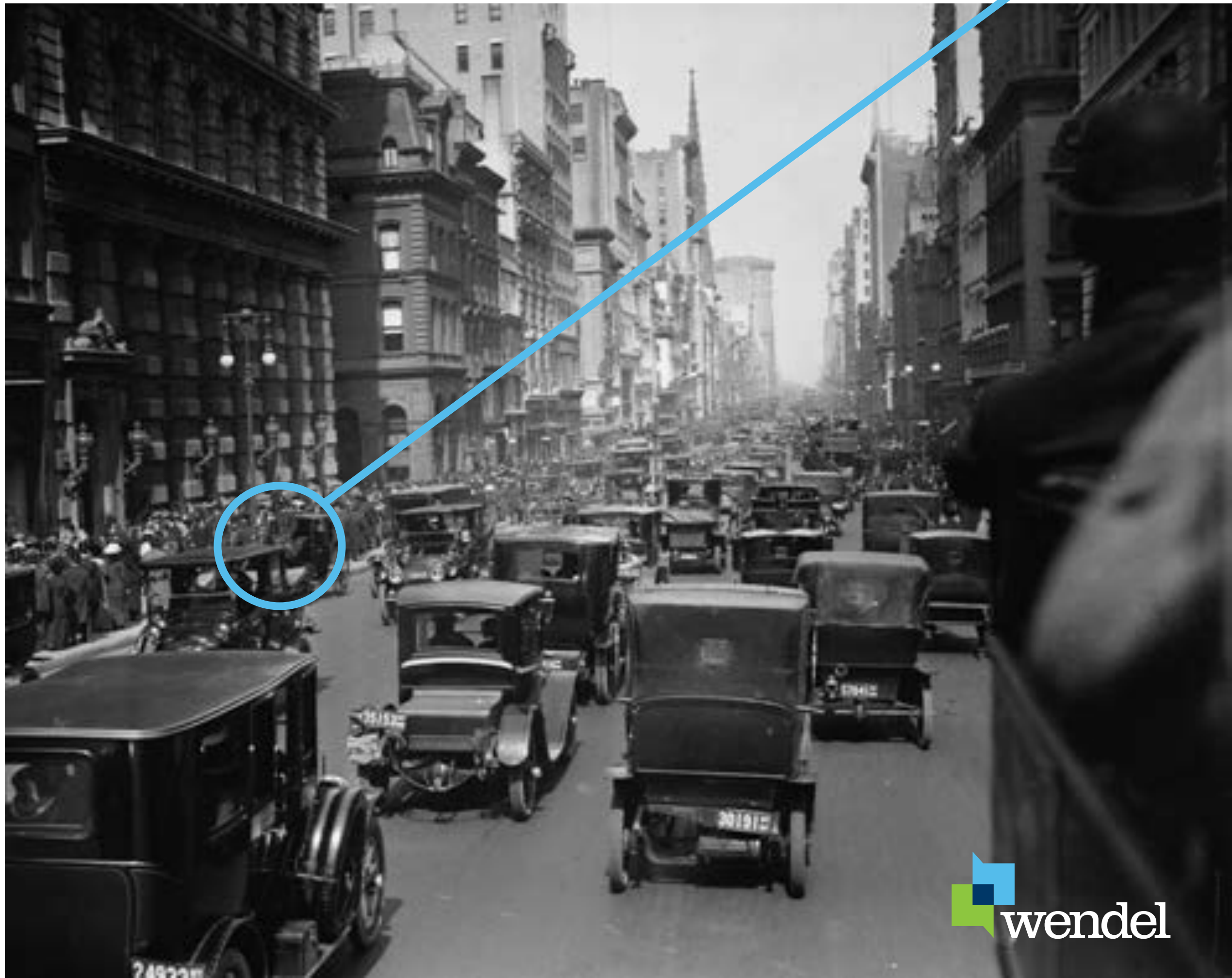
One Car

5TH AVE NYC CIRCA 1900



One Horse

5TH AVE NYC CIRCA 1913



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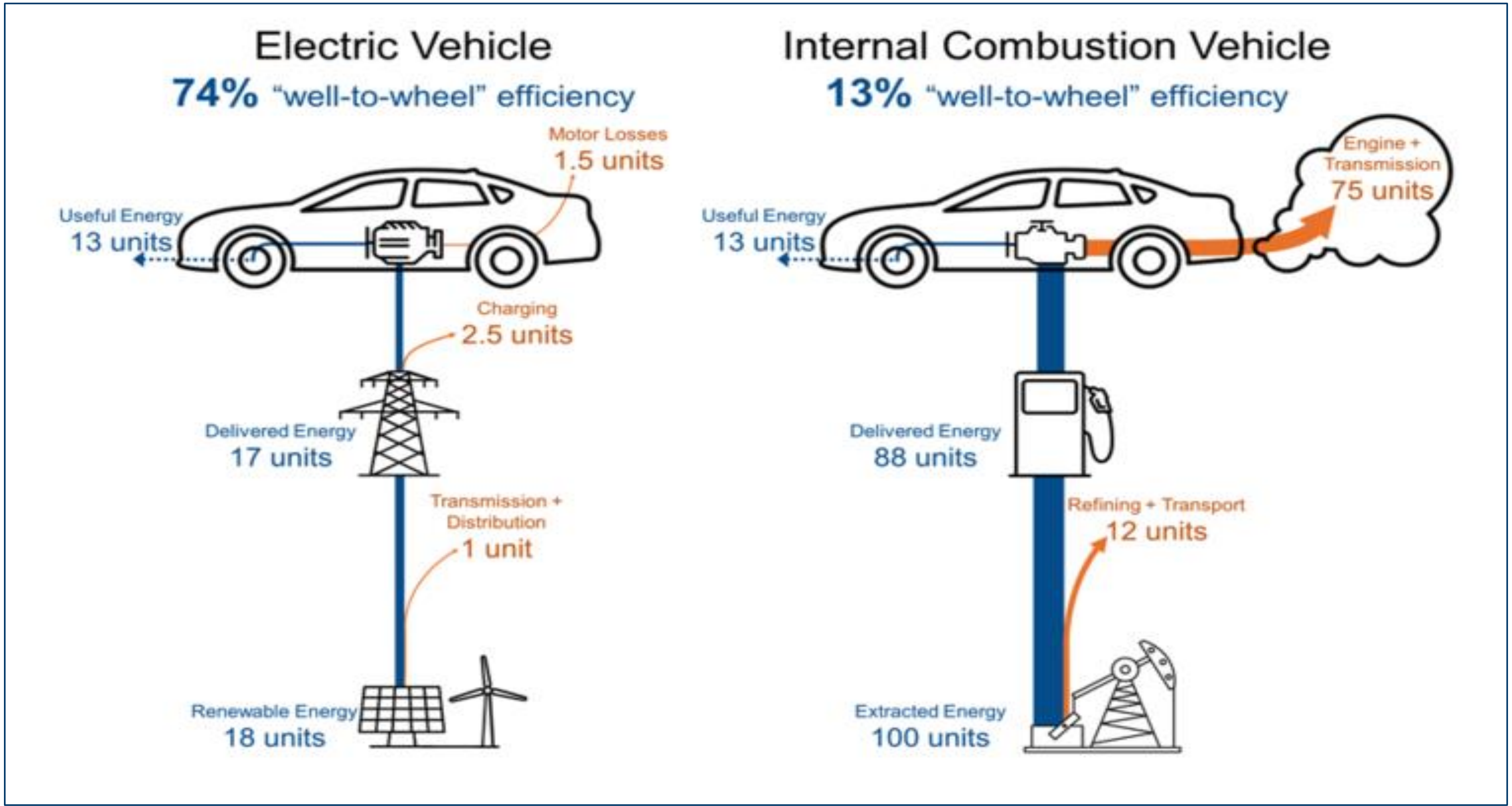
BEB Overview

Overall Efficiency



Battery Electric Bus - Challenges

- BEB's are Significantly more expensive than traditional buses: on average a premium of over $300,000.
    - Depending on how it is equipped a transit ready BEB can cost anywhere from $750,000 - $1,000,000.
    - Charging infrastructure and depot/route modifications are in addition to the bus costs.
- Charging infrastructure and depot modifications also must be considered
- Electric rates can have a significant impact on total cost of ownership and charging strategies
- Maintenance personnel will have to be trained on BEB systems, including high voltage
- Standardization is still an issue
    - Particularly in charging infrastructure
- Bus weight vs range is an issue

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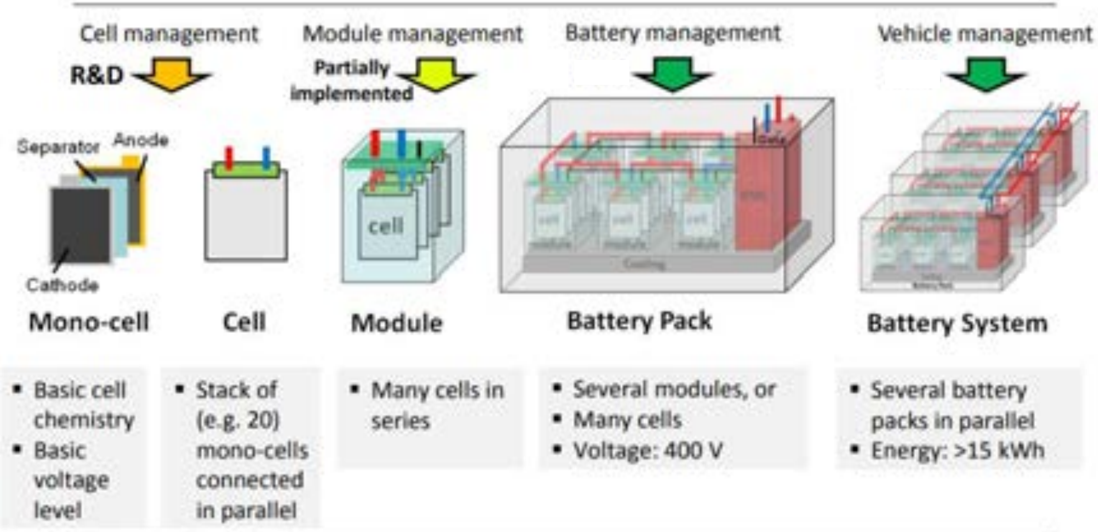
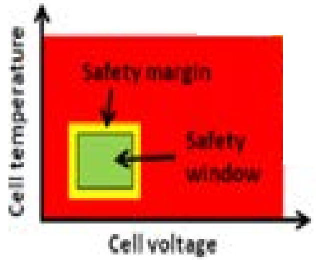
Battery Considerations

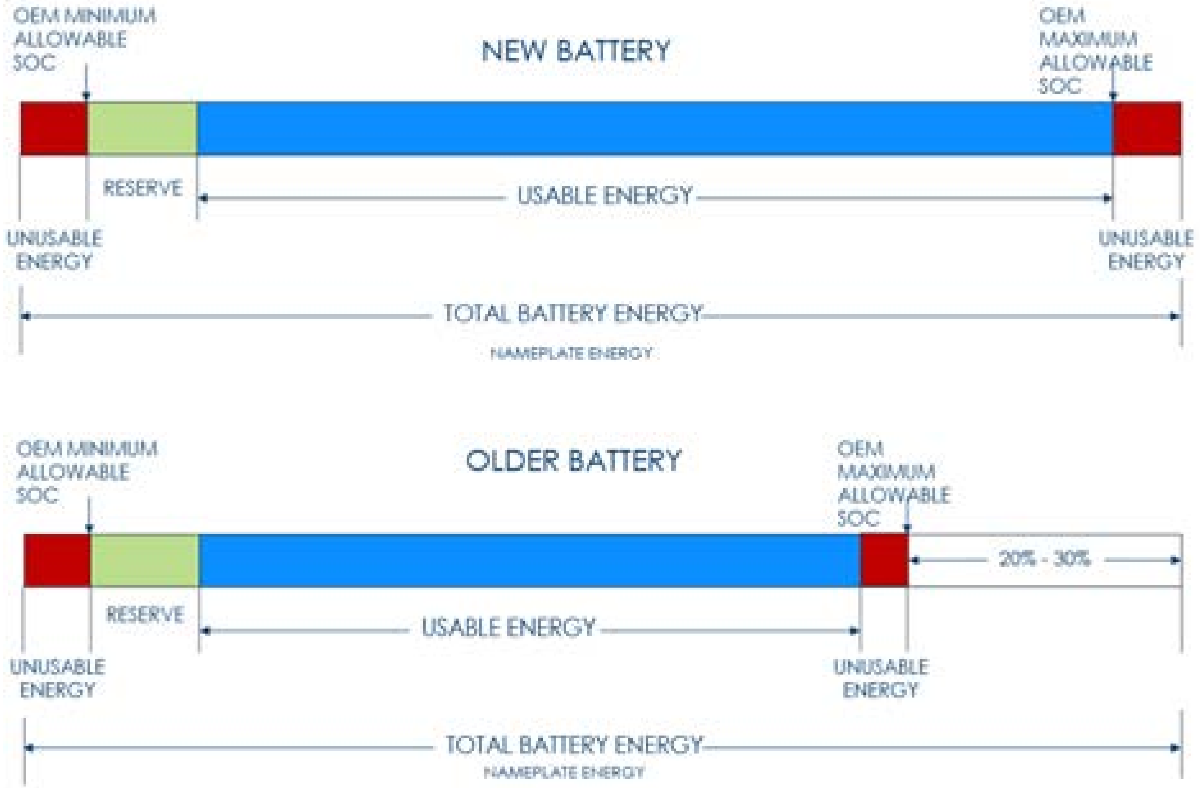
BEB Overview: Battery Fundamentals

KNOW WHAT YOU ARE GETTING.



Source: Battery Management Network for Fully Electrical Vehicles Featuring Smart Systems at Cell and Pack Level By Alexander Otto May 2012

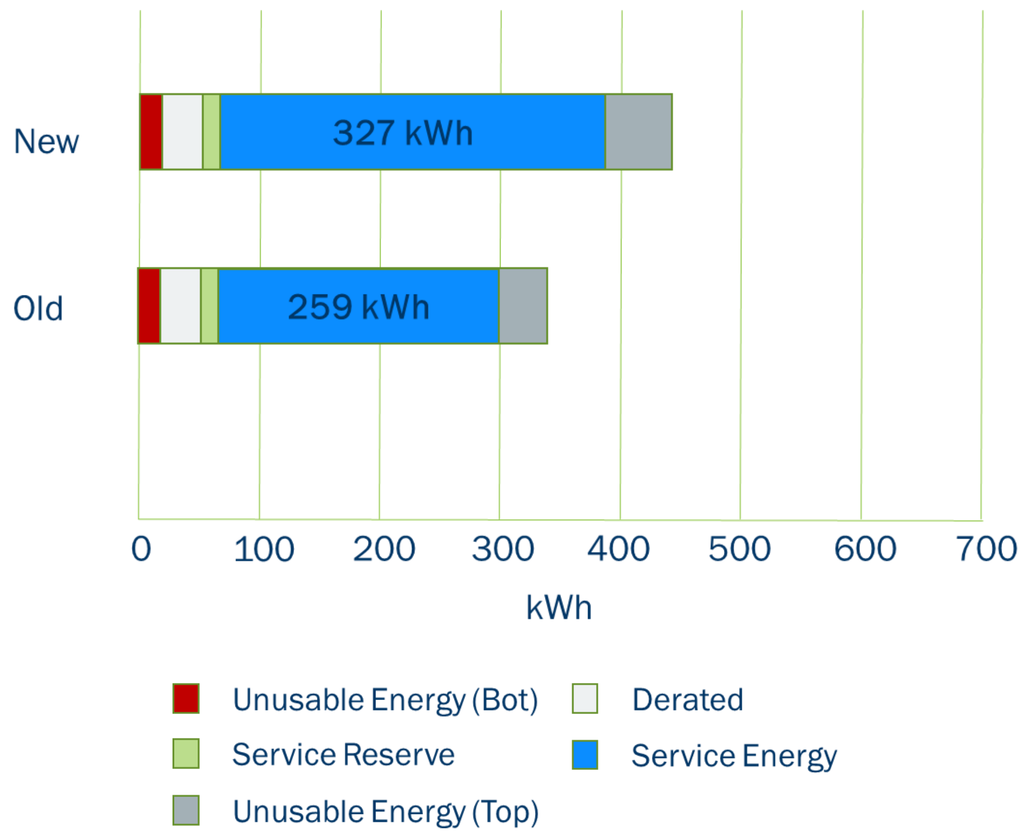




Proterra 440 kWh Example

KNOW WHAT YOU ARE GETTING.

Service Energy for New Proterra E2 440 kWh



Nominal Range			
CAPACITY	**EFFICIENCY**	**MPGe**	**RANGE**
327 kWh [New]	2.2 kWh/Mile	15.3 MPGe	149 miles
259 kWh [Old]	2.2 kWh/Mile	15.3 MPGe	118 miles
327 kWh [New]	1.7 kWh/Mile	19.8 MPGe	192 miles
259 kWh [Old]	1.7 kWh/Mile	19.8 MPGe	152 Miles

2.2 kWh/Mile (15.3 MPGe)– efficiency through modeling of performance on routes in the state of Connecticut.

1.7 kWh/Mile (19.8 MPGe) – efficiency from Altoona testing on a test track in Altoona PA by the FTA. No heat or A/C, flat track, no passengers.

Traditional diesel bus mileage 4.0 - 5.0 MPG

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Battery Considerations

- Most BEB batteries are Lithium-Ion Batteries
- Bigger isn't always better
  - o The larger the battery the longer the range of the bus
  - o The larger the battery the heavier the bus, the heavier the bus the fewer passengers
- On route Charging vs Depot Charging
  - o Smaller battery – on route charging
  - o Larger battery – depot charging

Catalyst E2 440 kWh	Curb	Seated	Seated & Standing
Overall	31,360	37,230	43,530
Front	14,000	15,860	17,950
Rear	17,360	21,370	25,580
Driver		1	1
Seated		38	38
Standing			40
Total		39	79

Intermodal Surface Transportation Efficiency Act (ISTEA)
Year Enacted: 1992 End Date:1994 In 2012 extended indefinitely
Transit buses temporarily exempted from 20,000 pounds single axle weight limit on Interstate Highways. States are not allowed to enforce a single axle weight limit of less than 24,000 pounds

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Large BEB Concerns

BEB OVERVIEW

Most transit agencies run their fleet from 5 am to midnight or longer.

Some common issues with Transit Operators and BEB's

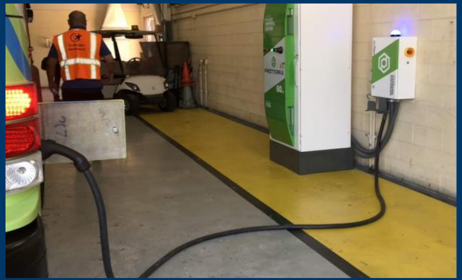
- Range Anxiety
- Passenger constraints: vehicle weight, size of battery, charging scenarios.
- Charging Types: fast charge, slow charge, depot charging, on-route charging.
- Utility Rate Impacts: On-Peak demand charges, off-peak charging and $$ impacts.
- Size and Location of Charging Equipment: depots are land constrained, so are city centers.

Charging Systems

Inverted Pantograph

Roof Mounted Pantograph

Inductive Charging



Plug-in Charging

Other depot impacts–

- HVAC/Ventilation Equipment: Chargers produce a lot of heat.
- Mechanical Lifts and Hoists: BEB's are heavier than their diesel counterparts.
- Fire Protection Systems for BEB's: Fire codes have not kept up with technology.

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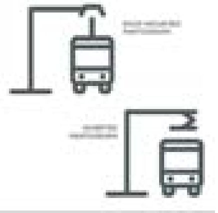
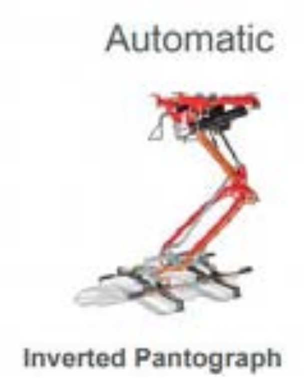
Charger Considerations



Pantograph Charging Options



Drop down Pantograph
Utilized heavily for on-route charging in the US.

Bus Mounted Pantograph
Utilized heavily for on-route charging in the Europe.
First Pantograph Indoor charging System In Europe.

<u>Advantages</u>

- Able to deliver high-capacity charge
- Able to provide on-route charging
- On-route applications may reduce battery size requirements

<u>Disadvantages</u>

- High maintenance – particularly in winter climates, icing, alignment issues, etc.
- Added cost to the bus (roof mounted)
- If deployed on-route will require:
  - Additional infrastructure in constrained areas (Switchgear, transformers, pantograph structure)
  - On-route would be all on-peak charging, potentially significantly increasing charging costs.
- If deployed in Bus facility will increase structural and height requirements with associated costs.

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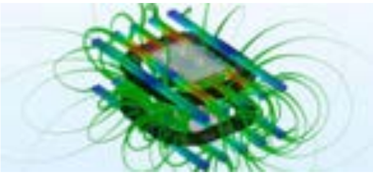
Inductive Charging Options



Deployed in Europe and the US. Multiple manufacturers.

Advantages

- Able to deliver high-capacity charge
- Able to provide on-route charging
- On-route applications may reduce battery size requirements
- No moving parts, less maintenance
- Little impact to bus storage processes
- Little impacts to system from weather

Disadvantages

- Added cost to the bus (receptors mounted under bus)
- If deployed on-route will require:
  - Additional infrastructure in constrained areas (switchgear, transformers)
  - On-route would be all on-peak charging, potentially significantly increasing charging costs.
  - If deployed in bus facility will require trenching for embedded equipment.

Plug In Charging Options

Deployed in Europe and the US. Multiple manufacturers.

Advantages

- Simple, low-cost option for bus charging
- Low maintenance
- Can be used for either high capacity or slow charging
- Can be used on-route but is mostly used in depot charging
- Chargers are typically the same as for other delivery options

Disadvantages

- Is manually operated
- Placement in tight bus garages becomes challenging – may require reels mounted in the ceiling, adding to capital cost (reels and structure costs) and maintenance
- Pullouts can damage equipment
- Drop down reel options are currently limited with cord length limitations

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Depot Charging

Greater Cleveland RTA garage mid-day

Advantages

- Charge vehicles overnight – Can charge off-peak
- Smaller chargers – but more of them depending on fleet size
- Slower charge better for battery life – long term
- Charger installation more likely less expensive

Disadvantages

- Results in larger battery size to meet route/block demands
- Larger battery – heavier bus
- Space, in older depots, can be a major problem
- May have major impacts on depot main electrical service including main transformers and switchgear

Depot Charging Options

PRODUCT	PROTERRA® POWER CONTROL SYSTEM 60KW	PROTERRA® POWER CONTROL SYSTEM 125KW	PROTERRA® POWER CONTROL SYSTEM 500KW
MAX POWER LEVEL AVAILABLE (kW)	60	125	500
PCS LOCATION	DEPOT	DEPOT	DEPOT / ONROUTE
DISPENSER TYPE	PLUG IN / OVERHEAD	PLUG IN / OVERHEAD	OVERHEAD
CONNECTION STANDARD	J1772 CCS PLUG IN J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH	J1772 CCS PLUG IN J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH	J3105 INVERTED PANTOGRAPH J3105 BUS-UP PANTOGRAPH
VEHICLES	CHARGING TIME OR MILEAGE PER CHARGE*		
FC	1.1 HOURS	0.9 HOURS	19 MILES PER 10 MINUTES
FC+	1.5 HOURS	0.7 HOURS	38 MILES PER 10 MINUTES
XR	2.9 HOURS	2.4 HOURS	9 MILES PER 10 MINUTES
XR+	4.4 HOURS	2.4 HOURS	13 MILES PER 10 MINUTES
E2	5.9 HOURS	2.8 HOURS	17 MILES PER 10 MINUTES
E2+	7.3 HOURS	3.5 HOURS	20 MILES PER 10 MINUTES
E2 MAX	8.8 HOURS	4.2 HOURS	24 MILES PER 10 MINUTES

* Efficiencies based on DuoPower drivetrain; FC series charges at max overhead power limit; XR/E2 series charges at continuous power limit for plug-in; all charge times are approximate.

Case Studies

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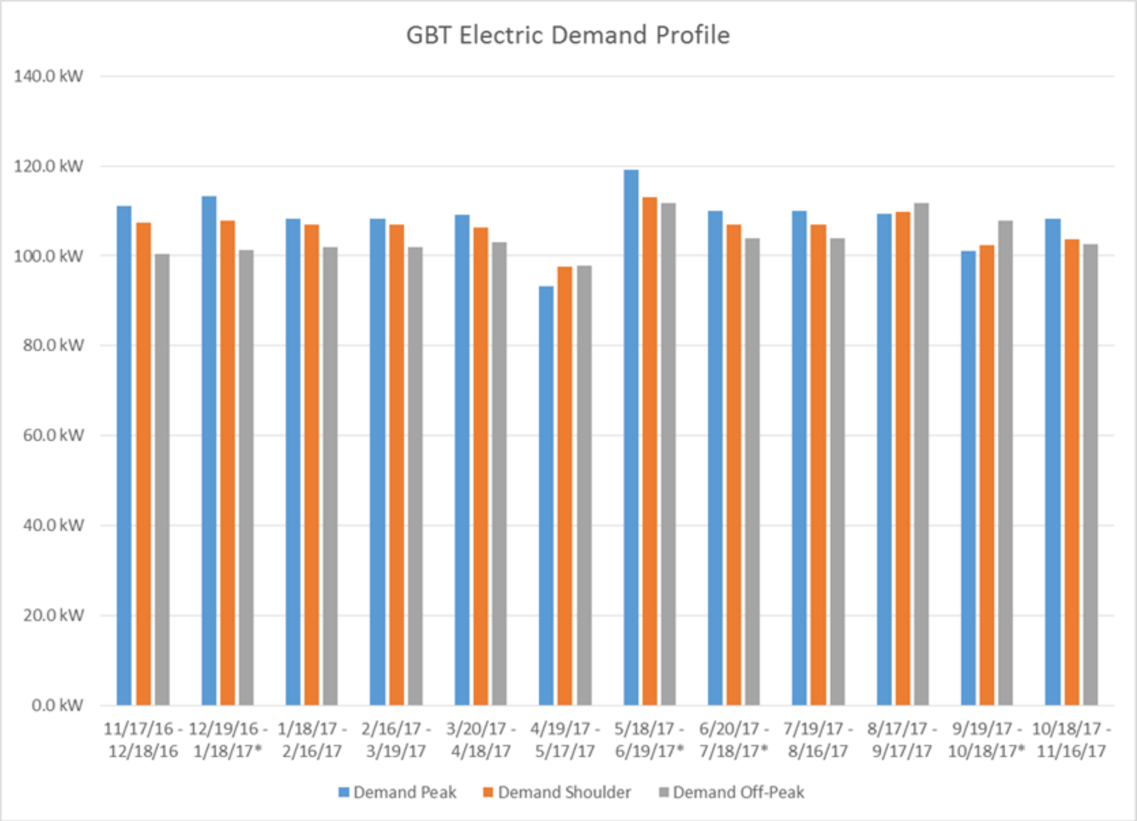
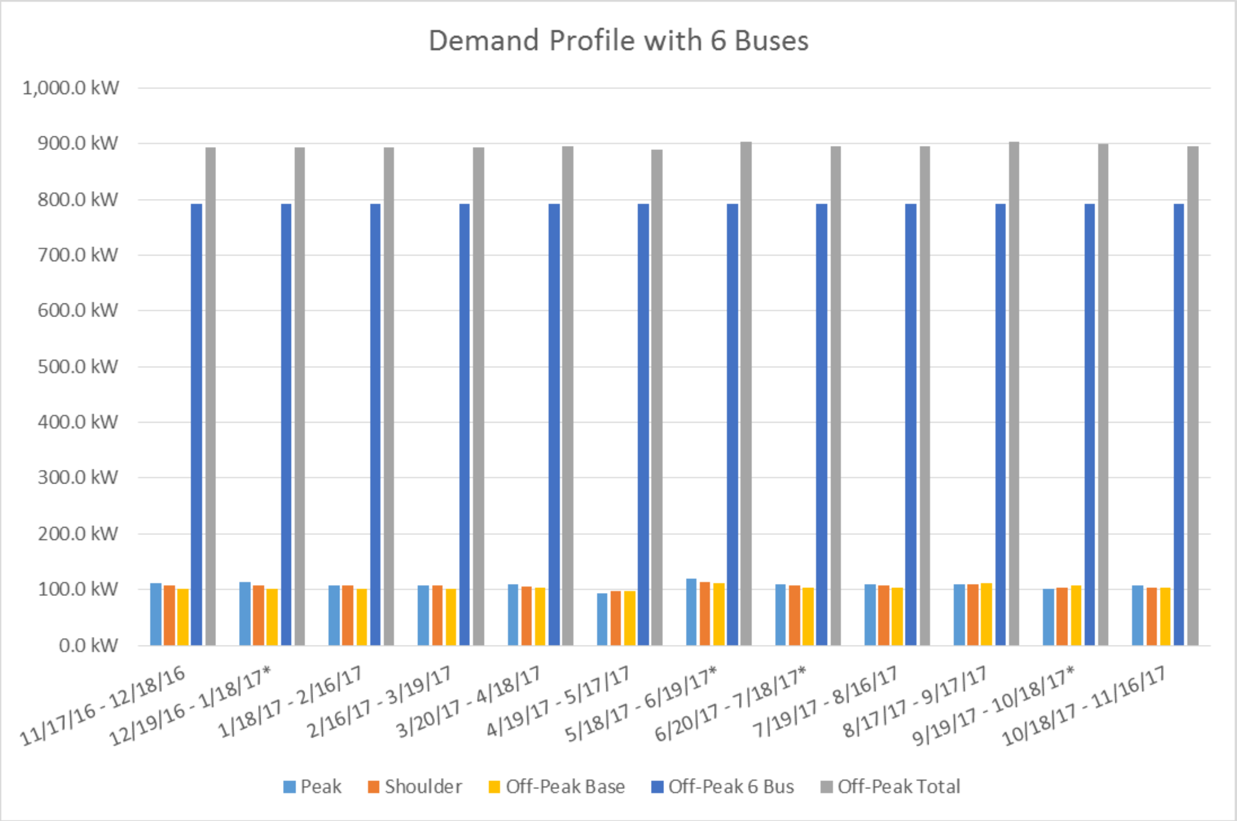
Case Study 1

Greater Bridgeport Transit (GBT)

- (2) BEB chargers, 1 charger per bus.
- Depot Peak Demand was 119 kW. At full 11 BEB build out it will be 1,659 kW, an increase of over 1.5 MW of power.
- Service Upgrade (up to 11 BEB capability).
- Outdoor charger location.
- Developed electrical safety plan and conducted personnel training.

Electric Rate Analysis





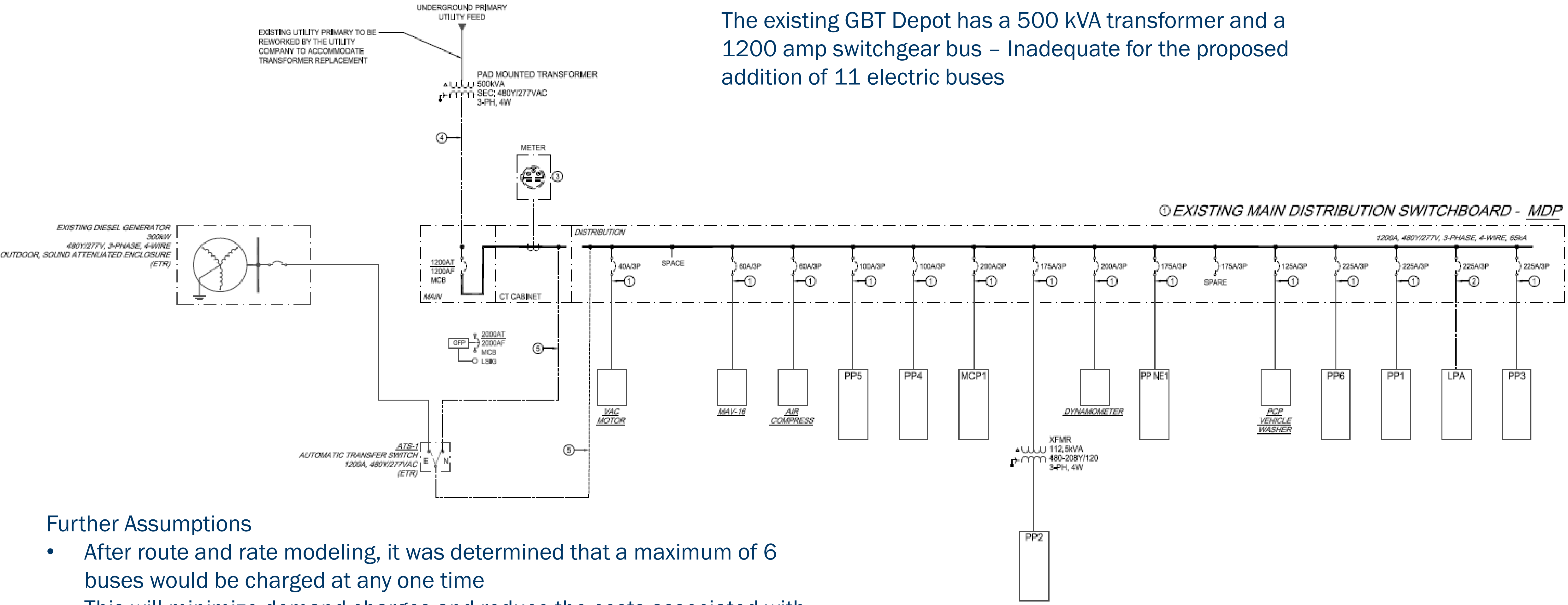
Existing GBT Demand Profile

Average monthly bill $8,106.52

Adds an average of $8,852.53 per month to demand charges
And $3,632.4 per month to the energy charges
Average total monthly bill increase $12,696.51

Impacts to Depot Distribution System

The existing GBT Depot has a 500 kVA transformer and a 1200 amp switchgear bus – Inadequate for the proposed addition of 11 electric buses



Further Assumptions

- After route and rate modeling, it was determined that a maximum of 6 buses would be charged at any one time
- This will minimize demand charges and reduce the costs associated with the depot electric distribution system upgrades
- Electric bus charging would not occur when on emergency power

1 PARTIAL SINGLE LINE DIAGRAM - DEMOLITION
SCALE: NO SCALE

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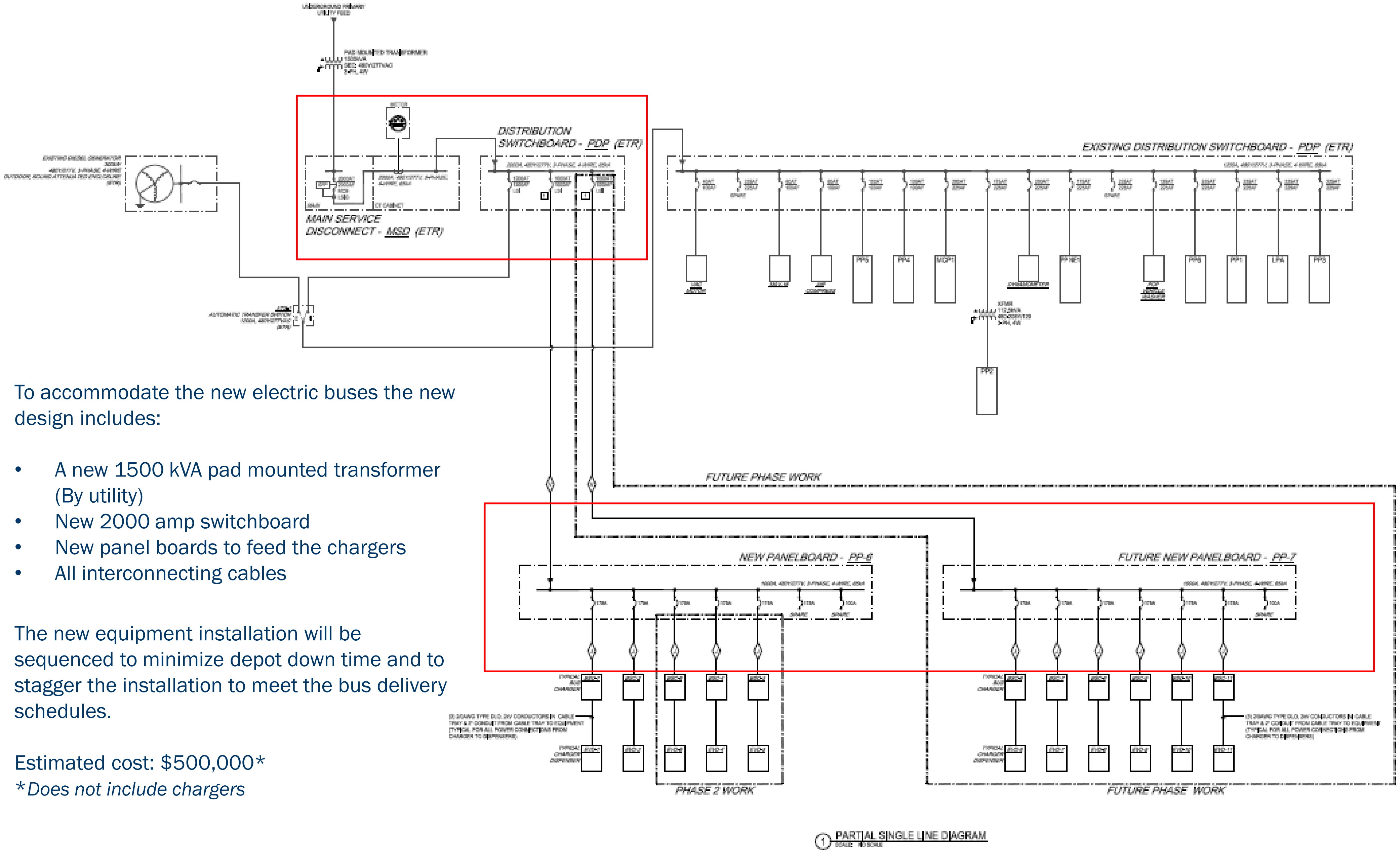

To accommodate the new electric buses the new design includes:

- A new 1500 kVA pad mounted transformer (By utility)
- New 2000 amp switchboard
- New panel boards to feed the chargers
- All interconnecting cables

The new equipment installation will be sequenced to minimize depot down time and to stagger the installation to meet the bus delivery schedules.

Estimated cost: $500,000*

**Does not include chargers*

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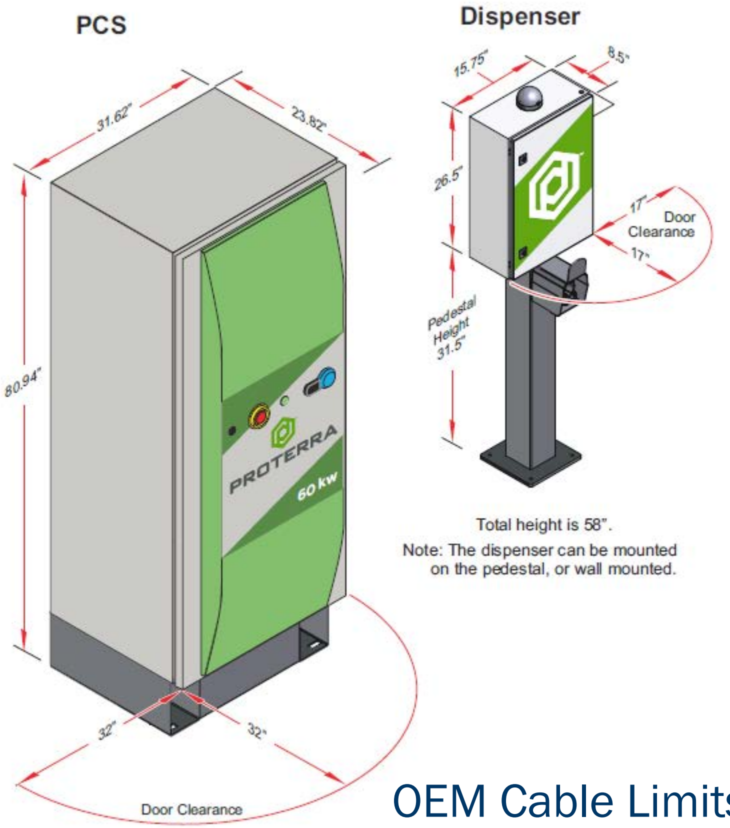
Charging System

Based on route and rate modeling, and an analysis of upgrade costs to the depot distribution system the following decisions were made:

1. All 11 buses could be charged during the off-peak time period.
2. Only 6 buses would be charged at any one time – This will require “intelligent chargers” that can network together to sequence the charging of the buses.
3. Due to space constraints in the depot bus storage area, a charging system that has a base charger and a remote dispenser would be required.
4. Given the sequencing of the bus purchases and overall costs of charging equipment and installation, standard chargers rather than induction chargers were selected.
5. Various locations for the chargers were considered, but due to the heat generated by the chargers and the resulting HVAC equipment necessary to remove the heat, it was determined to locate the chargers outside of the depot.

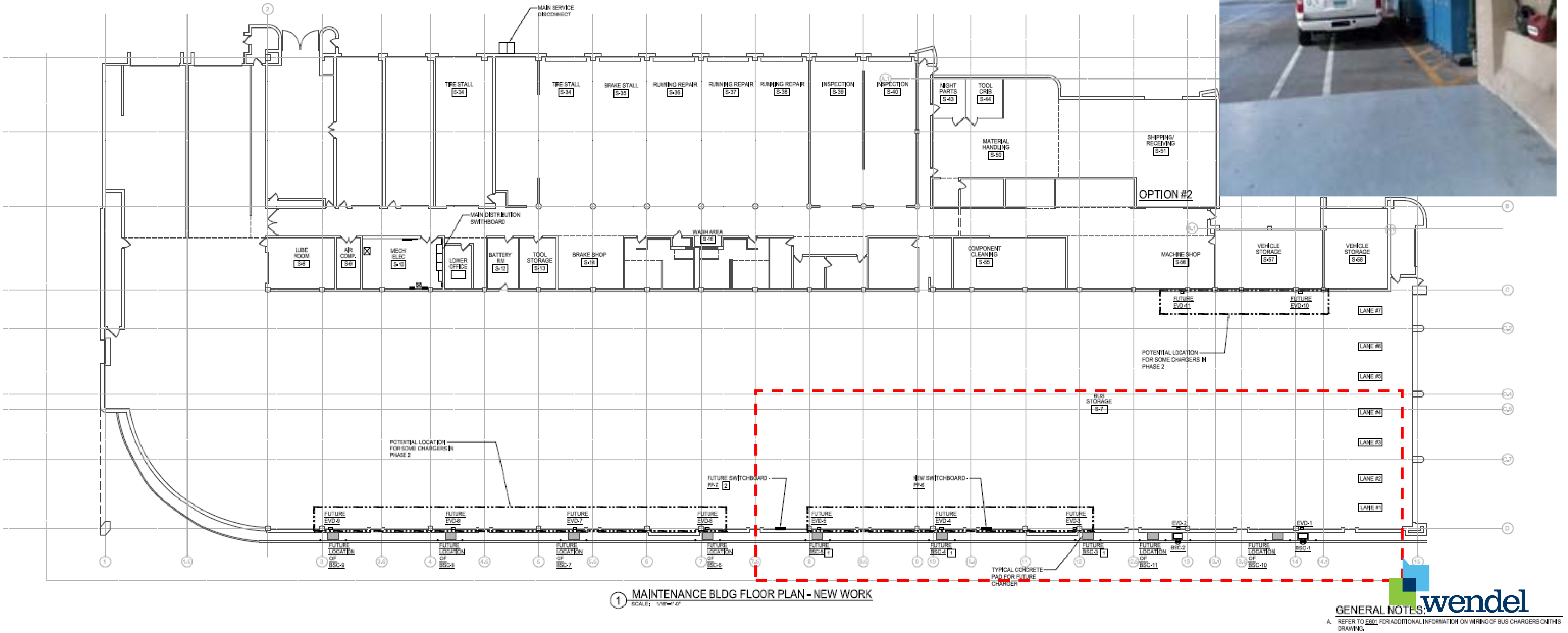
Charging System - Proterra

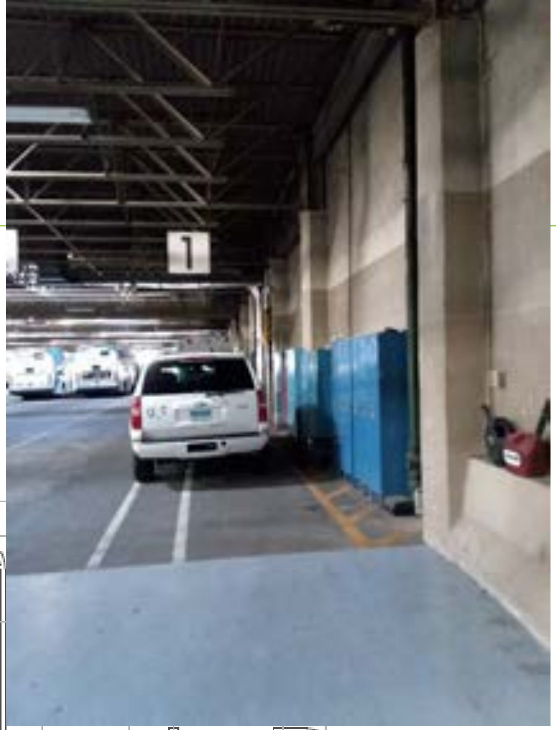


OEM Cable Limits:

- Max 492' from PCS to Dispenser
- 12' from Dispenser to Bus

Charger Layout





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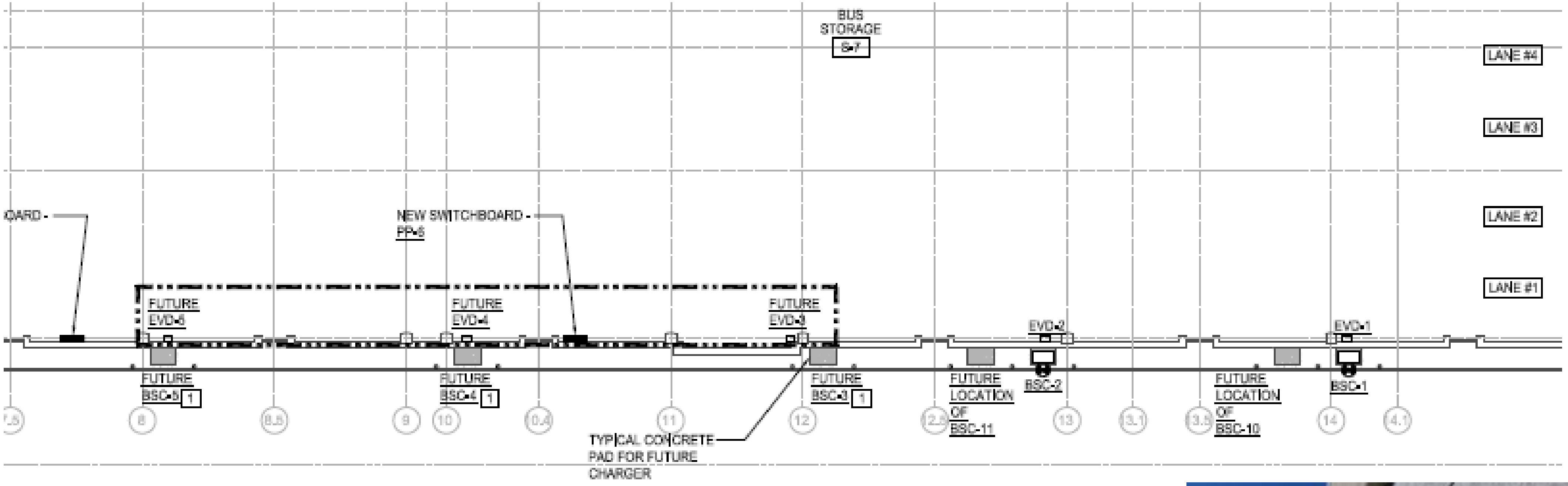
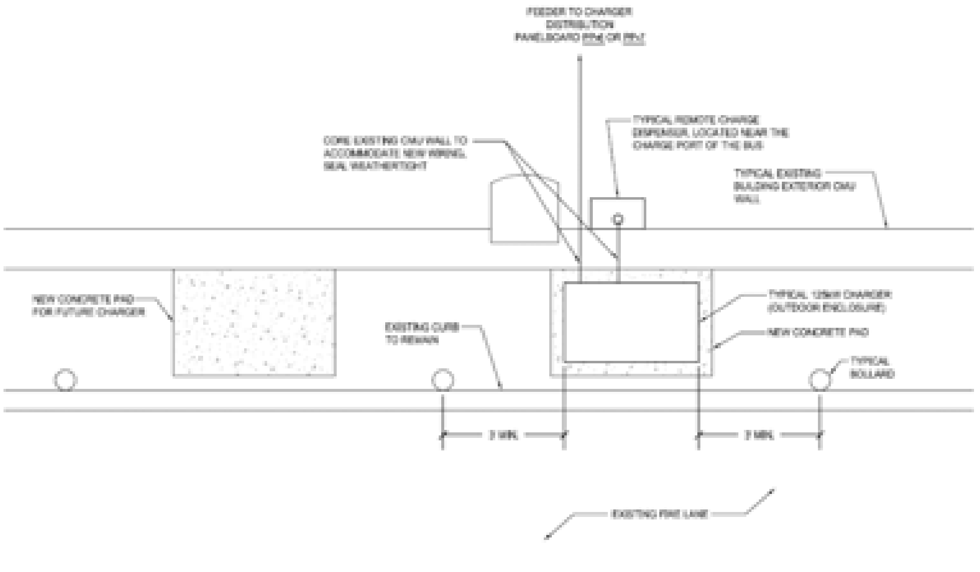


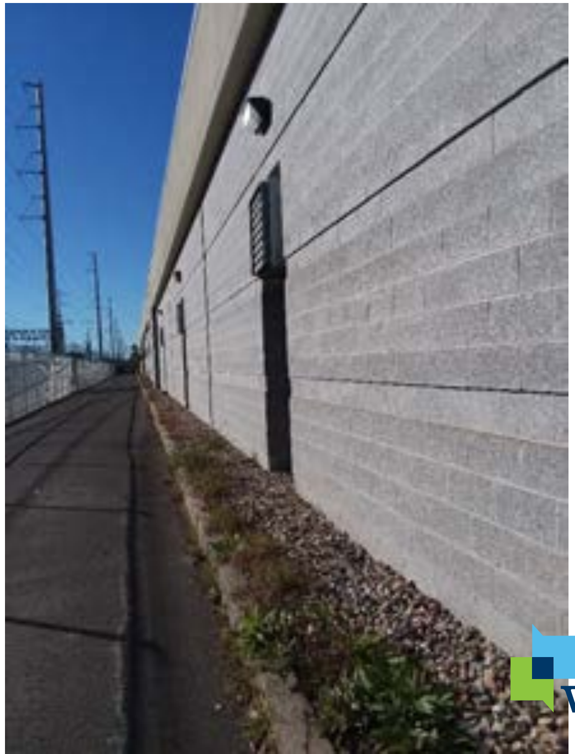
Phase 1 includes:

- 2 Chargers
- All foundations and pads
- All Bollards
- Power & Communications wiring to new equipment

Estimated Cost $404,000



2 TYPICAL CHARAGER INSTALLATION LAYOUT



Do you have any questions?

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