APTA Standards Quarterly Webinar Series

Battery Electric Bus Charging Infrastructure for a 100+ Bus Depot

Presented by APTA Clean Propulsion Committee

Mike Finnern

Sr. Director, Customer Service

Proterra Inc.

Chair, APTA Clean Propulsion & Support Technology Committee

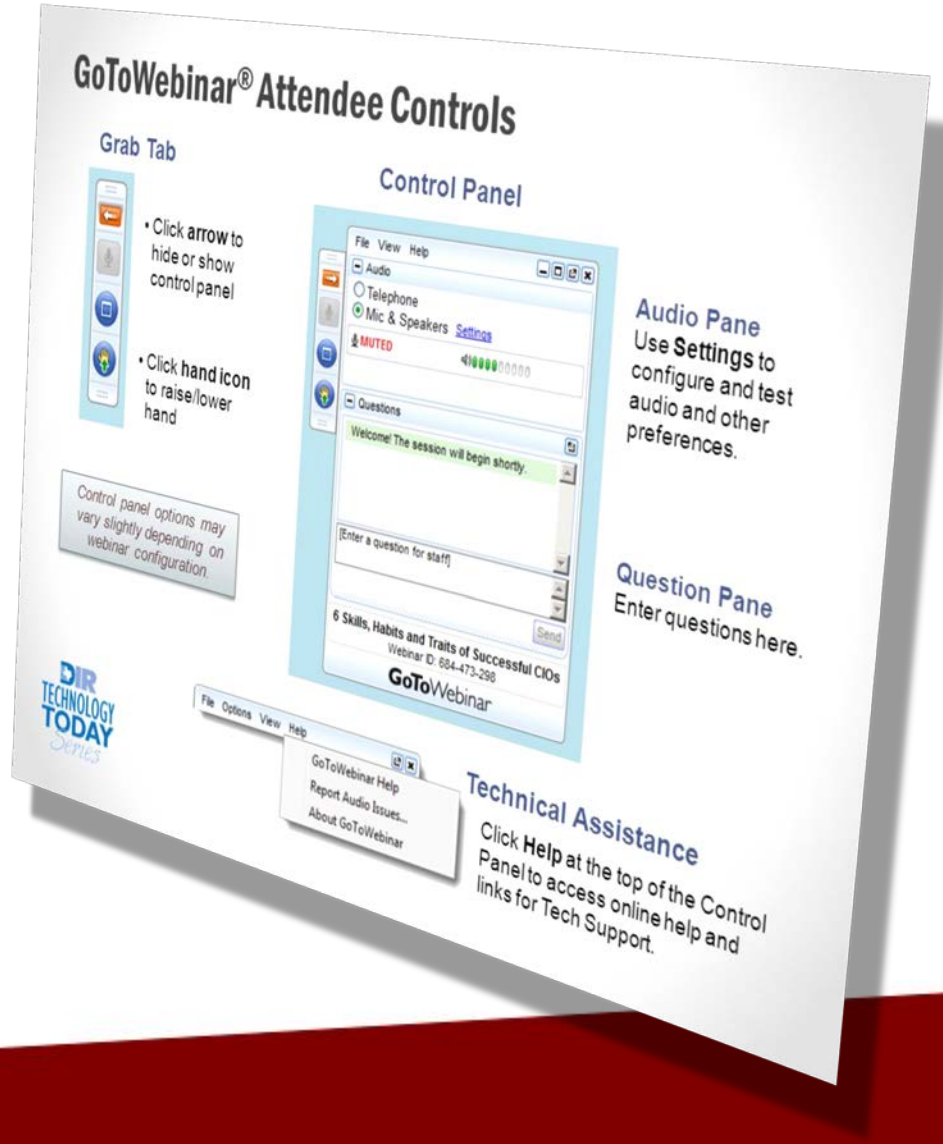
Moderator

Joel Donham

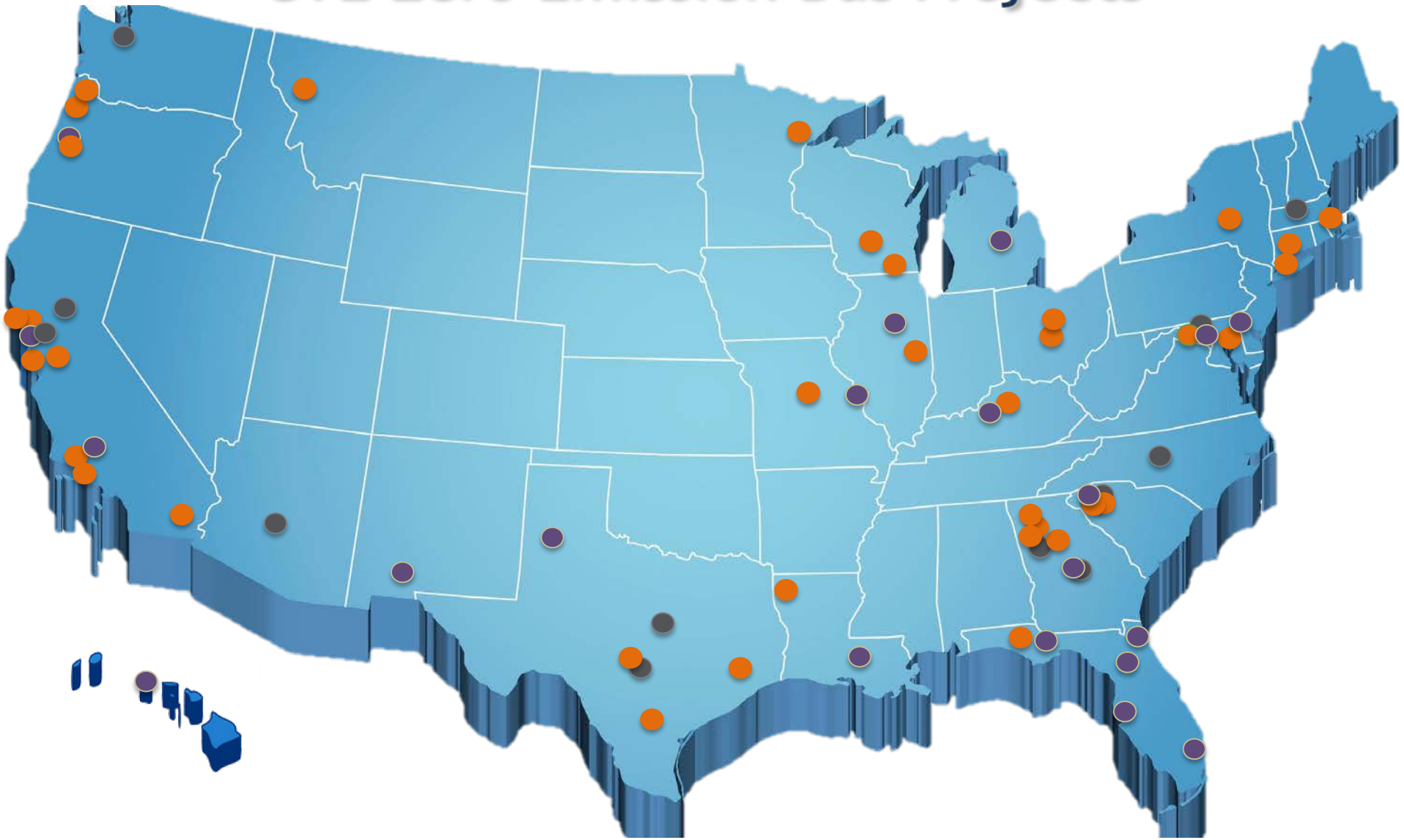
Engineering Consultant
Center for Transportation and the Environment

Housekeeping Items

- All attendee audio lines have been muted
- Questions will be addressed at the end of today's presentation
- Questions can be asked via the "question" dock on the attendee control panel
- Please complete webinar survey that will be emailed at the end of today

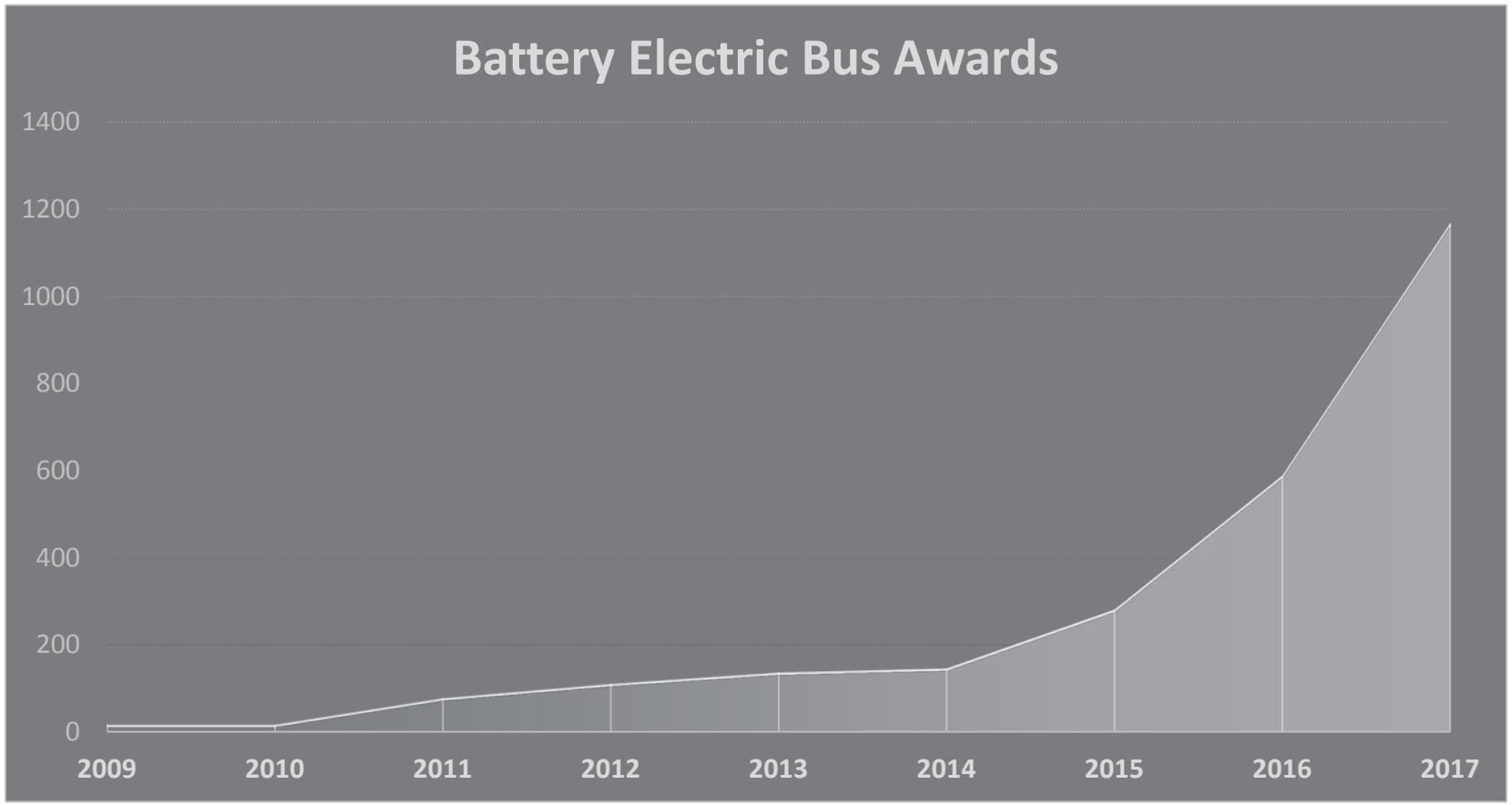


CTE Zero Emission Bus Projects



www.cte.tv

BEB U.S. Annual Sales & Deliveries



Sales more than quadrupled in last two years

> 140 Agencies—average fleet size 6-7, for now…

100+ BEB fleet considerations

Range varies greatly with conditions

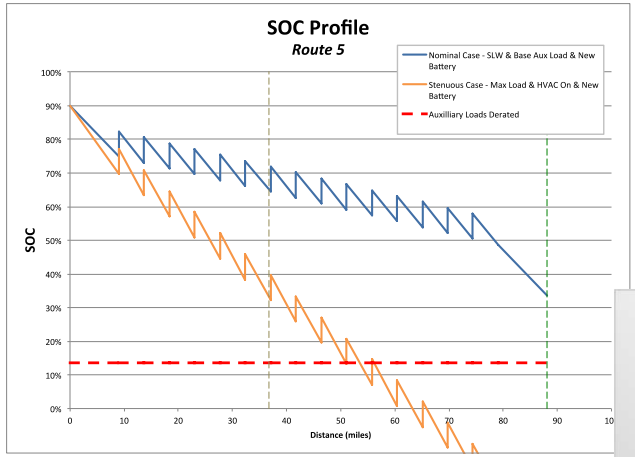
How to handle this variability when assigning vehicles?

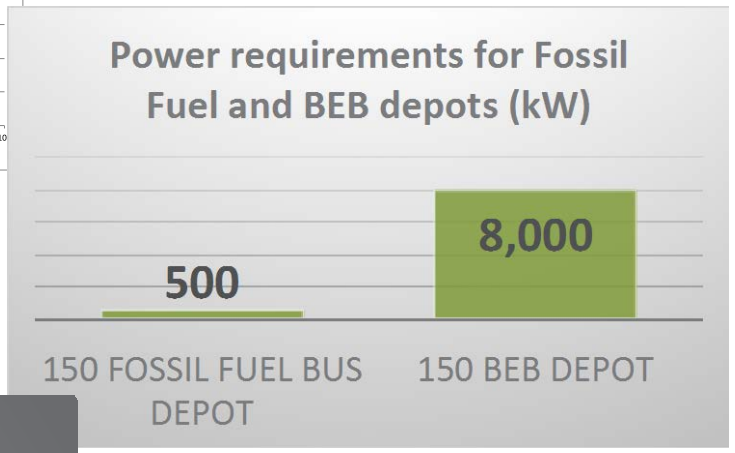
Electrical infrastructure for BEBs has to be larger than for fossil fuel buses

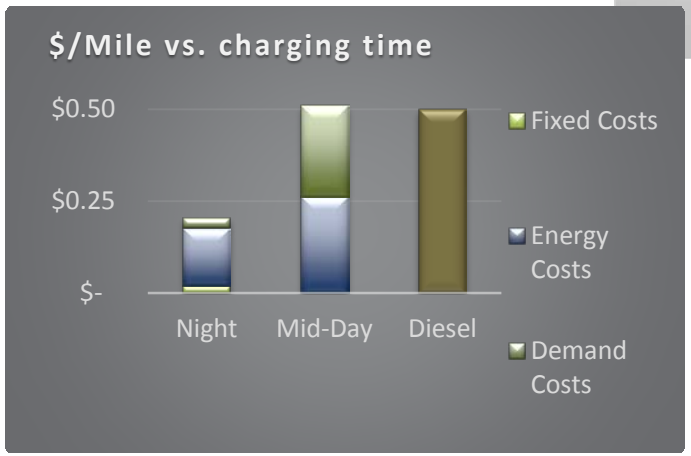
How to strategically develop and manage large-scale electrical infrastructure?

Per-mile energy costs are based on the time of day, time of year, and the fastest/greatest number of buses you charge simultaneously in a month.

How to control cost in complicated energy rate structures?







NOTE: results based on specific agencies. Not all agencies will have identical findings.

Today's Presenters

Leah O'Dwyer

Director, Business Development eBus
ChargePoint

Gary Miskell

Chief Information & Technology Officer
Santa Clara VTA

APTA BEB Webinar

- Infrastructure to Support a 100 Zero-Emission Bus Fleet

August 30 2018

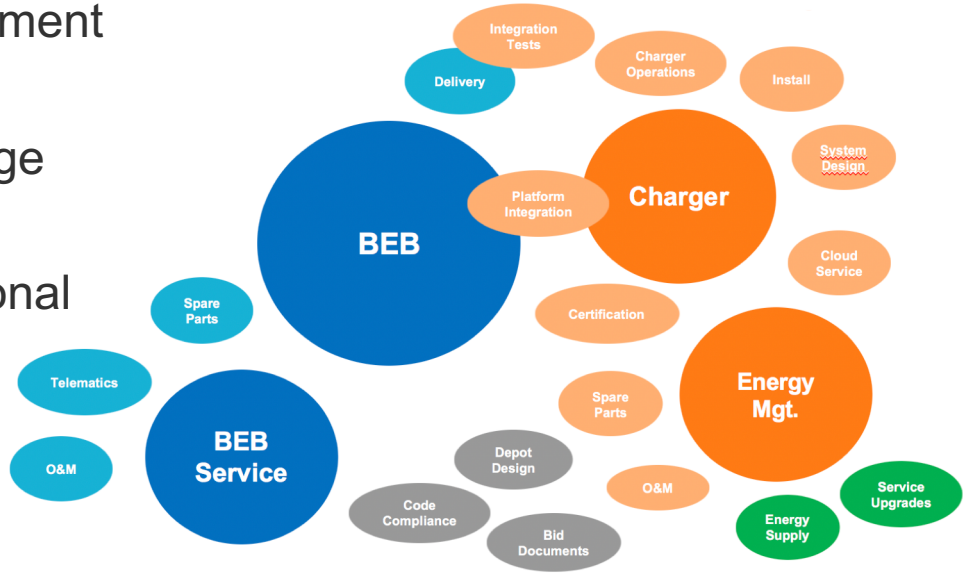
Agenda

Infrastructure for a 100 BEB fleet:

1. The eco system for BEB at scale
2. Power versus Energy
3. Depot design and fuelling footprint
4. System design and configuration modelling
5. Hardware considerations scale and cost
6. Hardware performance
7. Charger management

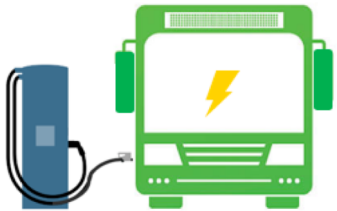
The eco system for BEB at scale

- Complex multi stakeholder environment with competing interests
- Scale applies to both small and large deployments in equal measure
- Significant technology and operational interfaces
- Easily over complicated and often misunderstood
- System architecture and energy calculations determine all outcomes

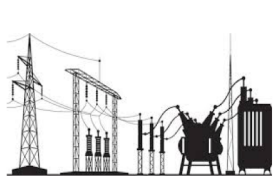


Power versus Energy

- Cost per kWhr for energy (fuel) is not the same as cost per kW for power (capacity)
- Cost of power is a new ‘per billing period’ fixed cost with no liquid fuel equivalent
- Managing peak demand is not the same as reducing overall demand capacity!
- Reducing demand capacity at scale can be achieved in several different and competing ways - smaller batteries, smart charging, site storage, micro grid



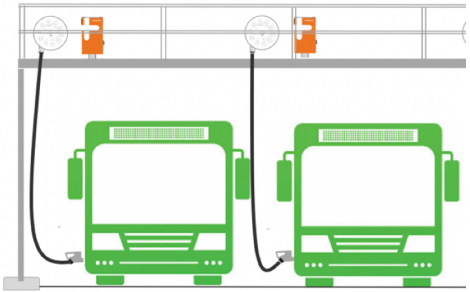
Dispensed energy = cost of electricity per kWhr delivered to the battery



Power = cost per kW of capacity to provide the electricity service

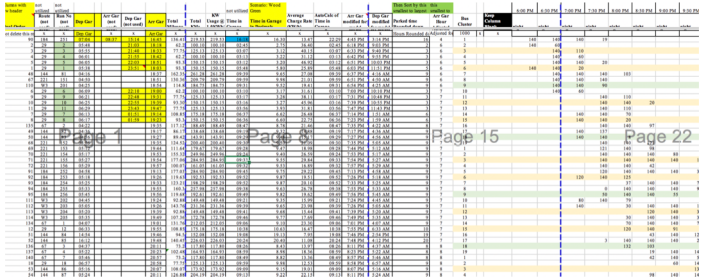
Depot design and fueling footprint

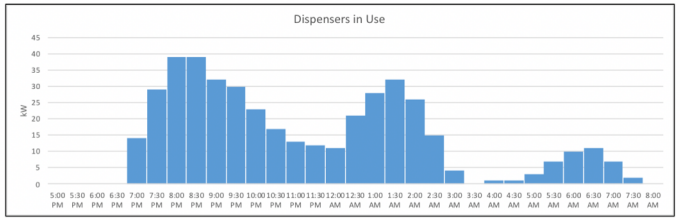
- Buses are typically parked closely using the least amount of real estate – inside or out
- Without careful design & planning, parking at scale for BEB's may result in capacity loss
- Planning for subsequent deployments should be considered even at initial pilot stage
- Overhead mounting structures prevent capacity loss but are unsuitable for traditional monolithic DC chargers
- Plug-in charging presents significant cable management challenges for daily operations



System design and configuration modelling

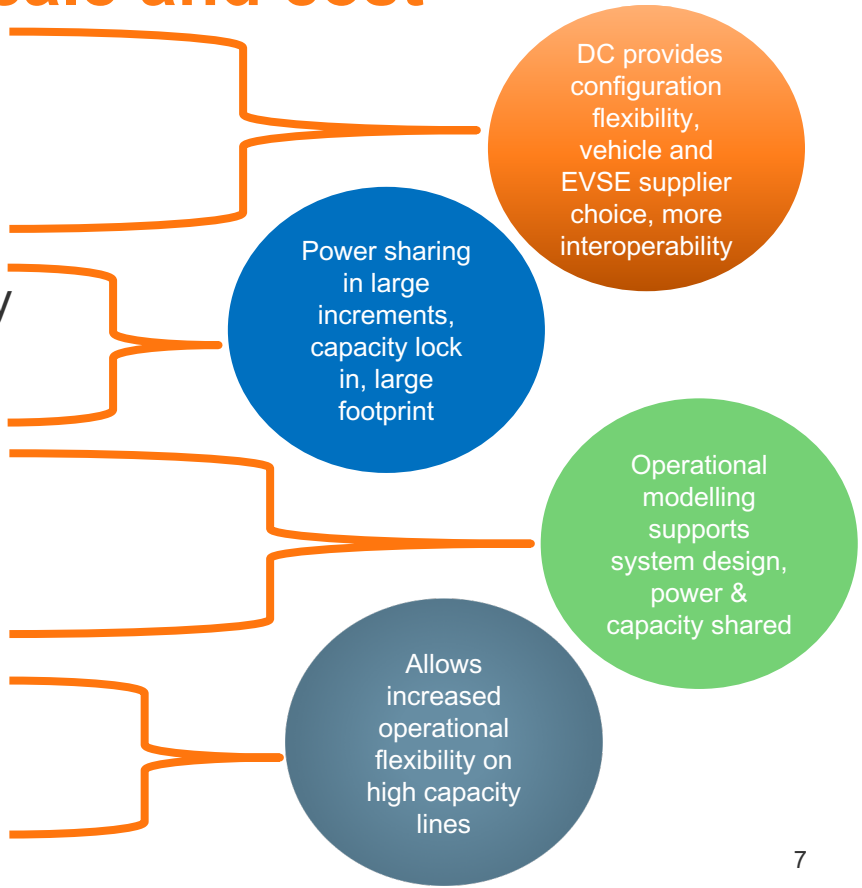
- A comprehensive plan is required to model the system requirements and map the physical and operational scenarios
- Blending route analysis, operational requirements and constraints with BEB performance metrics will result in a multi dimensional model which supports system design, depot layout and provides a fleet energy profile
- The fleet energy profile, after sensitivity analysis and stress testing is then used to configure and size the charging system





Hardware considerations, scale and cost

- AC deployed on early pilot projects, though DC charging now more widely supported across the industry in preparation for larger deployments
- Monolithic DC systems are power hungry and require complex management to deliver optimization
- Modular DC systems support dynamic charging and drive overall CAPEX reduction with less HW & reduced peak loads. Needs cloud service.
- On-route charging may have a role in certain operational scenarios

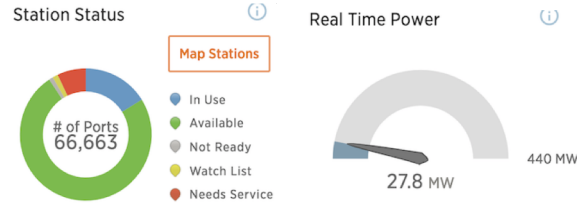


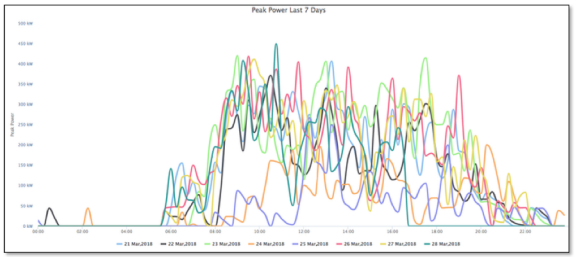
Hardware performance

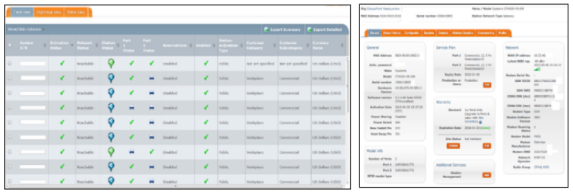
- Depot charging is often described as slow charging – but at scale – slow charging will not be sufficient to support normal operations
- Charging at scale needs to be flexible and capable of recharging a 450kWhr battery in 5hr or less
- Using 150kW chargers at 200A avoids the need for cooled cables, while delivering sufficient power across the typical BEB voltage range
- Higher power charging supports greater flexibility and faster BEB turn around

Charger management

- Operational availability of the charging system is a critical function to ensure service is maintained
- Chargers and grid service devices need to be networked and enabled with proactive monitoring and alert systems to ensure uptime
- Large depot monitoring comprises remote back up servers, sophisticated cyber security, performance monitoring at component level
- Multi system integration including with vehicle telematics, fleet and depot management platforms are essential







Thank You

For further information on this topic,
please contact Ms. Leah O'Dwyer;

leah.odwyer@chargepoint.com

VTA's Electric Bus Charging & Advanced Energy Management System

Battery Electric Bus Charging Infrastructure for a 100+ Bus Fleet

Gary Miskell, Chief Technology/Innovation Officer
Santa Clara Valley Transportation Authority
August 30, 2018

Valley Transportation Authority

Electric Buses

VTA is rolling out all-electric Proterra buses

VTA ZEB program will help meet ambitious state goal of 1.5 million zero emission vehicles (ZEVs) on California roadways by 2025.

"About 279,000 barrels a day of fuel won't be needed this year due to EV's"
Jeremy Hodges Bloomberg Technology

Electric Buses – Energy Cost

Per EV bus = $7.0K to $10.2K of electricity per year

First 5	$ 35.0K	$ 51.0K
25 buses	$175.0k	$225.0k

VGI project 5% to 14% Impact

On site Storage Incremental $34K + Savings/year
20/25 buses

Vehicle to Grid Integration (VGI) Collaboration: PARTNERS

VTA working with Prospect Silicon Valley, and Bay Area tech companies to pilot a cutting-edge system that will manage charging and energy consumption on electric buses while reducing the impact on the state's electricity grid.

Funding from the California Energy Commission will serve as a major case study for transit agencies throughout the country

Connected & Making Real Time Decisions

PROSPECT Silicon Valley

Valley Transportation Authority

STATE OF CALIFORNIA ENERGY COMMISSION

CALIFORNIA ENERGY COMMISSION

KISENSUM

CALSTART

NREL NATIONAL RENEWABLE ENERGY LABORATORY

chargepoint

PROTERRA

CISCO

ENERGY SOLUTIONS

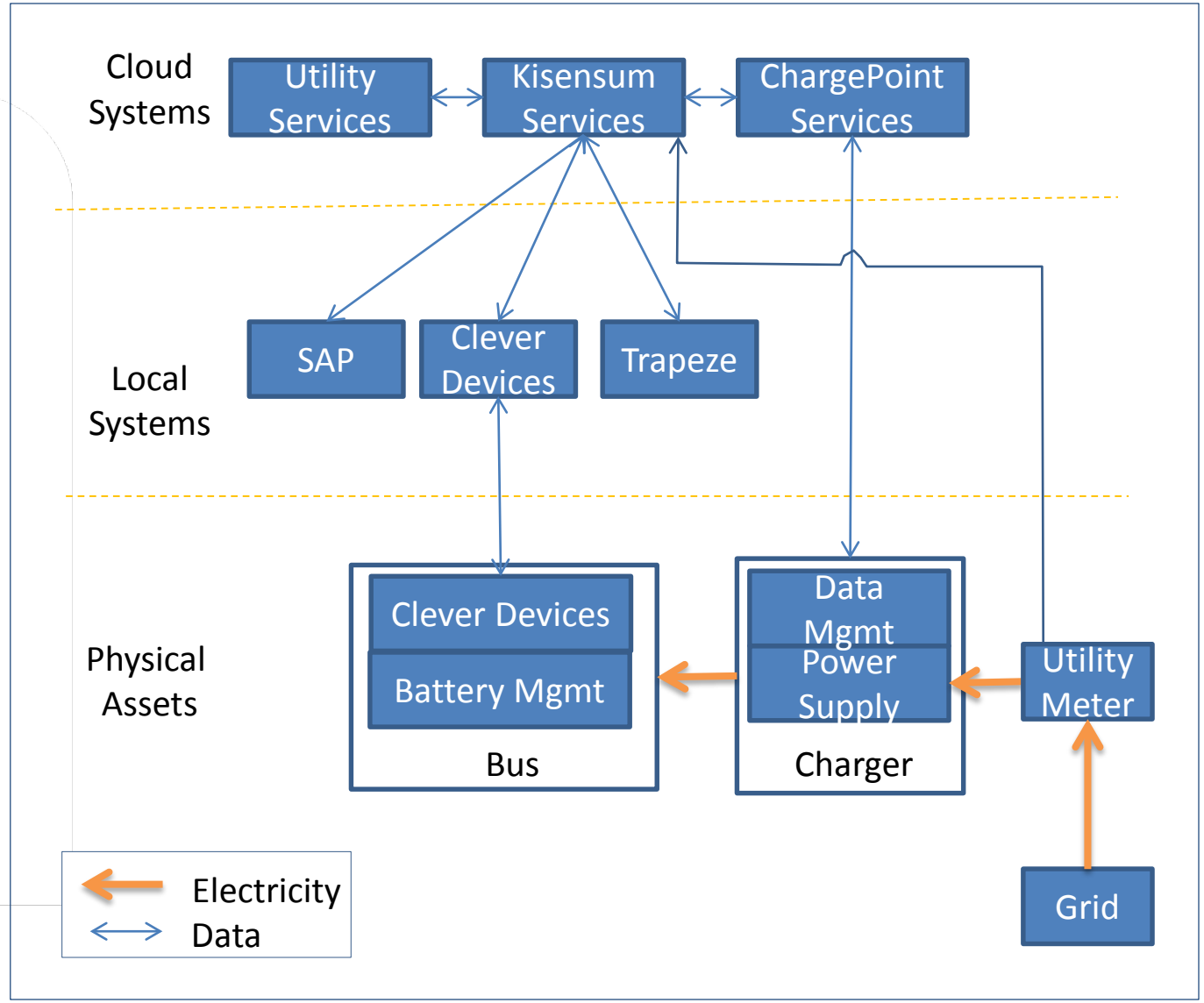
nova WORKFORCE DEVELOPMENT

ZNEAlliance

Solutions that move you

Primary Goals of the VGI Solution

1. Ensure buses are charged and ready to go before pullout time
2. Provide visibility into charging process
3. Send alerts when issues in the charging process or during daily operation need to be addressed
4. Support the assignment of bus to block process
5. Minimize PG&E utility bill
6. Simulate Grid interactions with system

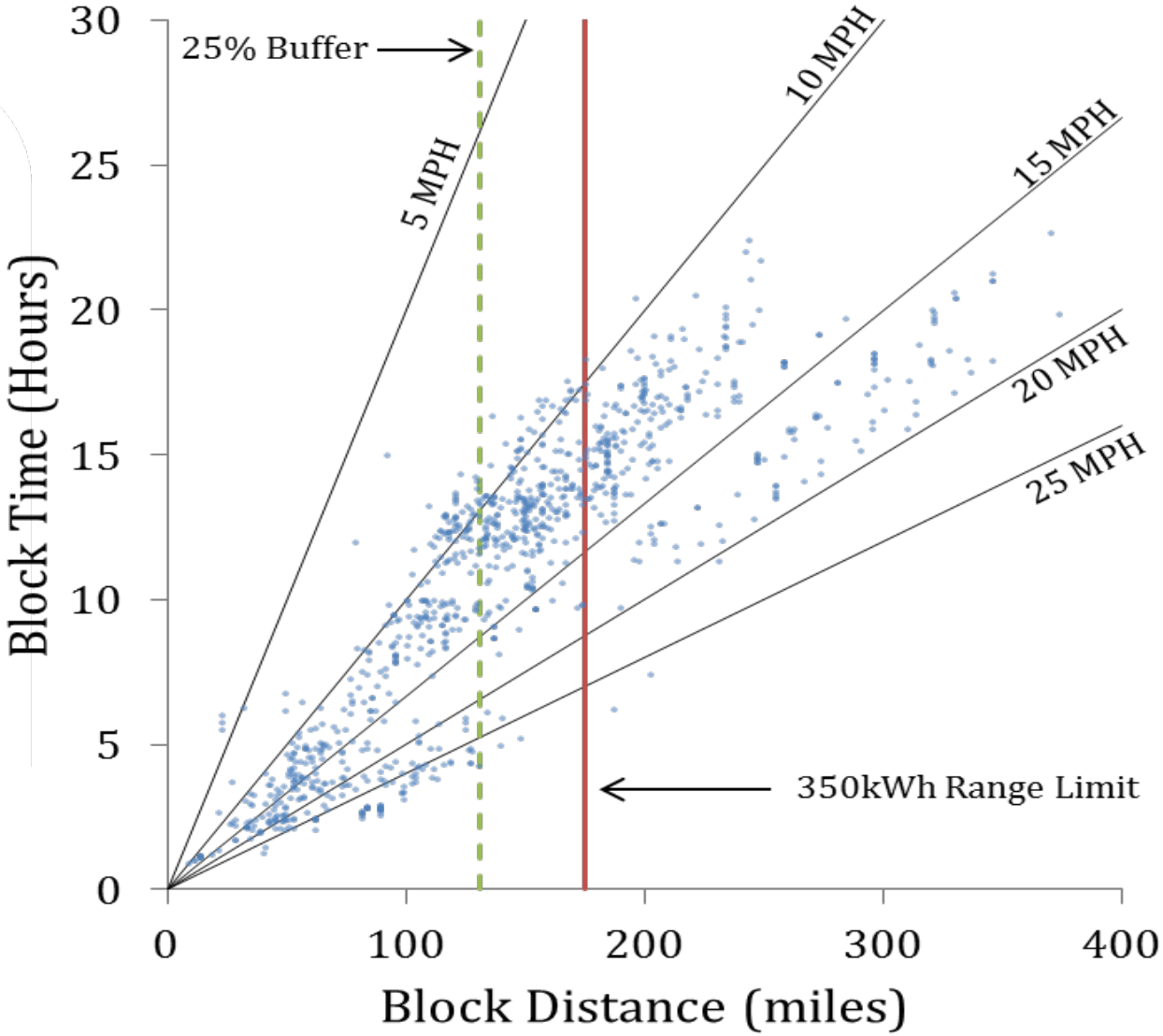


Operational Analysis and Simulation Strategy

Leverages the National Renewable Energy Lab's expertise in analysis and modeling of Electric Vehicles

Analysis Development
- Develop the analytic
- Develop operational & cost models

Models being used to predict and recommend operational parameters during the pilot and post implementation analysis to validate the effectiveness.
- **Analyze operating conditions**
- **Recommendations**.
- **Fleet wide Analysis**



Comparison of distance versus travel time for each block

So, What is the Big Deal?

Data Flow & Connected

Core Application = Kisensum

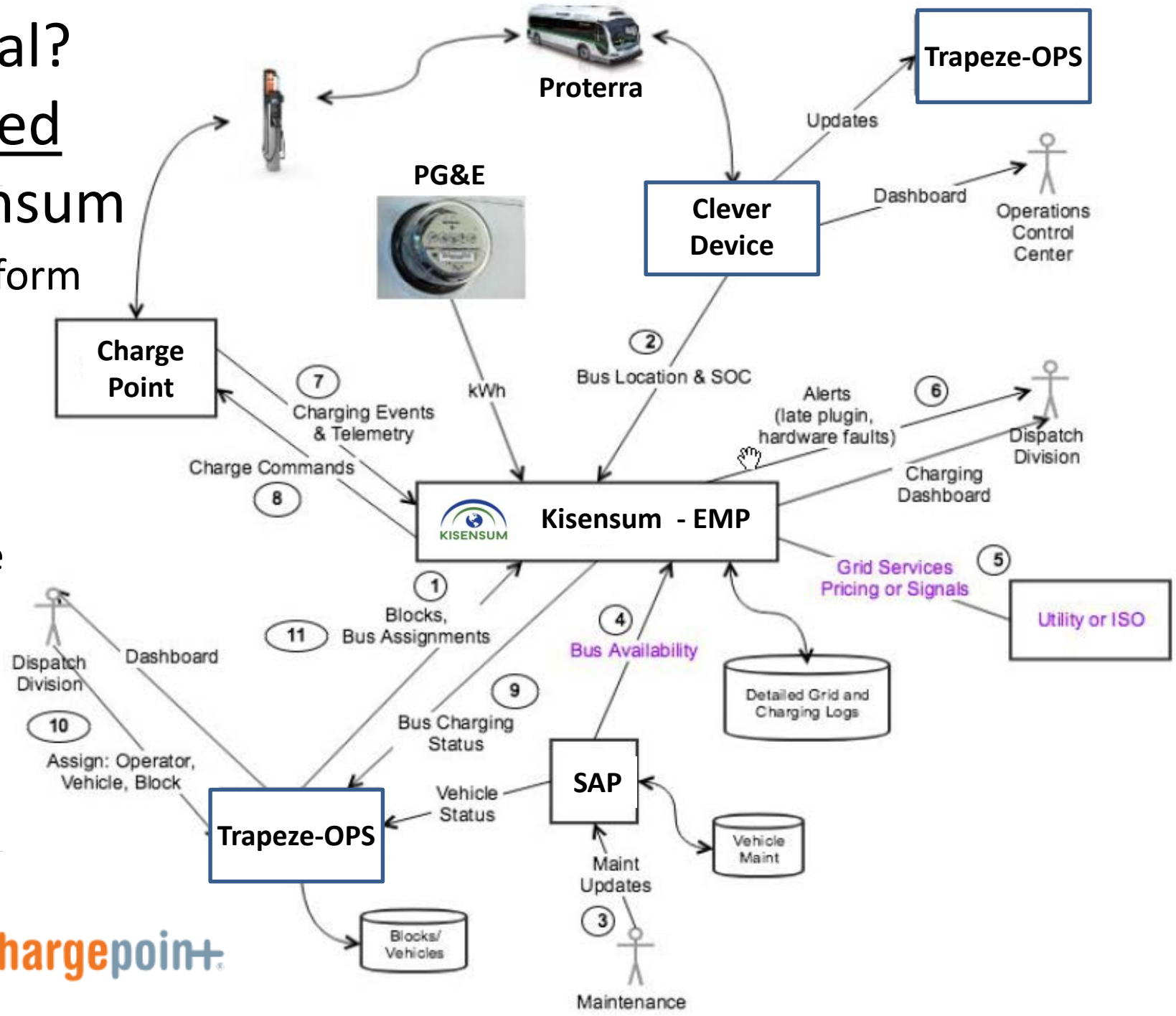
EMP = Energy Management Platform

Inputs

- Trapeze-FX
- Trapeze-Ops
- SAP
- ChargePoint
- Clever Devices
- Grid Signals
- Electric Meter
- Proterra Bus

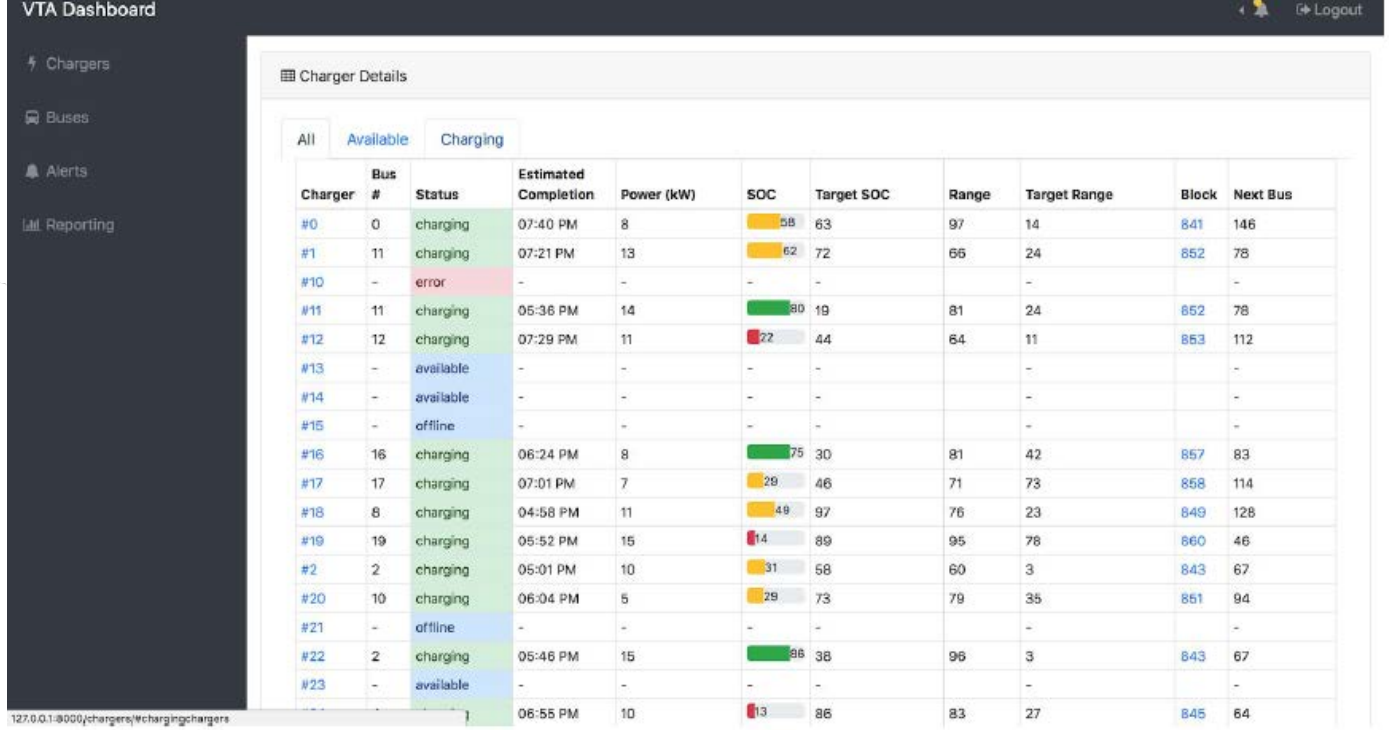
Outputs

- Trapeze-Ops
- ChargePoint
- Clever Device
- Operators



What Are The Major Innovations?

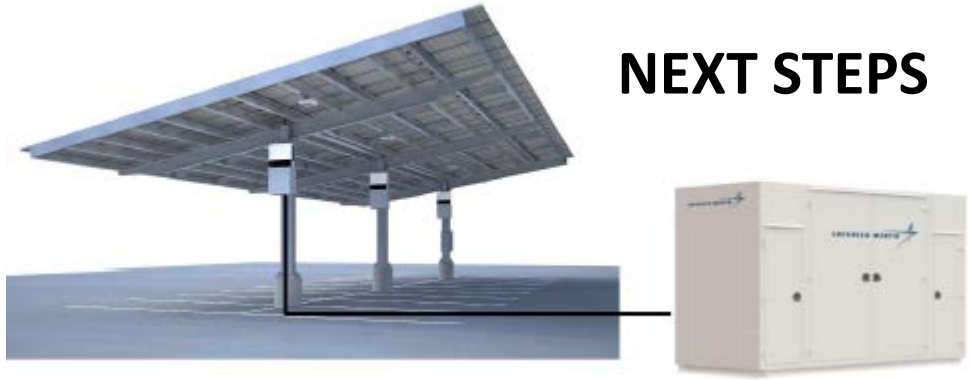
- Creating charge plans that support more buses than charge stations
- Energy Management Platform that interoperates with VTA and Grid systems
- Dashboard and alerting system supporting vehicle Charging & operations
- Realtime cost minimization process through demand leveling and Time of use aware charging
- Performing Grid Service simulations while not jeopardizing the bus charging operations



Charger	Bus #	Status	Estimated Completion	Power (kW)	SOC	Target SOC	Range	Target Range	Block	Next Bus
#0	0	charging	07:40 PM	8	58	63	97	14	841	146
#1	11	charging	07:21 PM	13	62	72	66	24	852	78
#10	-	error	-	-	-	-		-		-
#11	11	charging	05:36 PM	14	80	19	81	24	852	78
#12	12	charging	07:29 PM	11	22	44	64	11	853	112
#13	-	available	-	-	-	-		-		-
#14	-	available	-	-	-	-		-		-
#15	-	offline	-	-	-	-		-		-
#16	16	charging	06:24 PM	8	75	30	81	42	857	83
#17	17	charging	07:01 PM	7	29	46	71	73	858	114
#18	8	charging	04:58 PM	11	49	97	76	23	849	128
#19	19	charging	05:52 PM	15	14	89	95	78	860	46
#2	2	charging	05:01 PM	10	31	58	60	3	843	67
#20	10	charging	06:04 PM	5	29	73	79	35	851	94
#21	-	offline	-	-	-	-		-		-
#22	2	charging	05:46 PM	15	86	38	96	3	843	67
#23	-	available	-	-	-	-		-		-
			06:55 PM	10	13	86	83	27	845	64

Dashboard: Charger Status

NEXT STEPS



Expanded Solar

Energy Storage

Solutions that move you

Thank you

Next Webinar:

Fuel Cell Electric Bus Infrastructure for a 100+ Bus Depot

Sept. 20, 2018 @ 2 p.m. East Coast time

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