

# Battery Electric Bus Charging

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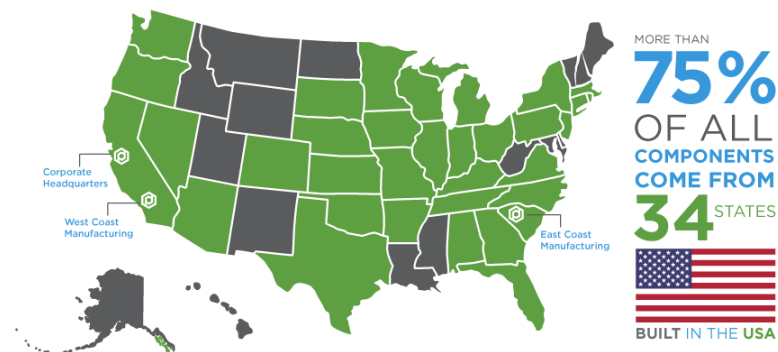
# ABOUT PROTERRA



## Proterra's Mission

Advancing electric vehicle technology to deliver the world's best-performing transit vehicles

- Founded in 2004
- Offices and manufacturing in CA and SC
- 300+ employees, strong executive management team
- Backed by industry-leading VC and corporate investors
- 40 customers; >400 vehicles sold
- >100 vehicles delivered; >3,300,000 service miles
- >13,700,000 pounds of CO2 emissions avoided



## Strong Executive Team

TESLA



SUNPOWER



A123  
SYSTEMS



Honeywell



## Solid Financial Backing



VENTURES



# Key Presentation Take-Aways

- Customer needs vary
- There are bad solutions, good solutions, and then the best solution
- Route and fleet modelling are key to success
- Energy management is required

# Customer Needs

**Table 5: Unlinked Passenger Trips and Passenger Miles by Mode, Millions  
Report Year 2014**

Mode of Service	Passenger Trips		Passenger Miles		Average Trip Length (Miles)
	Millions	Percent	Millions	Percent	
Bus	5,113	47.6%	19,380	32.5%	3.8
Bus Rapid Transit	54	0.5%	157	0.3%	2.9
Commuter Bus	107	1.0%	2,919	4.9%	27.3
Commuter Rail	490	4.6%	11,718	19.6%	23.9
Demand Response	233	2.2%	2,267	3.8%	9.7

**Table 6: Vehicle Miles Operated, Vehicle Hours Operated, and Speed in Transit Service  
by Mode, Report Year 2014**

Mode	Vehicle Total Miles (Millions)	Vehicle Revenue Miles (Millions)	Vehicle Total Hours (Millions)	Vehicle Revenue Hours (Millions)	Average Speed in Revenue Service (Miles per Hour)
Bus	2,189.7	1,903.0	172.4	156.6	12.2
Bus Rapid Transit	10.2	9.5	0.9	0.9	10.6
Commuter Bus	233.7	182.2	7.8	5.9	30.6
Commuter Rail	370.8	342.5	11.8	10.7	32.0
Demand Response	1,595.1	1,372.6	106.7	92.5	14.8

Source: <https://www.apta.com/resources/statistics/Documents/FactBook/2016-APTA-Fact-Book.pdf>

- Circulator
  - Operates 24 hours a day
  - Runs 45 min loops
- Long distance commuter route
  - Operates morning and evening
  - Runs 1 x 4 hour route
- Surge route
  - Operates ~4.5 hours morning and evening
  - Runs 3 x 1.5 hour loops

# Charging Solutions

- On Route
  - Opportunity charge at regular layover
  - Generally charge at a higher rate
  - Charge as function of convenience or necessity
  - Likely to be automatic coupling
- In Depot/Yard
  - Charge in the depot at night or during afternoon
  - Generally charge at a slower rate
  - Can be plug-in or automatic coupling
- Standards and Innovation are Key
  - SAE J1772 CCS – US DC Plug-in
  - SAE J3105 - Overhead



# Customer Needs – Example Cases

- Circulator
  - Operates 24 hours a day
  - Runs 45 min loops

} On-route charging is the ONLY solution
- Long distance commuter route
  - Operates morning and evening
  - Runs 1 x 4 hour route

} Ideal for yard charging
- Surge route
  - Operates ~4.5 hours morning and evening
  - Runs 3 x 1.5 hour loops

} Either solution could fit well

# Customer Needs – Example Cases

- Circulator

On-route

**This is NOT the whole story.**

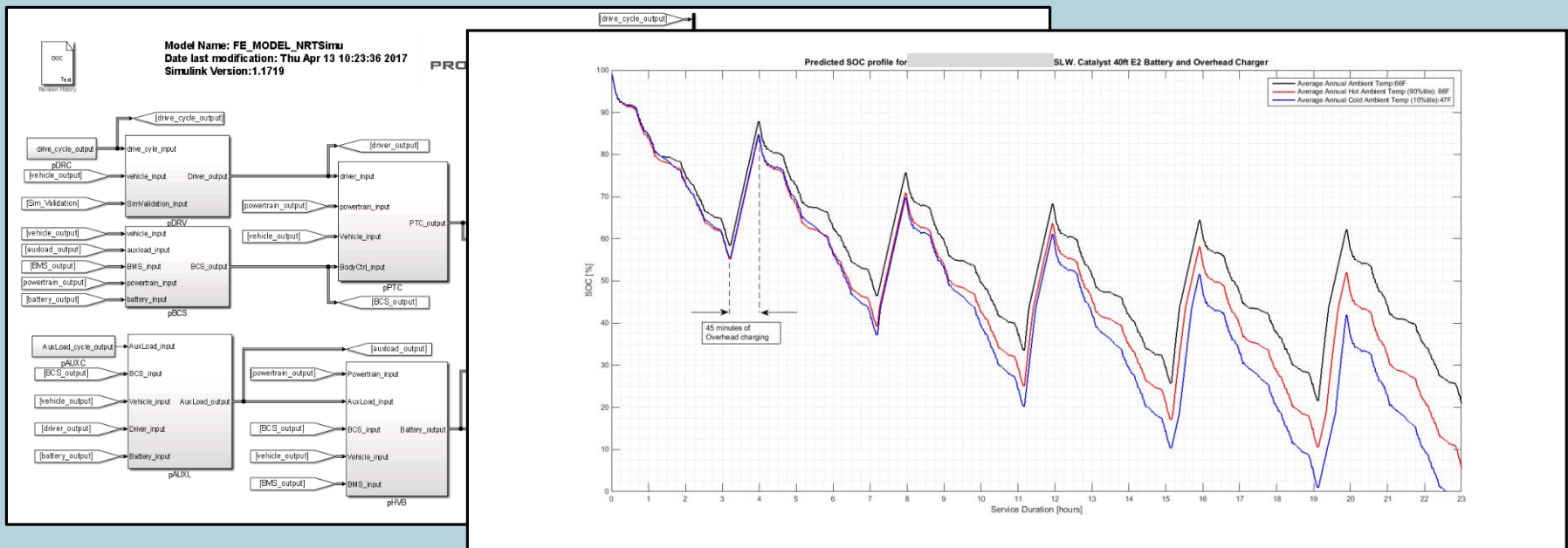
- Transit agencies have many routes, limited yard space, limited on-route property, multiple operating seasons, varying expansion plans, and regional tariff schedules.
- Route and fleet modeling are needed.
  - Operates 4.5 hours morning and evening
  - Runs 3 x 1.5 hour loops

could fit well



# Route and Fleet Modeling

- Route modeling provides an estimate of the performance of a single bus on a single route in all expected operating conditions.
- Fleet modeling looks at aggregate values for the fleet to allow proper infrastructure planning.



# Energy Management

- When charging occurs
  - Coordination with other sources and loads
  - Coordination with other buses
  - At night or during day
- How fast charging occurs
  - Faster is not always better
  - Need fast for certain operation conditions
- Impacts fuel(electricity) costs and infrastructure costs
- Another session on tariffs and Demand Management



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