

***Zero Emission Bus
Deployment Best Practices
and
Lessons Learned from Around the World***

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October 10, 2017



About CTE

Mission: To advance clean, sustainable, innovative transportation and energy technologies

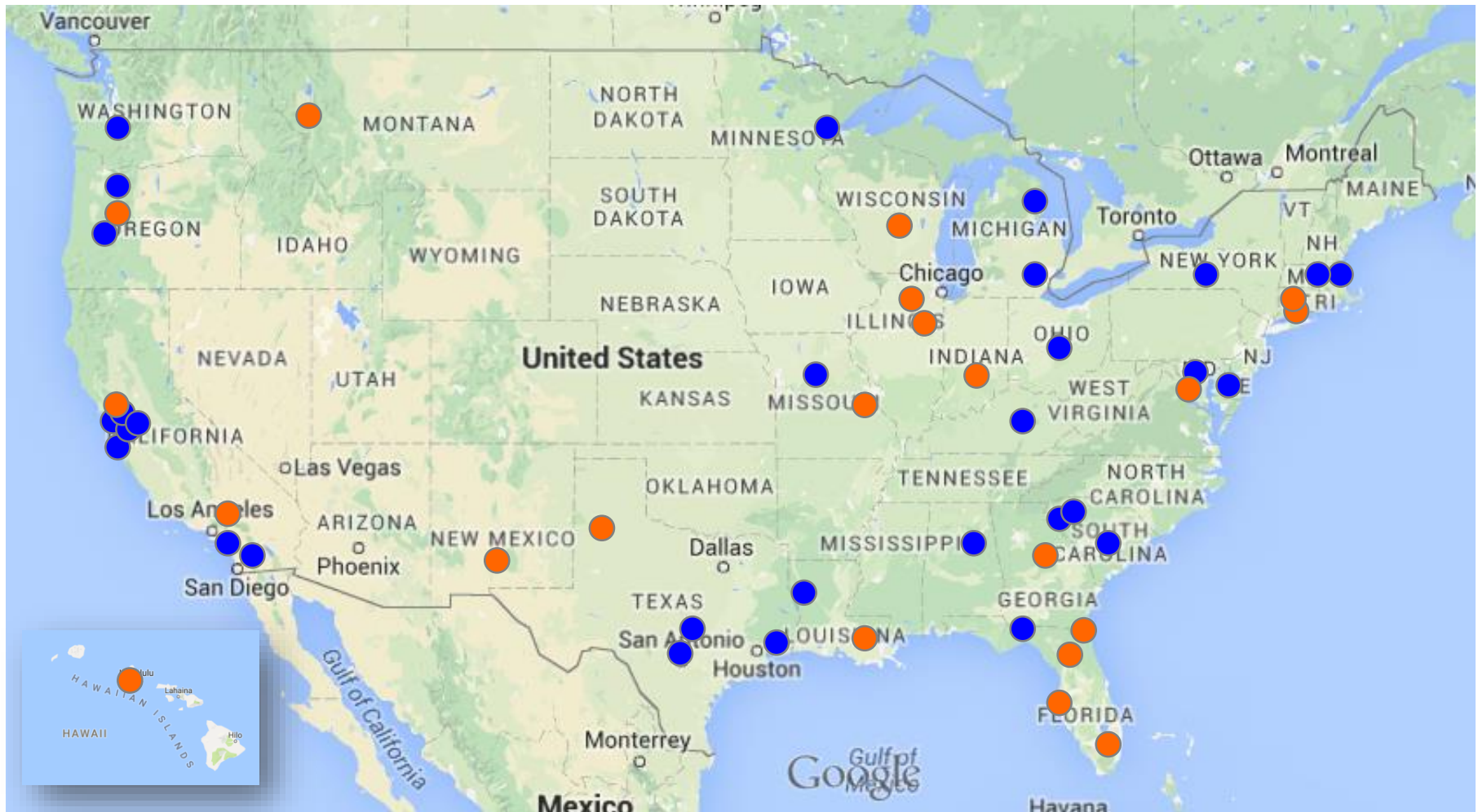
- Portfolio: \$450m+ research, demonstration & deployment
- National presence – Atlanta, Berkley, Los Angeles, St. Paul

Our ZEB Services

- Grant Applications
- Feasibility & Fleet Transition Strategy (a.k.a. ZEB Roadmap)
- Requirements Analysis and Technology Assessment
- Technical Specifications and Procurement Evaluation
- Production Oversight, Buy America Audits, & Resident Inspections
- Deployment Project Management and Technical Assistance
- Benefits Analysis and Key Performance Indicator Reporting

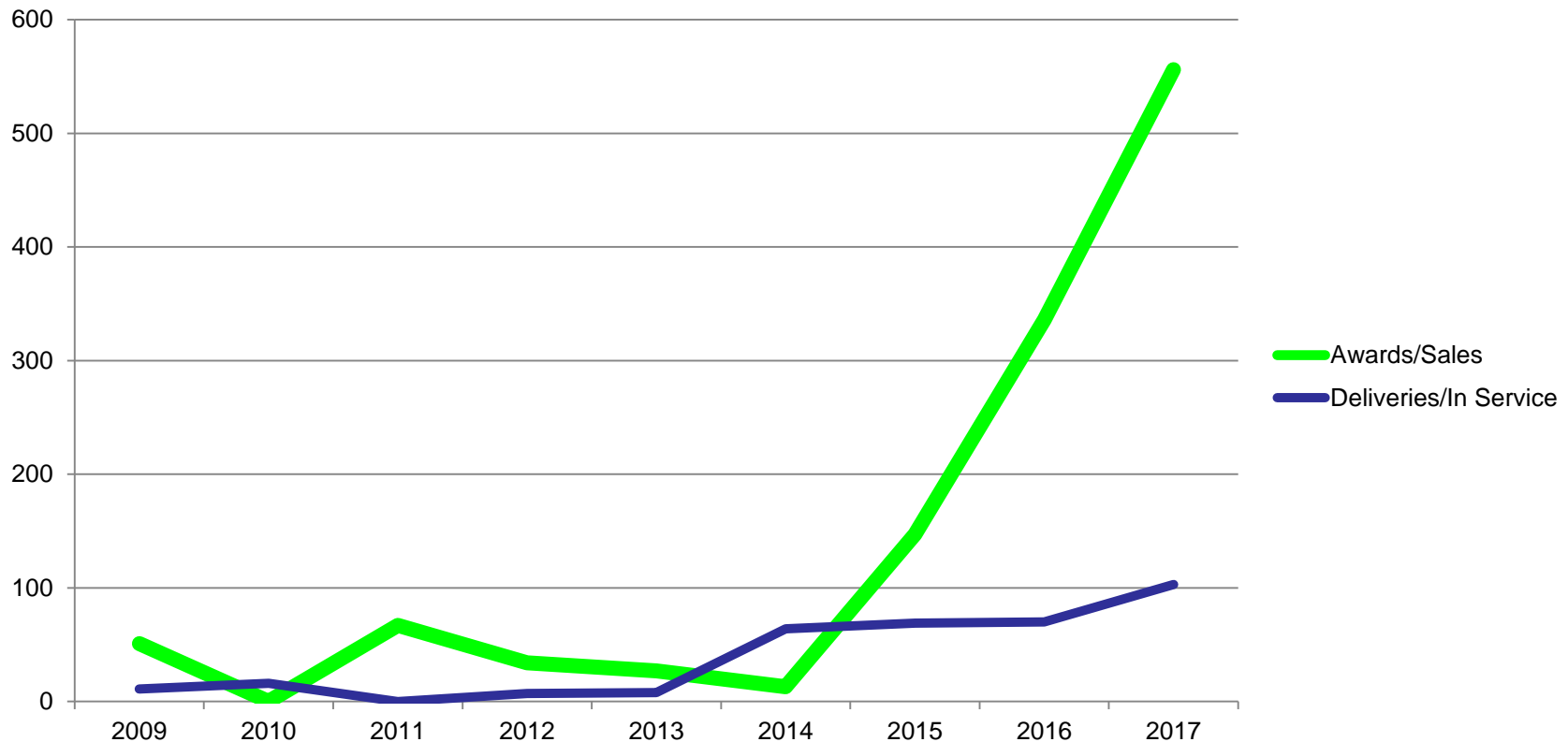


CTE Zero Emission Bus Projects



- **Current Zero Emission Bus (ZEB) Projects with CTE (>140 ZEB's with over 30 Agencies)**
- **2017 Low-No Awards with CTE (> 50 ZEB's with 25 Agencies)**

ZEB U.S. Annual Sales & Deliveries



- **> 140 Agencies**
- **> 1200 cumulative awards/sales**
- **> 340 cumulative deliveries/in service**

ZEB Market Development

Calendar Year	Awards & Sales
2011 - 2014	141
2015	147
2016	336
2017	556

BEB

Calendar Year	Base Price	Energy Storage
2011	\$1.2 mm	75 kWh
2017	\$750k	300+ kWh

FCEB

Calendar Year	Base Price
2011	\$2.2 mm
2017	\$1.2mm

CENTER FOR TRANSPORTATION
AND THE ENVIRONMENT

Zero Emission Bus Deployment Best Practices



Keys to ZEB Success: Planning!

- Understanding available ZEB technology options
 - Battery vs. Fuel Cell
 - Variety of battery configurations
 - 75 kWh - 660 kWh
 - Variety of charging configurations and adapters
 - Depot Plug-in, On-Route Overhead Conductive, On-Route In-ground Inductive
 - Variety of charge rates
 - 50 kW – 500 kW
- Understanding ***your*** requirements to determine the best zero emission buses and infrastructure for ***your*** transit agency
- Understanding how to deploy ZEB technologies

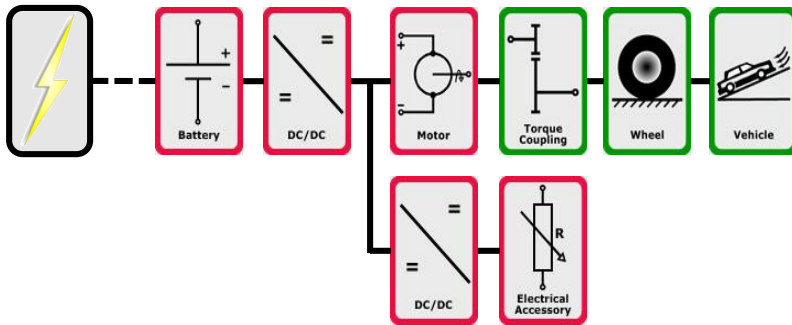
Technology Assessment

- Objective:
 - Assess how various ZEB technologies can be utilized to meet service requirements
 - Assess potential impacts to service
 - Assess transit facilities capacity to meet ZEB fueling requirements
 - Assess “Fuel” Costs
- Why?
 - Fuel efficiency and range are impacted by
 - Passenger Loads
 - Climate: Auxillary Loads
 - Route Profile: topography/grades, speeds, stops, acceleration/deceleration
 - Battery Degradation
 - Operator Behavior



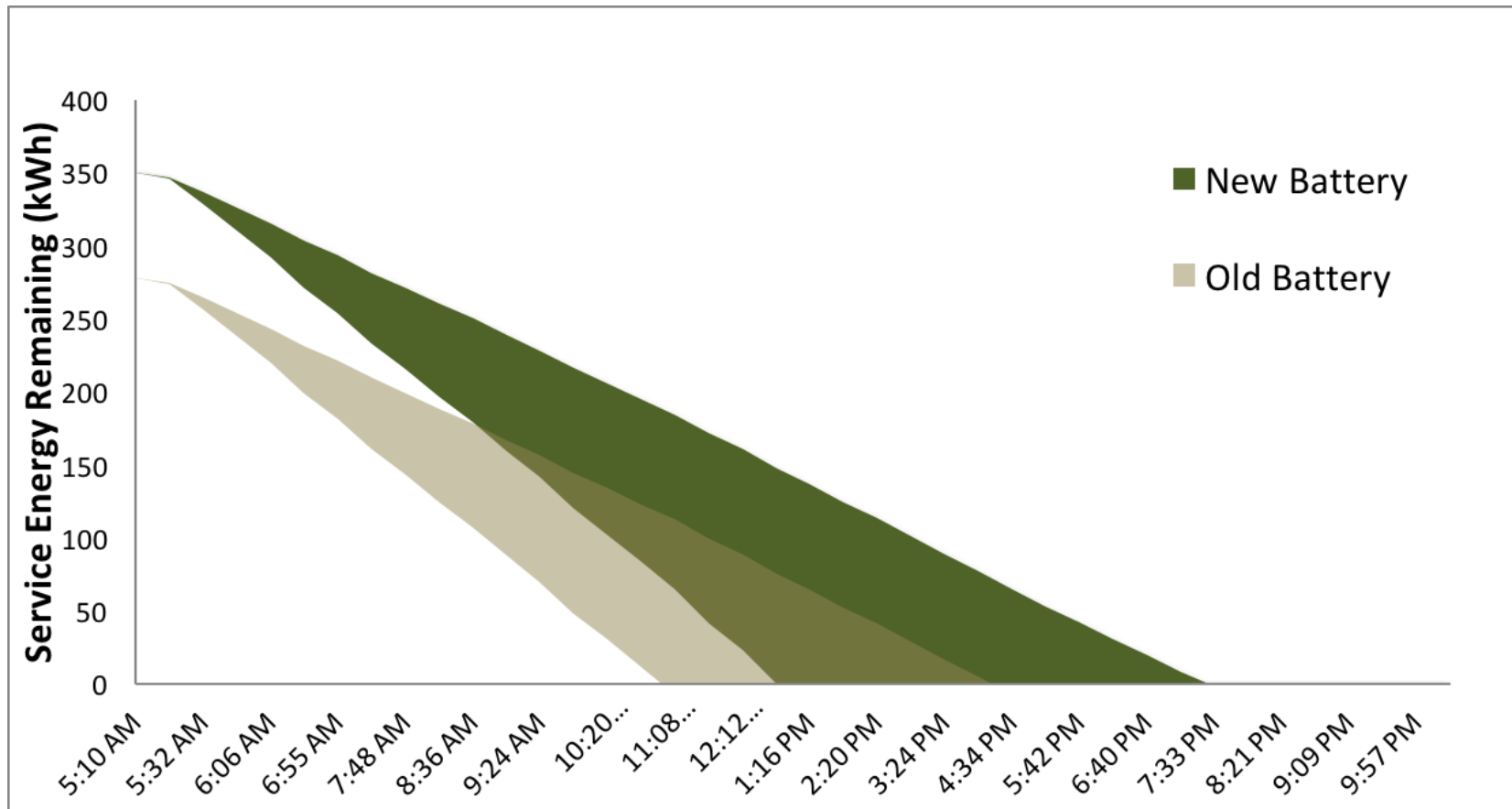
Data-Driven Decision Making

- ZEB Modeling & Simulation
 - CTE uses Argonne National Labs' Autonomie, augmented with CTE-defined methods, models, and procedures



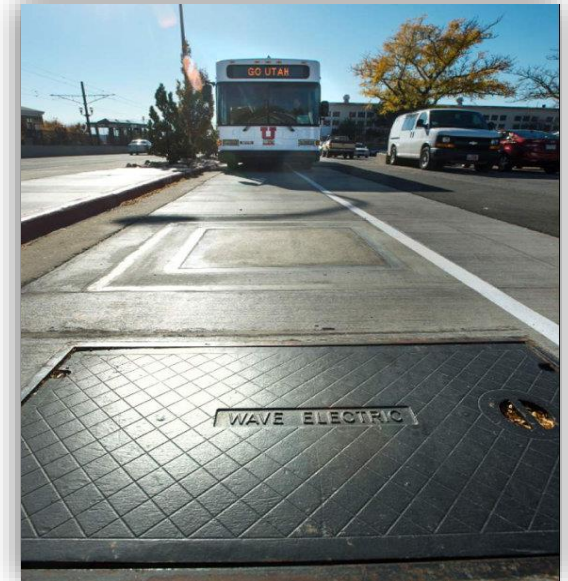
Technology Assessment

- Assess energy consumption based on:
 - Nominal vs. Strenuous Loads
 - Beginning-of-Life vs. End-of-Life Batteries



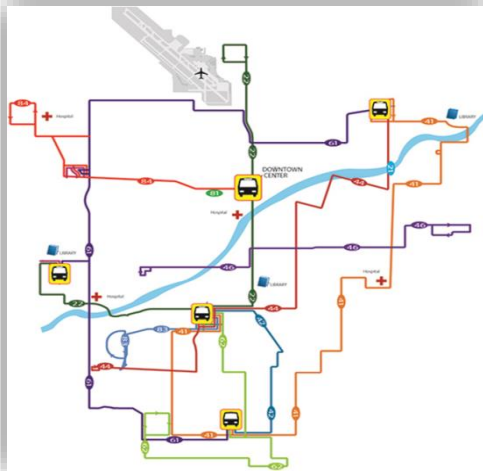
Infrastructure Planning

- Site Selection
- Capacity Planning/Utility Coordination
- Redundancy – Contingency Planning
- Scalability for fleet expansion
- Parking, Staging, Yard Operations
- Data Networking / Charge Management Requirements
- Planning/Design/Permitting
- Construction, Installation, Commissioning
- Coordination with Vehicle Delivery



Deployment Planning

- Operator Training
- Maintenance Training
- First Responder Training
- Route/Service Enhancements
- PR/Communication



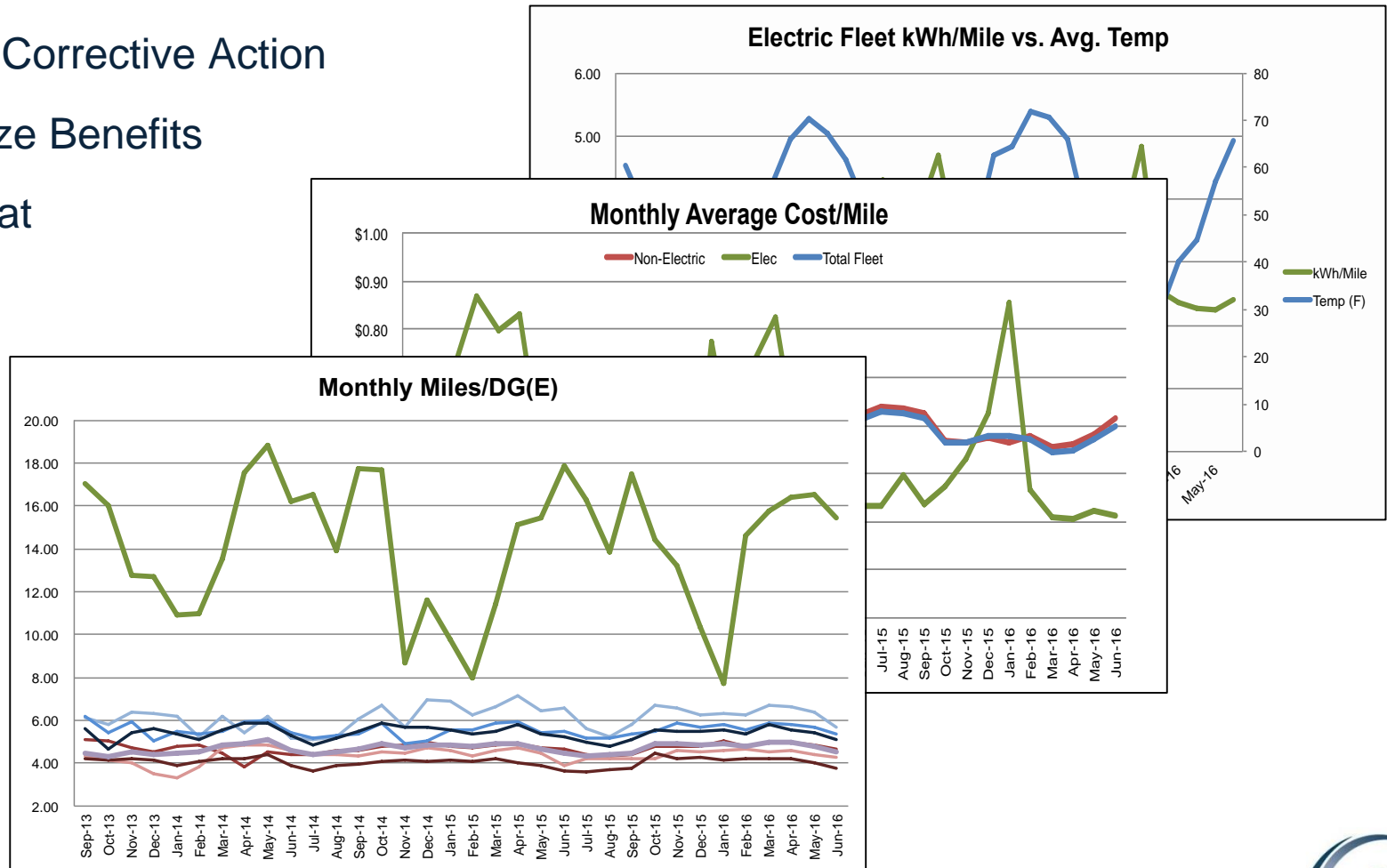
Implementation

- Bus, Charging, and Data System Testing
- Shadow Service – Route Validation
- Adjust deployment strategy, as necessary



Benefits Realization: KPI Analysis

- Track & Analyze Performance
- Take Corrective Action
- Realize Benefits
- Repeat



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Lessons Learned from Around
the World***



Snapshot of Europe's ZEBs

- 150+ BEB currently
 - 300+ by 2020
- 50+ FCEB currently
 - 200+ by 2020
- EU level large-scale demo programs:
 - ZeEUS
 - CHIC, HyVLoCity



Snapshot of Europe's ZEBs

- FCEB
 - JIVE – coordinated demand aggregation for 600+ buses
 - 100 buses total, 3 sites w/ 20 buses
 - Minimum 10 buses per site
 - Required price point 650K
- BEB
 - Cities taking the lead



London

- All new single decks zero-emission from 2020
- All new double decks zero-emission from 2025
- From 2037 all 9,000+ TfL buses zero-emission
- Presently:
 - 50+ BEB in operation
 - 8 FCEB in operation



Regulation

- Clearly driving the market
- Commitment to clean air and clean technology
- Interoperability
- Relationships with energy providers
- Market maturity



Clean Bus Deployment Initiative: Declaration of Intent of promoting large-scale deployment of clean alternatively fueled buses

Questions?

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