California Transit Association

Zoom to Zero: Fundamentals of Battery-Electric Buses

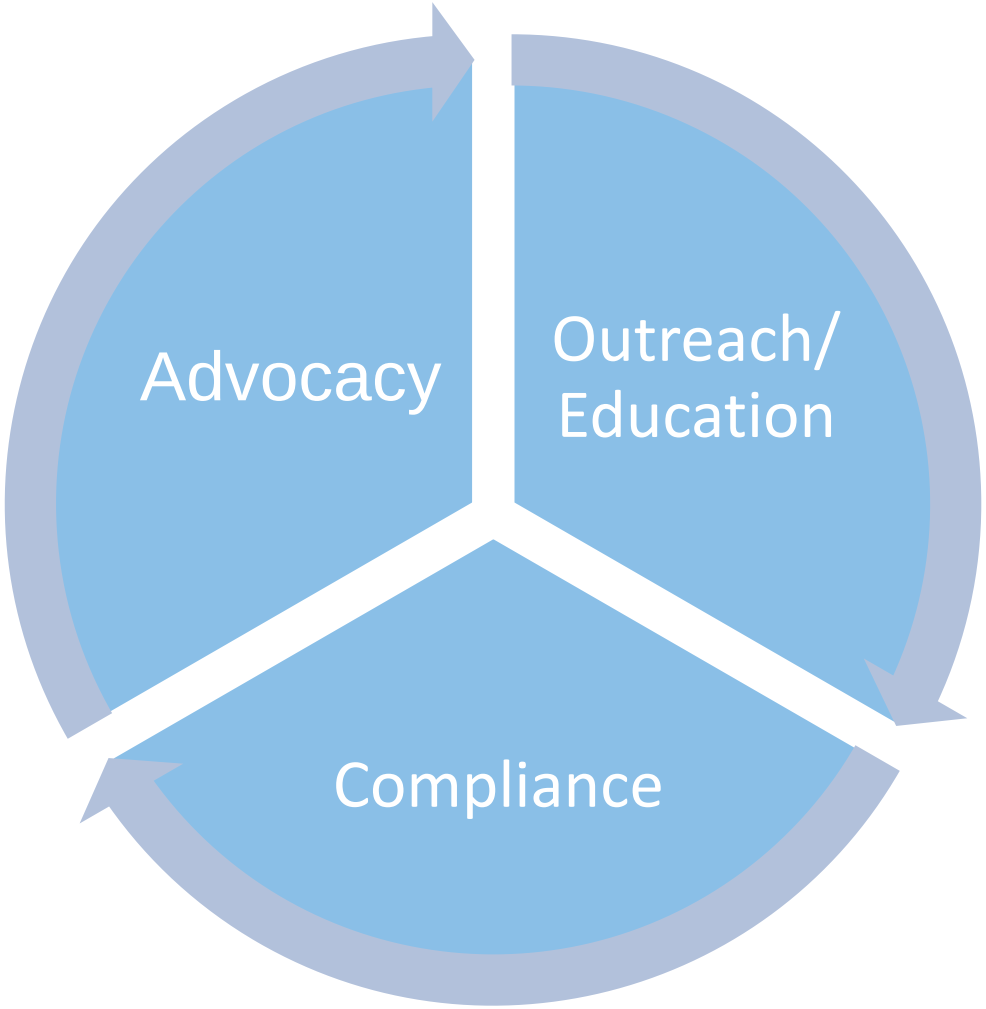
(Co-Hosted by CALSTART)

September 12, 2019

California Transit Association

- Represents more than 200 transit-affiliated entities, including more than 80 transit agencies in CA
- Advocates for policies and funding solutions that support and advance public transit

Support for ICT Regulation Implementation



How to Ask Questions

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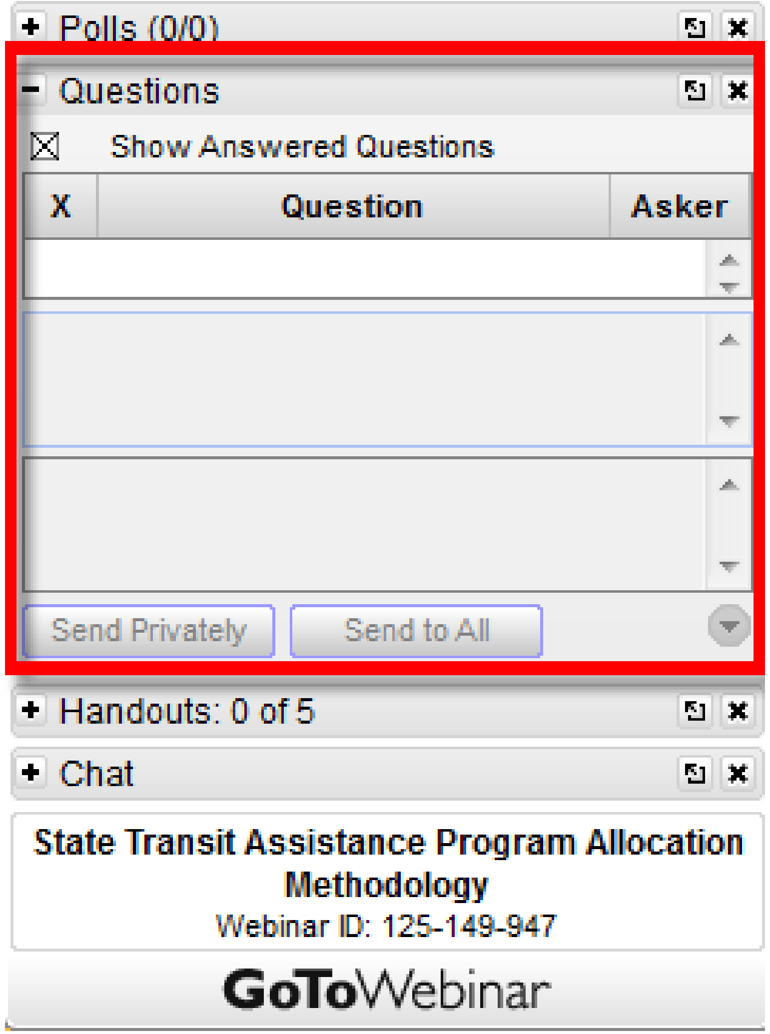


CALIFORNIA
AIR RESOURCES BOARD

Understanding The Deployment of Battery Electric Buses

CTA-CALSTART Webinar Series

September 12, 2019

ZEB ROLLOUT PLAN

- Approved by the transit agency's governing body and submitted to CARB
  - July 1, 2020 for large transit agencies
  - July 1, 2023 for small transit agencies

- Planning is key to success:
  - Identify suitable technologies
  - Understand the potential schedule for infrastructure construction
  - Planned bus purchase schedule

SYNCHRONIZATION & MULTIPLE RESOURCES NEEDED

Bus Procurement

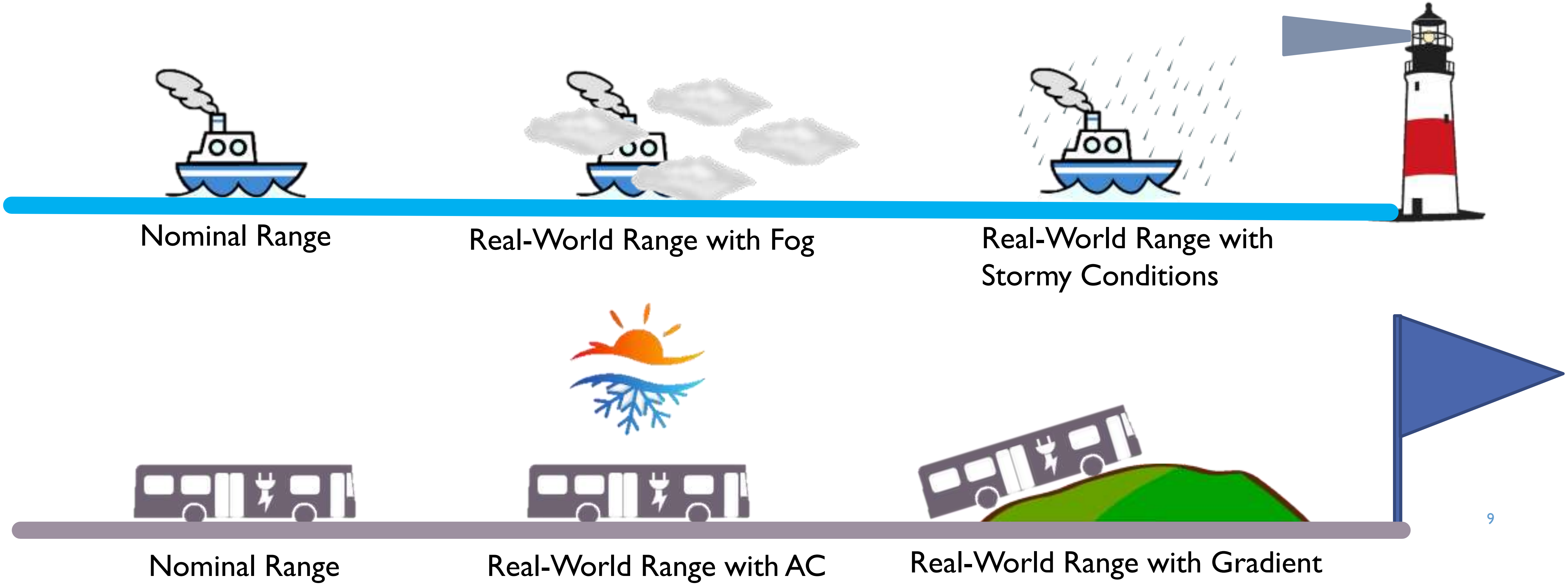
Infrastructure Installation

Fuel Cost Management

FACTORS FOR CONSIDERATIONS

- Bus procurement → Range
- Fuel cost management → Energy use management
- Infrastructure installation → Power needs

NOMINAL RANGE VS. REAL WORLD RANGE



RANGE MANAGEMENT

- Factors affecting range
  - Terrain, use of HVAC, driving behavior, driving cycle, etc.
- Potential range mitigation
  - Route simulation or testing—know how range is affected by conditions of your routes
  - Increase fuel efficiency
    - Driver training: Driver training (Antelope Valley Transit Authority study sponsored by CEC available to California transit fleets free of charge)
    - Reduce vehicle weight
  - Select suitable technologies
    - Depot charging → Battery size→ vehicle weight (therefore, fuel efficiency) and range
    - On-route charging

EXAMPLE FUEL EFFICIENCY FOR BATTERY ELECTRIC BUSES

	County Connection	**Foothill Transit**	**Foothill Transit**	**King County Metro**
Bus manufacturer/ model	Gillig/depot and wireless charge	Proterra/BE35	Proterra/Catalyst Fast Charge	Proterra/Catalyst
Model year	2016	2014	2016	2015
Length (ft)	29	35	42.5	42.5
Data period	6/2017 - 5/2018	4/2014 - 12/2018	1/2017 - 12/2018	8/2016 - 7/2017
Energy consumption (kWh/mile)	2.84	2.17	2.22	2.36

Sources:
Foothill Transit Agency Battery Electric Bus Progress Report, May 2019. https://www.nrel.gov/docs/fy19osti/72209.pdf.
Zero-Emissioni Bus Evaluation Results: County Connection Battery Electric Buses, December 2018. https://www.nrel.gov/docs/fy19osti/72864.pdf.
Zero-Emissioni Bus Evaluation Results: King County Metro Battery Electric Buses, February 2018.
https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/115086/zero-emission-bus-evaluation-results-king-county-metro-battery-electric-buses-fta-report-no-0118.pdf.

ENERGY VS. POWER

- Energy: a measure of how much fuel is contained, an ability to create changes, e.g. motion
  - Examples: calories for food, kWh for electricity
- Power: the rate at which energy is transmitted
  - Example: kW for electricity

ELECTRICITY AS AN ENERGY—
TRY TO THINK ABOUT FILLING UP A 10,000 GALLON POOL

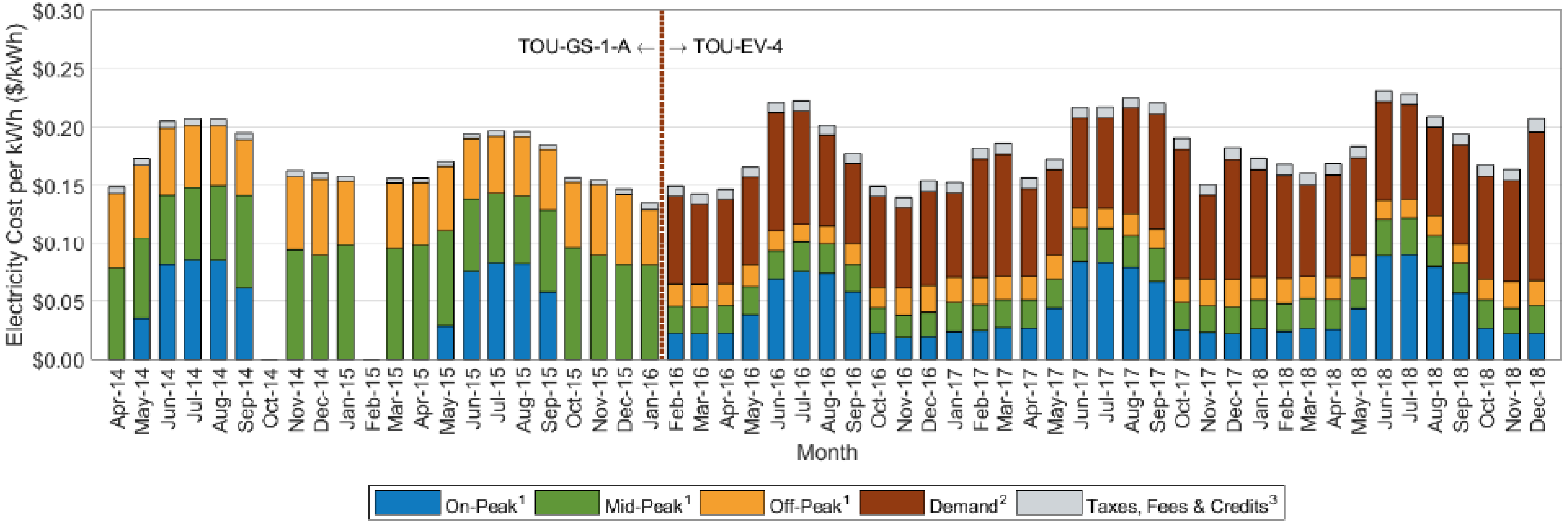
- Energy → how much water is needed
  - 10,000 gallons of water
  - Water could be more expensive during a drought
    - The cost of filling up a pool might vary based on how scarce water is

- Power → water supply rate
  - Water can be injected at a different rate
    - e.g. 2 gal/s vs. 10 gal/s
  - Faster filling requires a bigger pipe
  - A bigger pipe is more expensive

ENERGY COST

- Electricity cost formula is more complicated than water cost formula
- How electricity cost is incurred
  - Electricity consumption
  - Electricity rate
  - Time of use
  - Demand charge (per meter based)
- Not a linear relationship

EXAMPLE OF ELECTRICITY COST (FOOTHILL TRANSIT)



1. On-Peak, Mid-Peak, and Off-Peak charge categories include respective costs for delivery and generation
2. Rate structure changed from TOU-GS-1-A to TOU-EV-4 February 2016, introducing demand charges
3. 'Taxes, Fees & Credits' category includes all remaining utility bill items (positive & negative charges)

Source: NREL Foothill Transit Agency Battery Electric Bus Progress Report, May 2019. https://www.nrel.gov/docs/fy19osti/72209.pdf.

POTENTIAL ELECTRICITY COST MITIGATION

- Take advantage of off-peak charging
- Try not to trigger a demand charge when the battery electric bus fleet is small
- If a demand charge s triggered, maximize the utilization of charger(s) to reduce the average electricity cost ($) per mile

POWER NEEDS AT A TRANSIT DEPOT YARD

- Power needs: how much power is needed to charge buses and support other on-site needs
- Design assumptions
  - Everything is turned on at the same time
  - Include both existing power usage (e.g. transit building electricity usage) and expected new power needs (e.g. charging 20 new BEBs)

EXAMPLES FOR POWER NEEDS TO CHARGE 200 BEBs

Fast Charging

- Example 1. Fast charging 200 BEBs at the 250 kW rate all at once
  - 250 kW x 200 = 50,000 kW = 50 MW
  - Infrastructure building could be expensive and time consuming
- Example 2. Fast charging 50 BEBs at the 250 kW rate each time
  - 250 kW x 50 = 12,500 kW = 12.5 MW
  - Infrastructure is less expensive
  - Fast charging makes 4 charging shifts possible

Slow Charging

- Example 3. Slow charging 200 BEBs at the 60 kW rate all at once
  - 60 kW x 200 = 12,000 kW = 12 MW
  - Infrastructure cost is similar to example 2
  - Slow charging is possible for 1 charging shift
- Example 4. Slow charging 100 BEBs at the 60 kW rate each time
  - 60 kW x 100 = 6,000 kW = 6 MW
  - Potentially least infrastructure cost
  - Slow charging 2 shifts may not work for morning peak hours

INFRASTRUCTURE PLANNING, BUILDOUT, AND PERMITTING PROCESS

- Involve utility in the planning process for the first step towards success
- Optimize infrastructure scale up in long-term planning
  - Particularly important if a single site has a large power demand and infrastructure installation might be phased in
- Consider parking arrangement and charger location(s)
- Understand charger permitting process
- Understand power need to estimate and control time and budget

CONTACT INFORMATION

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- Shirin Barfjani, Lead Staff for the Innovative Clean Transit Regulation
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- Innovative Clean Transit website https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit

Zoom to Zero: Fundamentals of Battery-Electric Buses

Web Meeting Sept 12, 2019

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California Transit Association

CALSTART

CALSTART's 220 + Member Companies and Organizations

(PARTIAL LISTING)

Making Clean Transportation Happen

CALSTART – A National Organization 9 Offices
Six Regional Offices + Four Field Offices

California
- 3 offices
- 2 field offices




More Than 30 Transit Style and Cutaway Bus ZEB Products Across Twelve Bus Makers













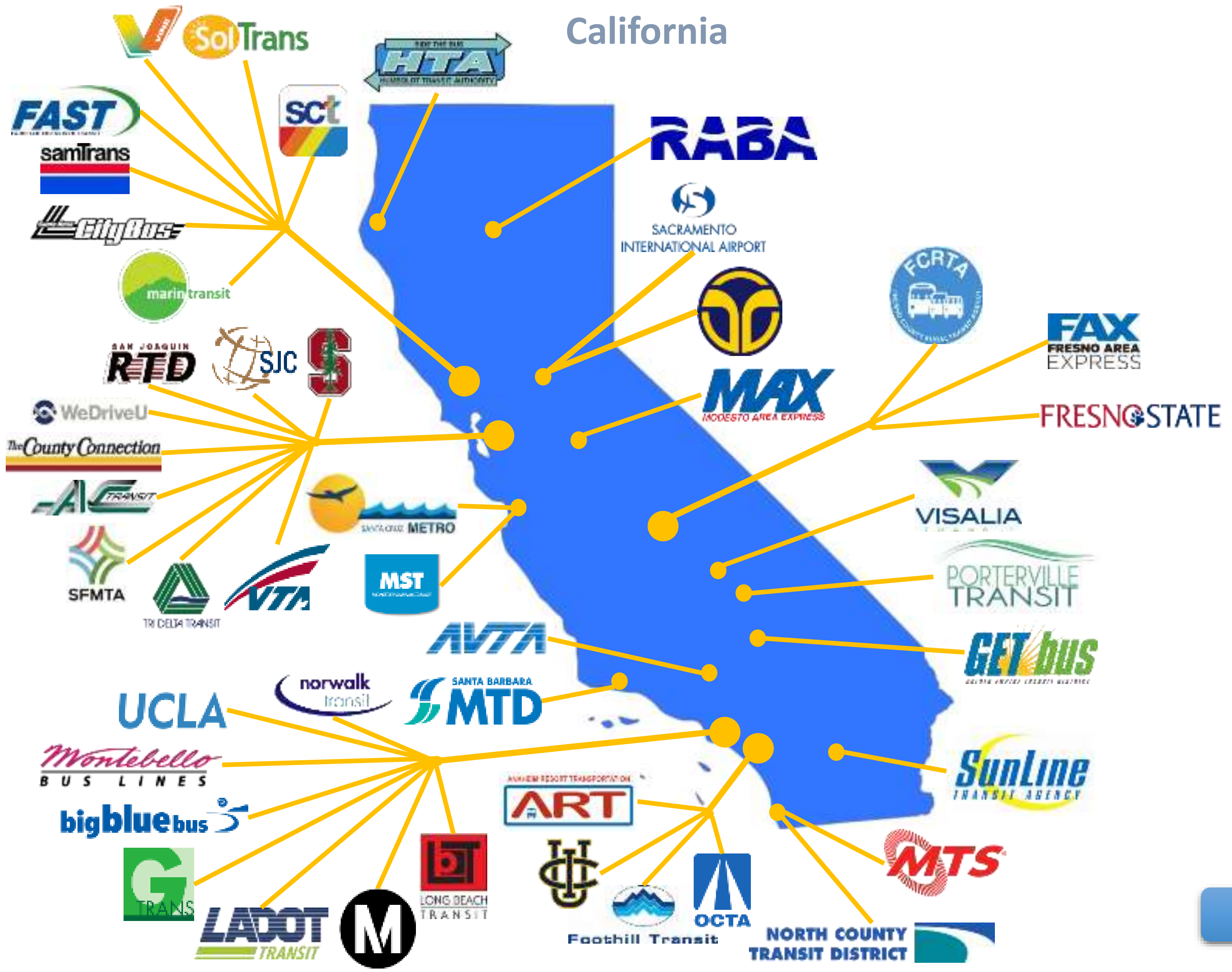
Zero Emission Bus Update
(Preliminary New Count)

- As of August, 2019, there are:
  - Total # of ZEB's nationwide: 2203
    - Total # of BEB nationwide: 2132
    - Total # of FCB nationwide: 71
  - California total # of ZEB: 1016
    - California total # of BEB: 964
    - California total # of FCB: 52
  - FTA FY2009 electric Drive Strategic plan set a target of 12,000 Cumulative ZEBs by 2030

- Breakout Regions
  - California is Number One
  - Midwest Number Two
  - Pacific Northwest Number 3
  - Florida will be Next <u>Major</u> breakout market

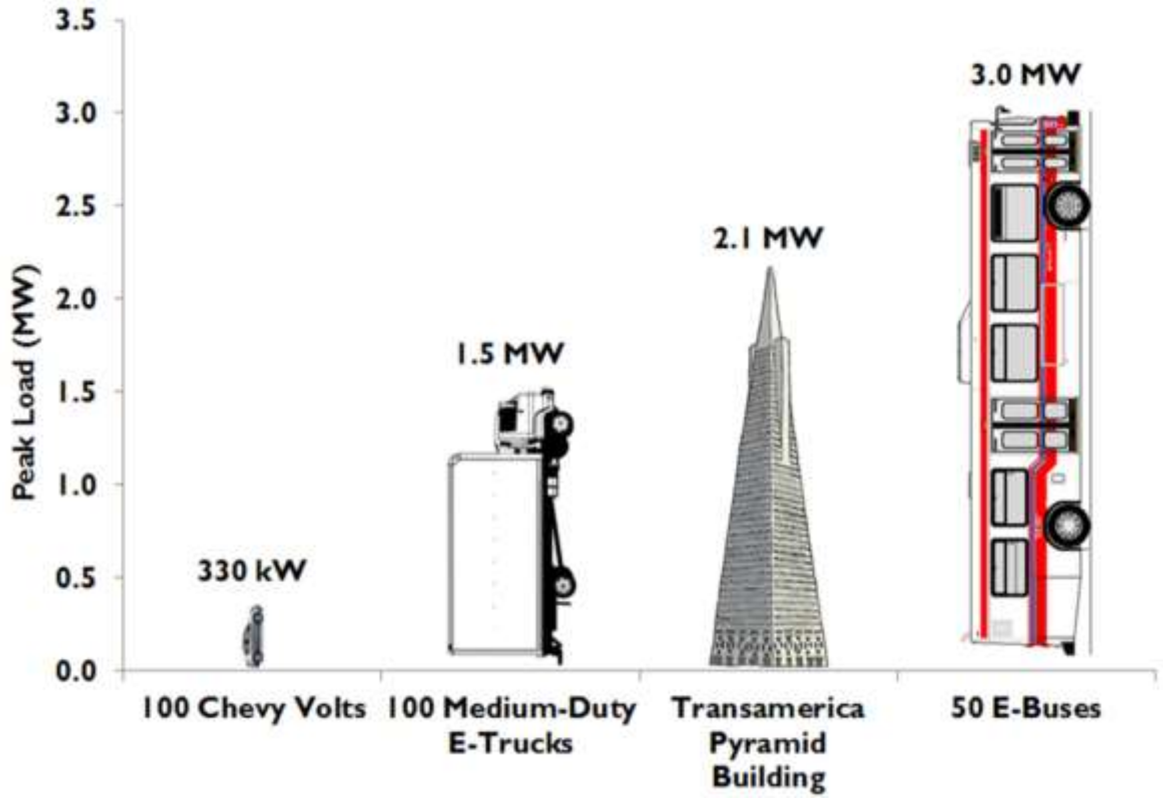
Transit Properties with Battery or Fuel Cell Electric Transit Buses

Last Updated: August 17, 2018



Return to Map

Infrastructure the Near Term Challenge for ZEBs
Peak Loads Considerations for Battery Electric Buses



Assumptions: the Chevy Volt charging rate is 3.3 kW, the medium-duty E-Truck charging rate is 15 kW and the E-Bus charging rate is 60 kW.

Plan Plan Plan

Caltrans Planning Funding Is Here

- **$17 million for Sustainable Communities** Grants to encourage local and regional planning that further state goals, including, but not limited to, the goals and best practices cited in the regional transportation plan guidelines adopted by the California Transportation Commission.
- Zero Emission Bus Transit Fleet Feasibility Studies are Eligible Grants and are Due October 11th
- Grants range from $50,000 Each to a maximum of $1,000,000 each
- Cost share is 11.7 % and CALSTART is an allowable Sub Applicant
- In 2018 LAEVWRG members reviewed this opportunity and CALSTART wrote and were selected to support Transit Bus Electrification studies for Pasadena, Burbank and Glendale Fleets
- CALSTART would be happy to assist any of our LAEVWRG members in their support or planning for these funds. Given the New CARB ICT regulation this is a timely opportunity

Planning Elements

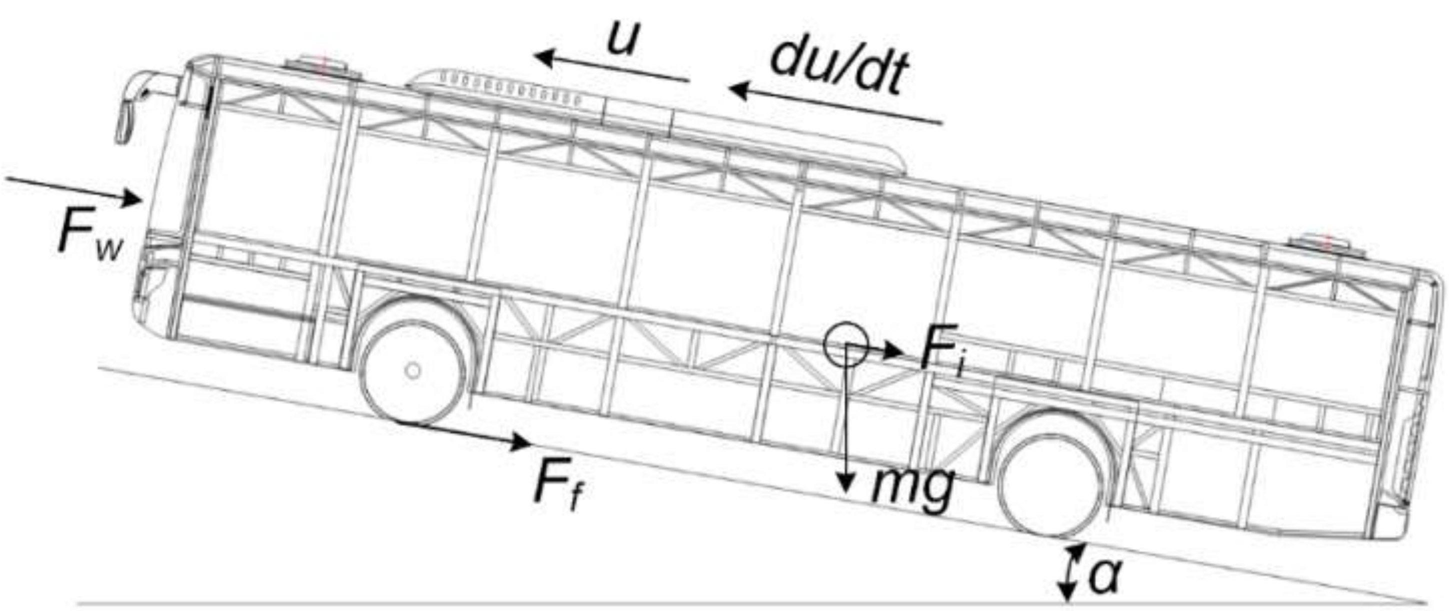
- Vehicle inventory analysis and ZEB timing
- Vehicle performance vs Vehicle route analysis
- Energy requirements
- Facility requirements
- Charging strategy
- Smart BEB dispatching systems
- Final infrastructure planning
- Preliminary electrical drawings
- Utility applications for new service

Overview Electric Bus Corridor Model (EBCM

- What is the EBCM and CALSTART's Process
- Bus Performance Results for each Route
- Further Analysis & Recommendations

Key Design Output	
Average Energy Consumption per mile in the design day in Summer (kWh/mi)	4.23
Average Energy Consumption per mile in the design day in Winter (kWh/mi)	5.32
Minimum battery size if using Depot Charger Exclusively (kWh)	732
Minimum required charging power for depot charger if using Depot Charger Exclusively (kW)	66
Minimum battery size if using On Route Charger Exclusively (kWh)	78
Minimum required charging power for on-route charger if using On-route charger exclusively (kW)	224
Minimum battery size if using both Depot and On-route Charger (kWh)	78
Minimum required charging power of depot charger if using both Depot and On-route	7

Additional Key Output for Typical Days in Spring and Fall	
Average Energy Consumption per mile in a typical day in Spring (kWh/mi)	3.54
Average Energy Consumption per mile in a typical day in Fall (kWh/mi)	3.64
Average Energy Consumption per lap in a typical day in Spring (kWh)	31.63
Average Energy Consumption per lap in a typical day in Fall (kWh)	32.52



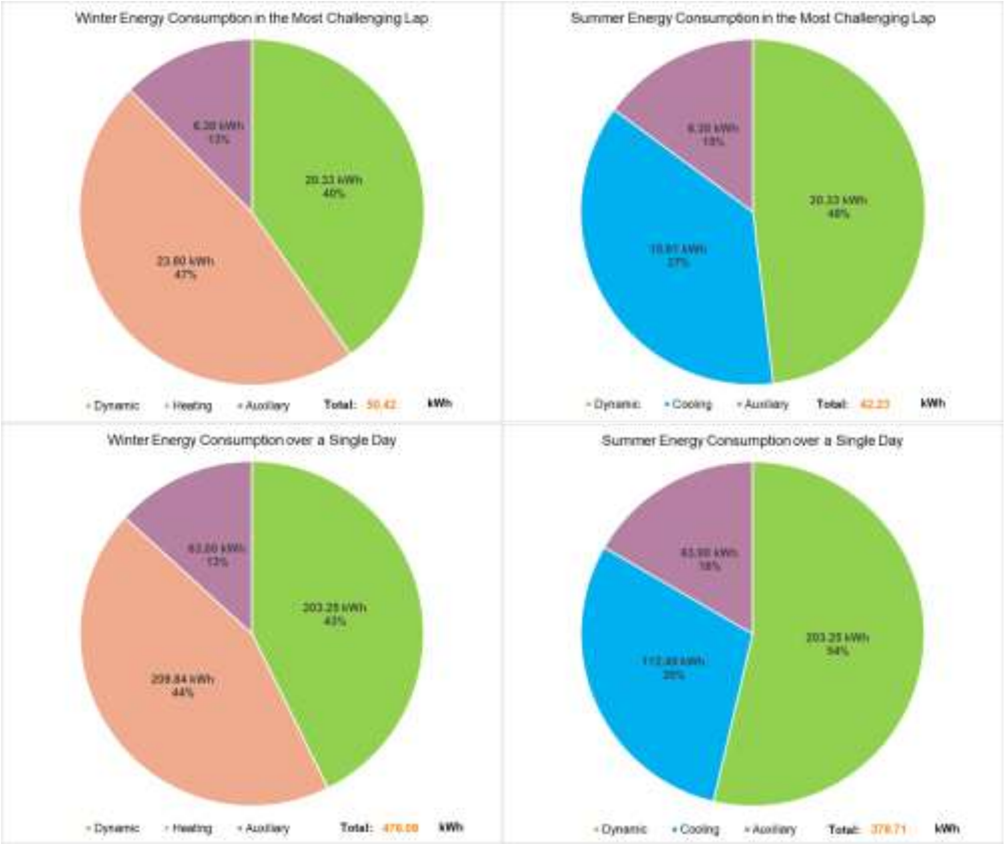
CALSTART's Process

- Step 1: Talk to the Fleet Manager
  - Half hour conversation by phone
  - Questions about the bus, the route, and the charging station design
- Step 2: Gather data from publicly available reports
  - Altoona bus testing
  - HVAC system
  - Climate conditions
- Step 3: Run the model

Bus Performance Results for Each Route

Key Outputs

- Seasonal kWh/mile rate in Summer, Winter, Fall, and Spring
- Daily Energy Consumption by Subsystem
- Energy Consumption for the "Most Challenging Lap of the Day"
  - i.e. 5:00 AM in the middle of a winter blizzard
- Daily State of Charge Change for Summer, Winter, Fall, and Spring



Further Analysis

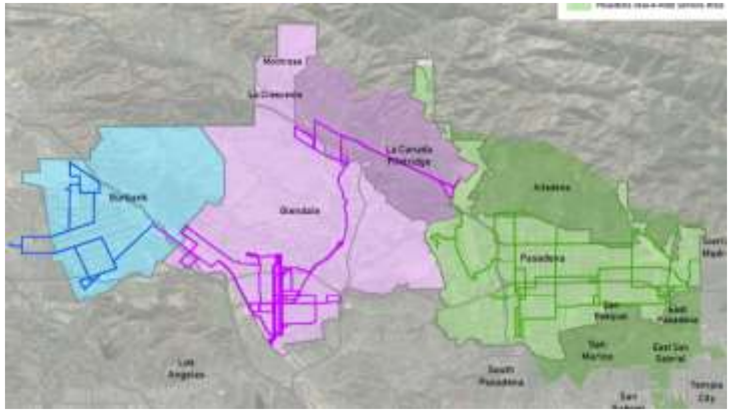
- The Charging Station is the most critical element to any bus route.

- CALSTART can create several scenarios for one route:
  - Depot Charger Only?
  - On Route Charger Only?
  - Both?
  - High Power or Low Power Chargers?

100/200 kW charger vs. 400 kW charge

Transit Fleet Electrification Feasibility Study for the Arroyo Verdugo Region Transit Operators

- Caltrans Sustainable Communities Planning Grant
  - $407,997 total funding for City of Pasadena, City of Glendale, City of Burbank and CALSTART
- Overall Project Objectives
  - Assessment of current conditions and risk assessment of moving to an electric fleet, including evaluating market conditions of electric vehicles and charging equipment.
  - Identify opportunities for Arroyo Verdugo Region Transit Operators to share in-route charging infrastructure.
  - Develop a timeline for bus replacement/purchases and infrastructure development.



Clean Transportation Technology Industry Coalition

Leading the Industry with Action in

Technology Development / Policy / Technical Analysis / Market Acceleration

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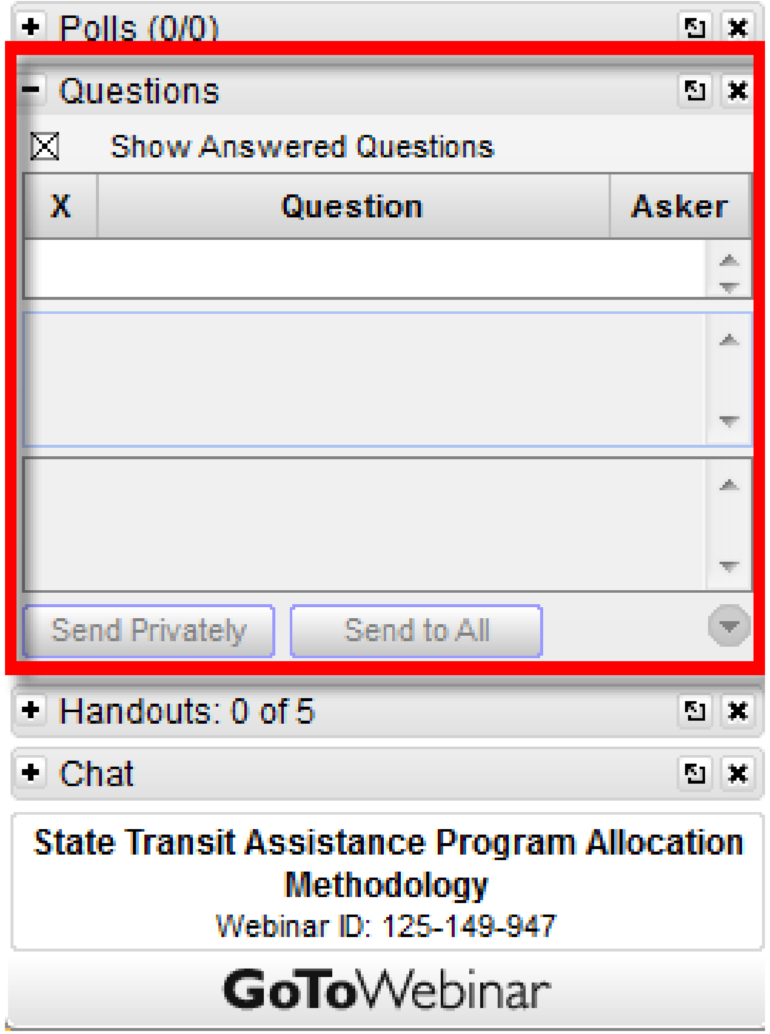

Remember to Register!

- Session 2: Zoom to Zero: Battery-Electric Buses on the Road (9/19)
- Session 3: Zoom to Zero: Best Practices for EV Infrastructure (9/25)
- Session 4: Zoom to Zero: Fund the Electric Fleet (10/3)

Fuel Cell Technology – a Four-Part Series

The California Transit Association and the California Hydrogen Business Council co-hosted a four-part webinar series addressing the potential of fuel cell electric bus (FCEB) technology to meet the requirements of the Air Resources Board's Innovative Clean Transit regulation. Review materials from each webinar in the series below.

Hydrogen and Fuel Cell Electric Transit 101

Held June 6, 2019, the first webinar in the series provided an introduction to the technology, discussed its benefits in meeting zero-emission requirements, and addressed safety questions and considerations. The program was moderated by California Transit Association Legislative & Regulatory Advocate Michael Pimentel. Featured presenters included Emanuel Wagner, Deputy Director of the California Hydrogen Business Council; Tim Sasseen, Business Development Manager with Ballard Power Systems; and Rudy LeFlore, Chief Performance Consultant with SunLine Transit Agency.

Watch the entire program, or download a PDF version of the presentation file from the program via the link below.

- Presentation file in PDF format

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Contact Us

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