Zero Emission Bus Workshop
San Diego Sierra Club
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Buses – Really?? Why?

- Climate change
  - California is doing a great job in renewables for electricity production and on a great trajectory. 50%+ by 2030, Via SB 100, 100% by 2045?
  - Transportation now contributes 40% of state's GHG
    - EVs largest portion – many folks and programs working on this
    - Significant contributions from medium and heavy duty vehicles – higher contributions for particulates, NOx and other toxic air pollutants
      - Buses best large application of electric drive trains
      - Will create battery volumes to lower costs, charging standards, eco- system that will pave the way for other medium and heavy duty transportation including school buses.
      - Feasible now.
  - A word about Fuel Cell Electric Buses

Benefits of Electric Buses

- For riders, drivers and bystanders – it's a quiet, low vibration, non-stinky comfortable ride. No tailpipe pollution – no tailpipe!
- Cleaner and healthier neighborhoods in disadvantaged communities and elsewhere.
- No fossil fuels and all the risks – no fueling infrastructure, potential for explosions, leaks, contamination of ground and aquifers, unpredictable price swings.
- Maintenance facilities clean for mechanics and neighborhoods. Check out a Tesla service center.

Environmental Justice

- Electric buses provide a more enjoyable experience.
- Removes pollutants in disadvantaged communities both from use of buses and for local depots and maintenance facilities
- May increase ridership from new riders – new riders can equal more revenue and improved service.

Good Paying Jobs!

- California is the electric bus capital of the US!
  - Proterra
  - BYD
  - Gillig
  - Green Power Bus
  - Many suppliers and others
- Jobs in bus manufacturing
- Jobs in installing chargers
- Jobs in installing solar.
- Resolution should ask for re-training of existing staff in developing new skills for electric buses

What's Driving This at State Level?

- SB 32 – reduce GHG by 40% compared with 1990 levels by 2030.
- SB 350 -
  - 50% RPS by 2030 or 2026? (means electric fuel will get "greener". With hydro and distributed solar, GHG electricity 15-20 % higher – e.g. 50% RPS = 65% emission free
  - Requires utilities to promote the electrification of transportation
- Low Carbon Fuel Standard (LCFS) – promotes increased use of low carbon fuels. Electricity is very low in carbon.
- Other programs – e.g. Mobile Source Plan

CARB's ZEB Rule Making Process

- Started nearly 20 years ago – First step was CNG buses, etc. but ZEBs were put on suspension because not feasible at the time.
- Re-started rulemaking with workshop in May 2015 – then not much until January 2016.
- Goal is to develop a rule that requires all public transit buses to be ZEB by 2040.
- We sent letter to CARB asking for a purchase requirement rule that requires at least 20% of all new bus purchases to be ZEB starting in 2020; 100% must be ZEB starting in 2027. Average bus life is 14 years.
- Very possible for transit agencies to go 100% ZEB by 2034 without any "stranded assets" if they start purchasing all ZEBs by 2020.

California Public Transit Buses

- California has about 10,000 transit buses
  - LA Metro has 2,700
  - SD MTS has 591 – fourth largest in state
- Types
  - Urban – low floor transit buses
  - Commuter buses – motor coaches
  - Paratransit – smaller ("Cutaways") flexible, on demand.
  - Can integrate with light rail to be feeders.

Who Makes Electric Buses?

- Electric only
  - Proterra – Corp in Burlingame, CA new factory in City of Industry
  - BYD – Factory in Lancaster, CA. Second largest in China
  - Green Power Bus – Factory ground breaking yesterday in Porterville CA
- Traditional
  - New Flyer – National market leader in US for fossil buses.
  - Gillig – just moving to Livermore, CA – second largest market share in fossil buses – just starting to do electric bus pilots.
- California is the electric bus capital of the US!

What Are the Types of Bus Propulsion?

- In California
  - 59% are CNG, LNG, LPG, RNG
  - 31% Diesel
  - 7% Diesel / Hybrid – electric traction motors, battery, regenerative brakes. + a diesel engine to charge the batteries
  - 3% All Electric (electric and fuel cell)

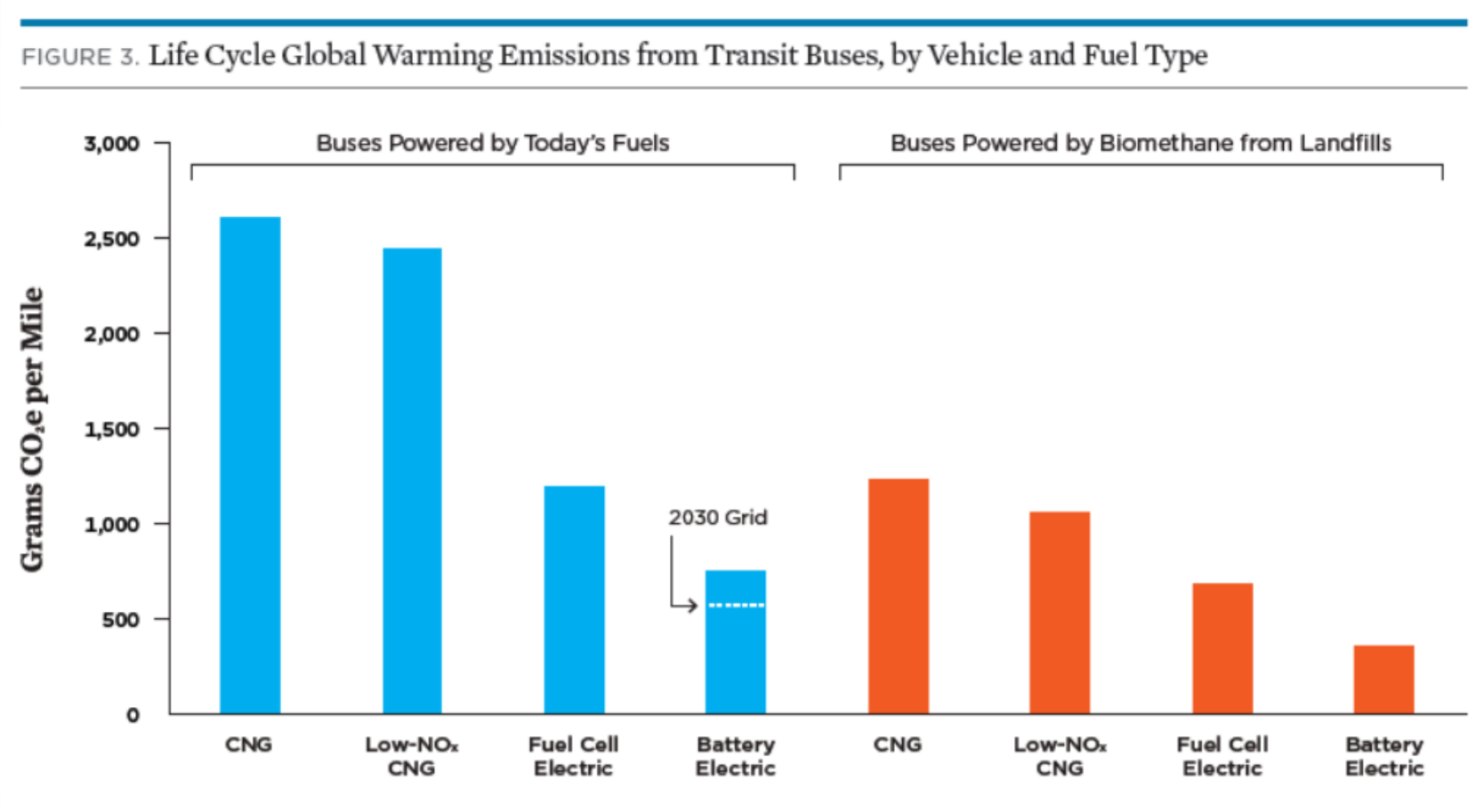
What is a “Clean” Bus?

- Clean Natural Gas?
- Clean Hybrid?
- Clean RNG (Renewable Natural Gas; Biomethane, Landfill gas) with low NOx engines?
- ZEBS – Clean Tailpipe; Fuel?
- ZEBS powered 100% with renewable energy – Clean tailpipe and clean fuel

Do ZEBs Really Reduce Emissions?

- ZEBs use electric drive trains which are nearly 4 times more efficient than a CNG fueled bus.
- Using today's grid, an electric bus produces 70% less GHG than a CNG bus. And 30% fewer than a CNG bus fueled with landfill gas and using a low NOx engine ("Renewable Natural Gas – RNG).
- As the grid continues to get greener, GHGs from a BEB will be even lower.
- For TAs that install their own solar, they not only lower electricity costs significantly but have truly zero emission buses.

Emissions by Fuel Types – From UCS



Do BEBs Have Enough Range?

- Yes!
- CARB Survey showed that 56% of bus routes with less than 150 miles.
- Proterra – up to 350 mile range
- BYD – 200 mile 60’ bus; 161 40’ bus mile range
- New Flyer – 208 mile range.
- Other routes can be met with in-route charging

Do BEBs Have Enough Range?

- Bus ranges have continued to improve with better batteries
  - New Flyer started with a 132 mile bus and now had a 208 mile.
  - Last year, Proterra announced new batteries that were 28% more dense. They put these in the same space as old 156 miles bus and got a 28% increase in range to 194 miles at no increase in cost.
  - BYD has increased battery density 40% over the last four years.
  - Billions of dollars are being invested globally to further improve batteries that will further extend range and lower costs.
- Buses will continue to have increased ranges available with denser and cheaper batteries.
- Transit Agencies can start with electric buses on shorter routes and go to longer routes in future years that will be met with longer range buses.

How are Electric Buses Charged?

Depot Charging

- Uses J1772 or CCS Standard
- Can use one or two plugs
- Slow charging – a few hours 80 kW

In-route Charging

- Very high power – up to 500 kW
- Very fast – 3-10 minutes
- More expensive

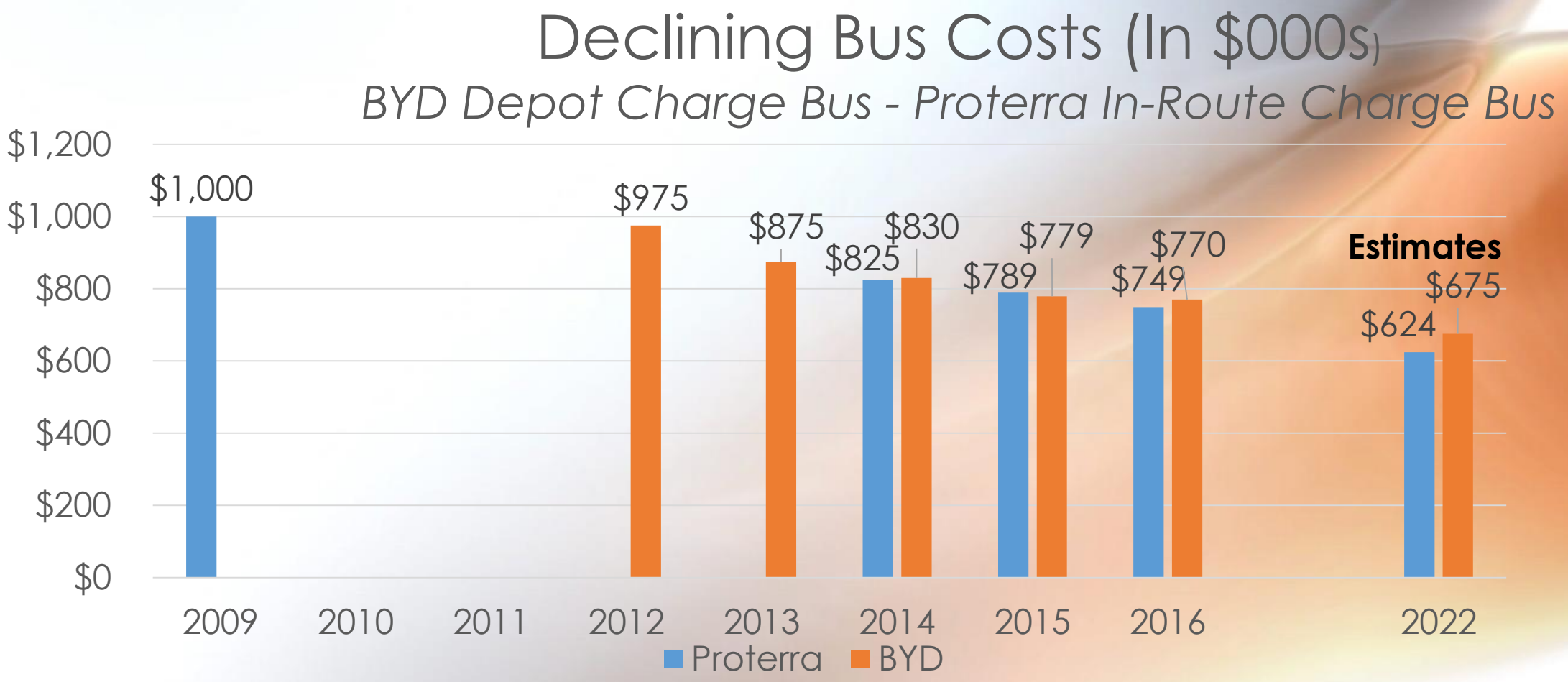
Wireless charging for both

- Convenient,
- More expensive,
- Up to 250kW

Are BEBs Affordable?

- Yes! The Total Cost of Ownership can be competitive or lower for many transit agencies.
- Key cost components of electric buses.
  - Capital Costs
    - Bus Costs
    - Upfront cost of installation of chargers.
  - Operating Expenses
    - Fuel Costs
    - Maintenance costs

Bus Costs Are Declining

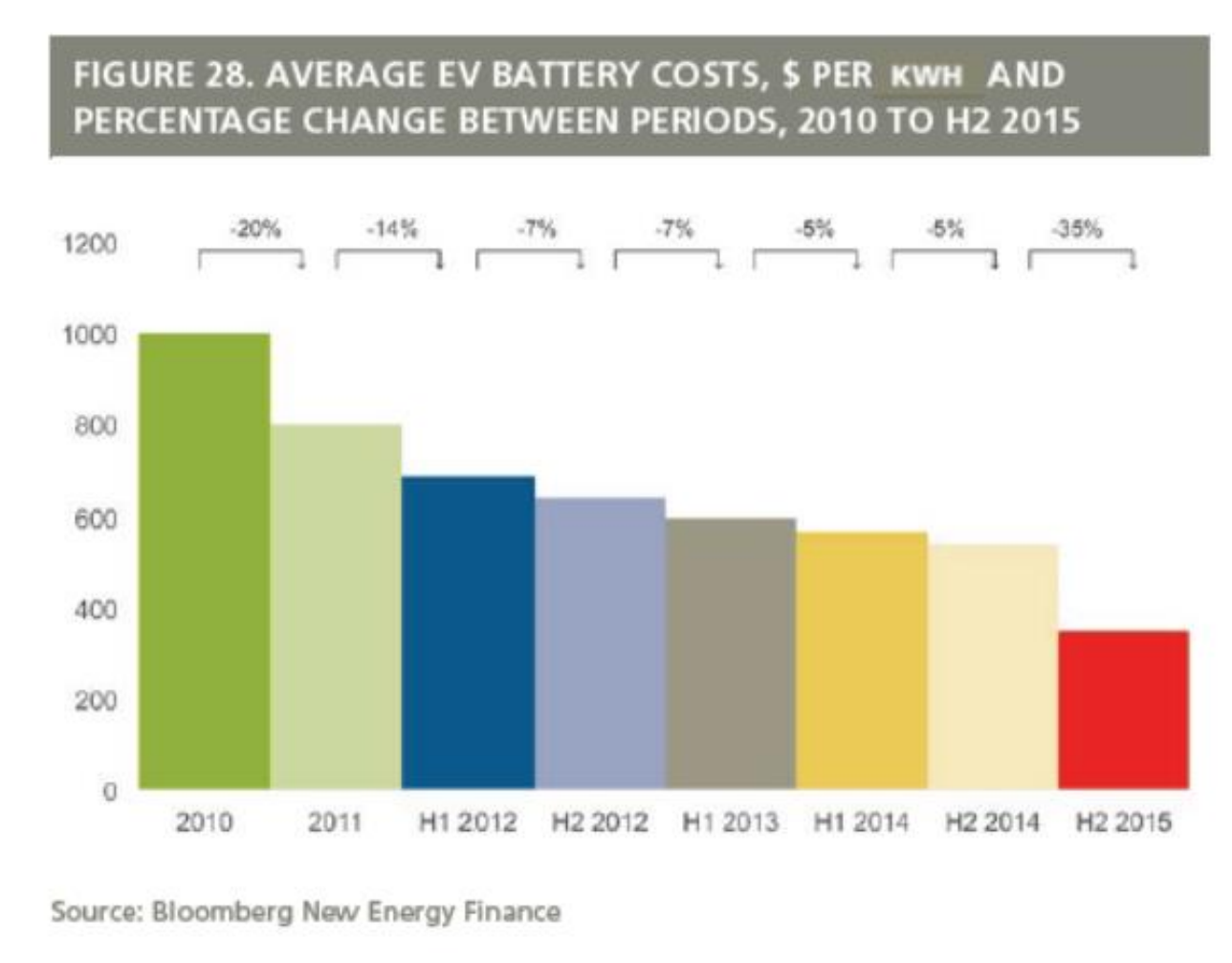


What's Making Bus Costs Go Down?

- Batteries are a large part of total electric bus costs
  - If an electric bus costs $750,000, the cost of the battery can be e.g. $250,000 today. (50% less than 4 years ago.) They are forecast to go down another $100,000 in the next 4-6 years and to continue declining in price at least through 2030 according to CARB research.
- As bus makers start selling buses in volume, economies of scale will contribute
- Continued improvements in other technologies – electric motors, inverters, control systems, etc.
- Increased competition – will be at least 5 major competitors.

Declining Battery Costs

Bloomberg New Energy Finance



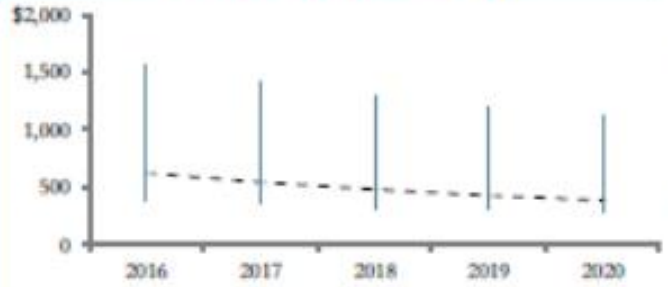
Declining Battery Costs

Lazard's Levelized Cost of Storage Analysis 12/2016

Capital Cost Outlook by Technology (cont'd)

LITHIUM-ENERGY

CAPITAL COST ($/KWH)



	LOW[4]	AVG[5]	HIGH[4]
CAGR	(7%)	(11%)	(8%)
5 Year	(26%)	(38%)	(29%)

TECHNOLOGY TRENDS & OPPORTUNITIES

- Scale manufacturing lowering cost
- Design improvements lower high cost component input requirements
- Chemistry improvements increasing capability of battery, increases usable energy

Declining Battery Costs

McKinsey & Company Report – January, 2017

Electric vehicle battery cost dropped 80% in 6 years down to $227/kWh – Tesla claims to be below $190/kWh

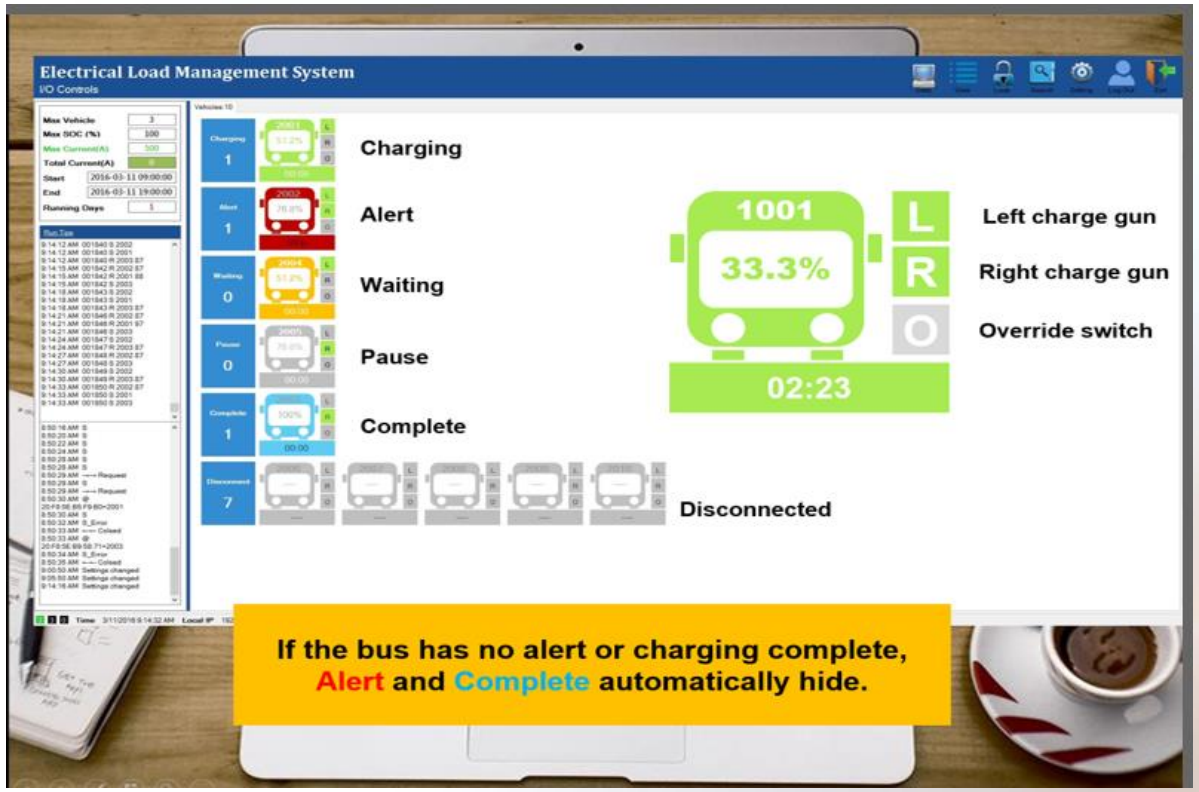
Electrek – January 30, 2017

Lower Maintenance Costs for BEBs

- According to CARB, the average maintenance cost for a CNG or Diesel bus is $.85/mile.
- They estimate BEB maintenance at $.60/mile
- King County estimates $.58/mile for BEBs
- This is a 30% reduction in maintenance costs.
- Largest contributors are decreased costs for brakes and drive train. Maintenance on rest of the bus should be the same.

Electric Bus Eco-System

Helps manage lower operating costs



Bus Scheduling Software

- Optimizes Electric bus scheduling
- Example: Hastus Software

Charging Management

- Optimizes Bus fleet charging
- Lowers electricity costs
- Example: I/O Controls (see photo)

Real Time Fleet Monitoring

- Helps drivers learn to maximize range
- Tracks State of charge, etc.
- Example: Viricity

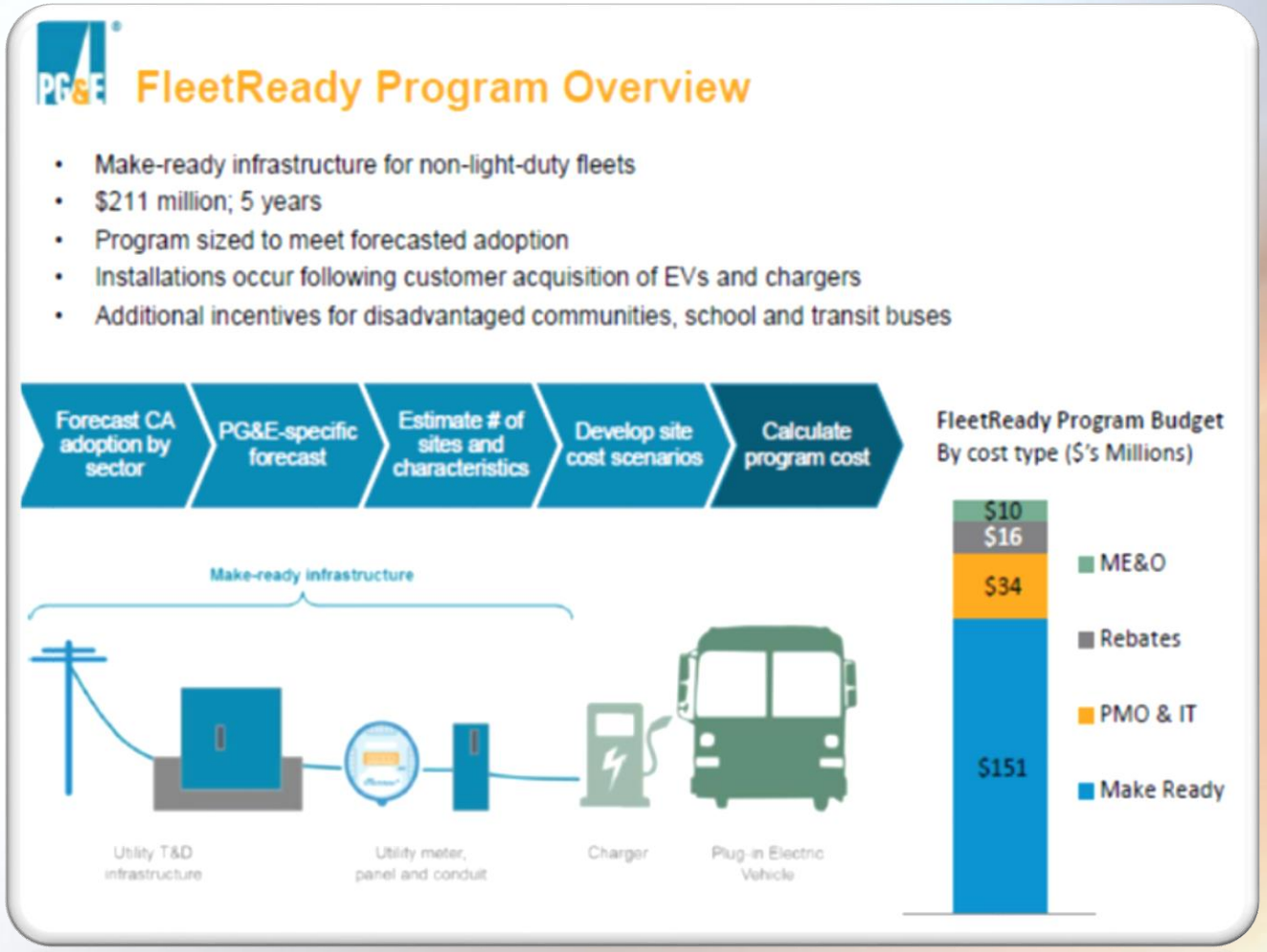
Fuel Costs - Electricity

- Fuel costs for electricity are lower than for CNG or RNG and are much more stabile and predictable than volatile CNG or RNG costs.
- A significant contributor to this lower cost is California's Low Carbon Fuel Standard Credits (LCFS). These credits can cover a substantial portion of the annual cost of electricity for an electric bus.
- SDG&E is proposing a new rate structure that may also further lower electricity costs.
- If MTS also installs its own solar power to fuel its electric buses, it will not only further lower its electricity costs directly but also realize a larger LCFS credit. An additional major benefit will be 100% zero emissions bus transportation.

Electric Infrastructure Costs

- Just as when TAs, including MTS, transitioned from diesel to CNG buses, there were one time costs for new fueling infrastructure. Electric buses require the installation of upgraded electrical infrastructure to the bus depots as well as the purchase and installation of chargers.
- SDG&E is in the process of creating a proposal to the CPUC this year which may be similar to what SCE and PG&E have done and may go even further.

PG&Es Proposal for Paying for Transit Agency Electrical Infrastructure Costs



Total Cost of Ownership – Draft Example

Agency Name:	San Diego Metropolitan Transit System
Timeframe:	2016 - 2050

Cost Category		S1	S2	Δ (S1-S2)
Vehicle	Bus Capital	$525,896,668	$624,615,249	-$98,718,582
	State Funding	$0	$0	$0
O&M	Bus Midlife	$26,713,793	$15,935,335	$10,778,458
	Bus Maintenance	$356,561,594	$291,132,792	$65,428,802
	Fuel Cost	$234,309,738	$225,016,715	$9,293,023
	LCFS Value at $100/credit	-$10,184,485	-$65,994,527	$55,810,043
Infrastructure	Fueling Infrastructure Capital Cost	$0	$6,599,342	-$6,599,342
	Charger Installation Cost	$0	$20,418,993	-$20,418,993
	Maintenance Facility Upgrade	$0	$328,642	-$328,642
	Infrastructure Maintenance Cost	$2,379,859	$9,204,618	-$6,824,759
	Total Cost	**$1,135,677,167**	**$1,127,257,159**	**$8,420,008**

What Can Transit Agencies do to Improve the TCO?

- Build Solar to power the fuel for their electric buses – Can do this on-site and/or offsite. Work with utility on this. Will get lower electricity costs and higher LCFS credits.
- Apply to utility to have them pay for and install electrical infrastructure including chargers.
- Work with utility to use most favorable rate structure.
- Early adopters can apply for Federal, State and local financial incentives. (As costs go down, these may not be needed in future years.) FTA Low-no Grants, CARBs HVIP program, local AQMD programs, others.
- Financing options to cover the higher up front costs.

What is ZEB Adoption in California?

- Of 39 TAs with 50 or more buses – nearly 50% have operational ZEBs or have them on order. 1/3 new in last year.
- AVTA (85 buses) will have 100% BEBs by end of 2018
- Foothill Transit (332 buses) has 17 BEBs with 17 more on order and has committed to 100% by 2030.
- UCI (20) will be 100% BEB by end of 2018 paid for with a student approved fee.
- UCLA (14) has 2 BEBs and will be 100% by 2026.

What is ZEB Adoption in California?

- LA Metro
- LA DOT
- Sac RT
- Long Beach
- Stanford
- UCSF
- School Buses

Summary

- Now is the time to transition to electric buses!
- We need to to mitigate climate change and pave the way for other medium and heavy duty transportation applications.
- California laws and regulations are requiring it
- Riders, drivers and bystanders love them!
- They produce no tailpipe emissions and the fuel emissions are continuing to get better and can go down to zero with TA supplied renewable energy like solar.
- They are reliable.

Summary

- Electric buses have ranges that can meet a majority of TA routes today.
- Rapid advances in battery technology will continue to lower costs and increase ranges.
- Maintenance and fuel costs are lower for BEBs and fossil buses.
- The state is financially helping Transit Agencies to reduce costs of implementation and operation of ZEBS through purchase incentives and requiring utility programs to help build infrastructure and lower electricity rates.
- The TCO already can be competitive in many TAs today
- Half the state's TAs have or are getting them