

Zero-Emission Buses

Benefits and Considerations

APTA Legal Affairs Seminar, New Orleans, LA 2/24/2019



About CTE

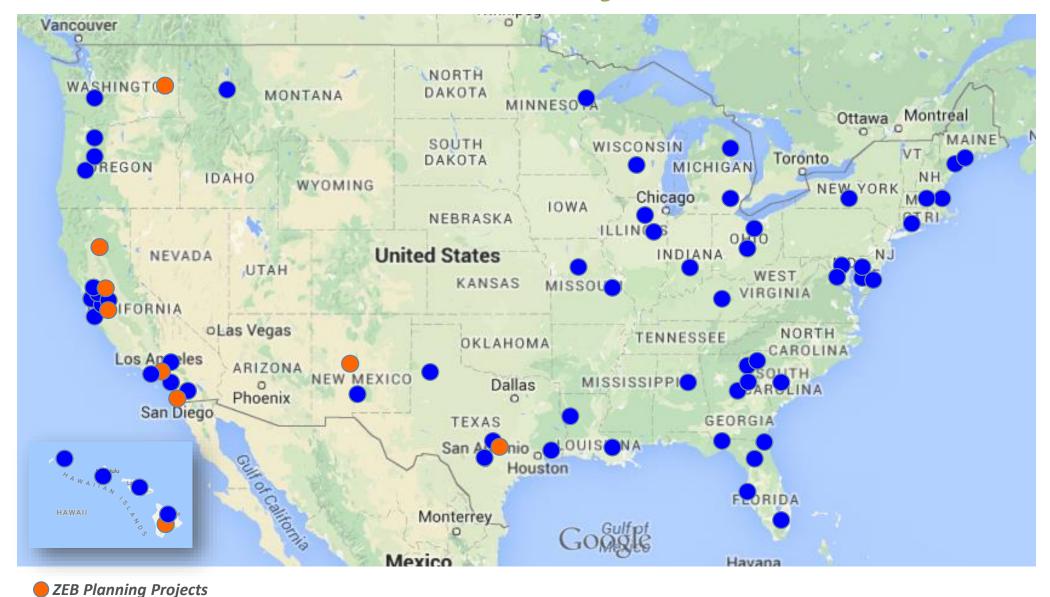
- 501(c)(3) nonprofit engineering and planning firm
- **Mission:** To improve the health of our climate and communities by bringing people together to develop and commercialize clean, efficient, and sustainable transportation technologies
- Portfolio \$540 million
 - Research, demonstration, deployment
 - 95 Active Projects Totaling over \$300 million
- Focused on Zero-Emission Transportation Technologies
- National presence

Atlanta, Berkeley, Los Angeles, St. Paul



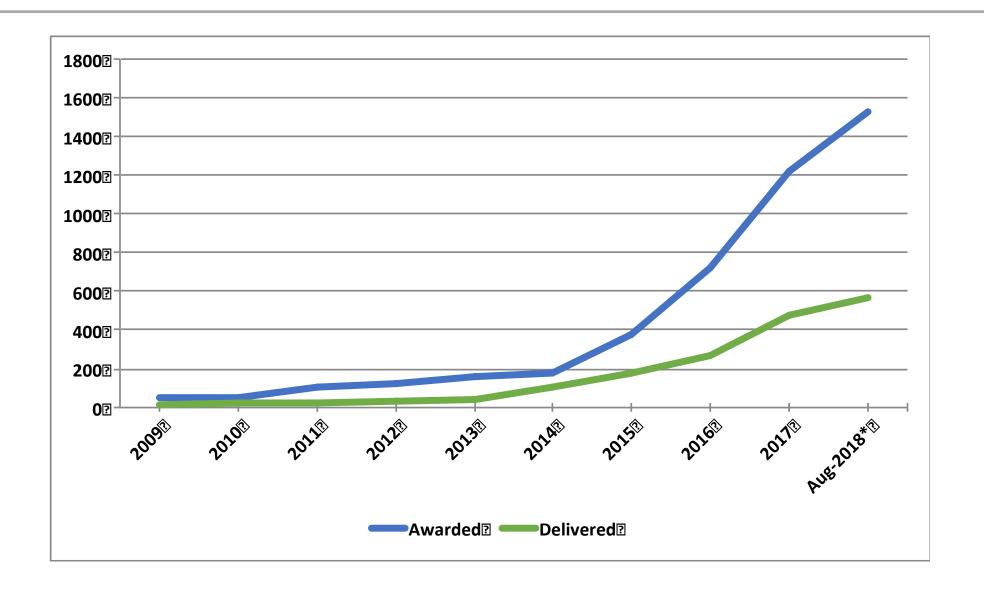
CTE Zero-Emission Bus Projects

ZEB Deployment Projects



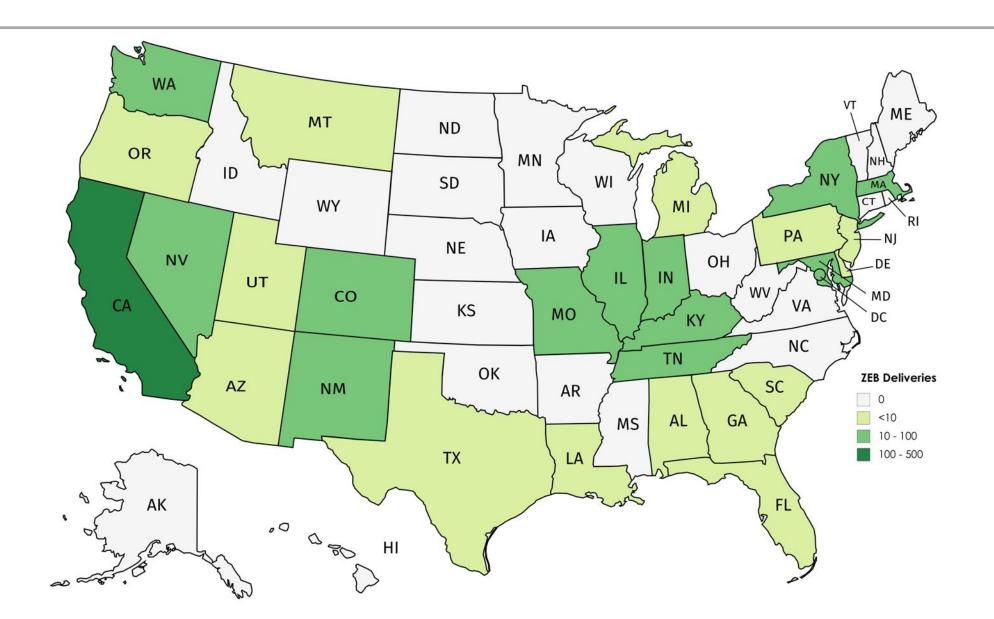


US ZEB Annual Awards & Deliveries



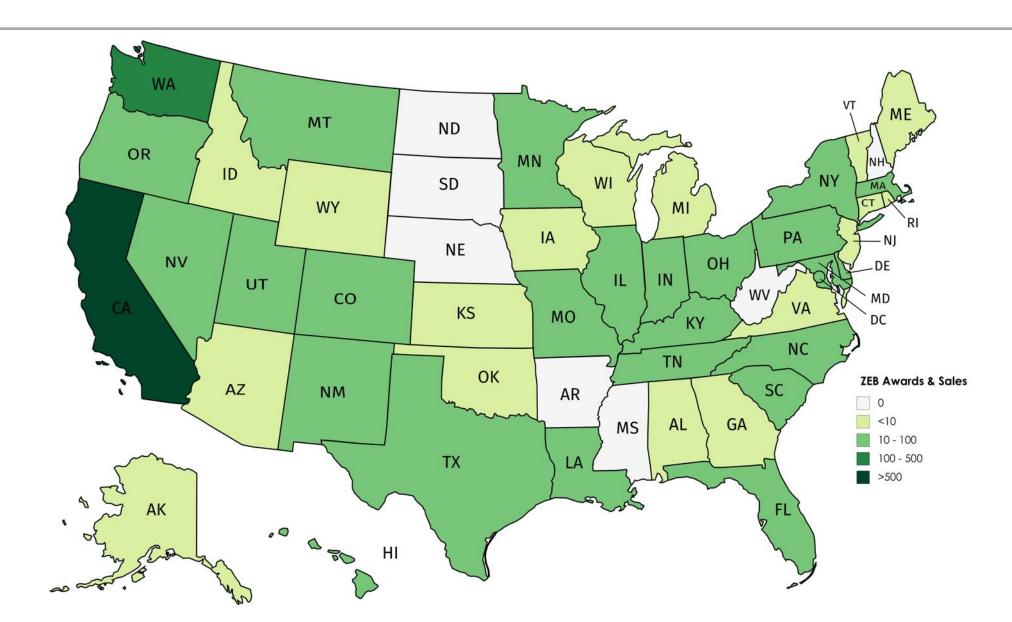


ZEB Deliveries





ZEB Awards & Sales





ZEB Market Development

BEB

Calendar Year	Awards & Sales						
2009 - 2014	138						
2015	179						
2016	322						
2017	492						
Aug-2018	314						

Calendar Year	Base Price	Energy Storage			
2010	\$1.2 mm	75 kWh			
2016	\$750k	300+ kWh			
2018	\$750k	450+kWh			

FCEB

Calendar Year	Awards & Sales						
2009 - 2014	44						
2015	12						
2016	28						
2017	1						
Aug-2018	0						

Calendar Year	Base Price					
2010	\$2.2 mm					
2016	\$1.2mm					
*2020	\$900k					



ZEB OEMs























ZEB Models

Body 5 tyle	Length		/ is torageil	SAL SAL		d EM	GII	Tic Cre	enPower	No	yaBus Pro	terra Nei	was Wer	total
	30	210	- 496	2	1	•		1						4
	35	94	- 440	1	1			1			5	1		9
BEB1Low1Floor	40	94	- 660	2	1	1	1	1		1	7	3		17
	45	320	- 323	1				1						2
ľ	60	320	- 818	1								3		4
	23	134	- 134	1										1
 BEB ፤ Coach ∗	35	348	- 348	1										1
DEDIACOACTI *	40	391	- 391	1										1
ľ	45	496	- 496	1					1				1	3
BEB@Double@	35	170	- 170	1										1
Decker	45	230	- 478	1			······································	1						2
BEBTotal				13	3	1	1	5	1	1	12	7	1	45
CCEDEL OWELLOOF	40					1						1		2
FCEB@Low@Floor	60					\$						1		1
FCEB@otal				0	0	1	0	0	0	0	0	2	0	3
ZEBTotal				13	3	2	1	5	1	1	12	9	1	48

- Altoona Tested?
- Range vs. Passengers?



BEB Charger Vendors

-chargepoin+













SIEMENS







Charging Equipment Types

















Why Zero-Emission Buses

- Reduces dependency on foreign oil
- More efficient
- Cleaner
- Quieter
- Passengers prefer to ride in them
- Lower operating costs
- Longer life
- Stable, US-produced fuel source





Hydrogen Fuel Cell Buses

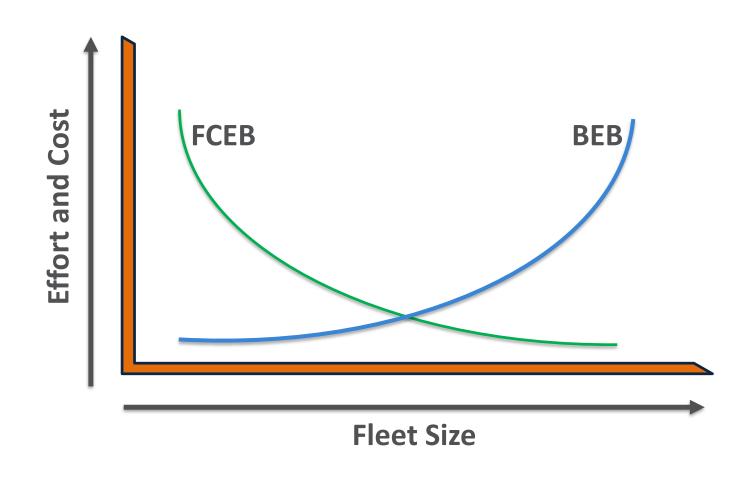
- Vehicle fueling is similar to CNG
 - 10-minute fueling
 - Operationally consistent with typical transit workflow
 - Small overall station footprint
- Sufficient range for most transit service
- FC system can be used to support cabin heat
- Bus costs are still high and fuel costs are still inconsistent





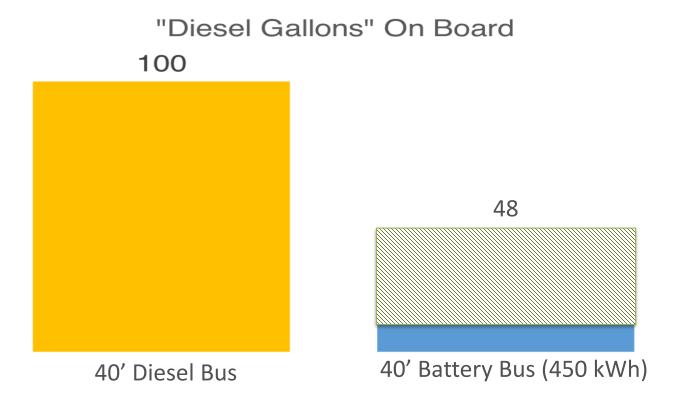
Both ZEB Technologies Will Play a Role

Infrastructure and Scalability





The Biggest Challenge for BEBs



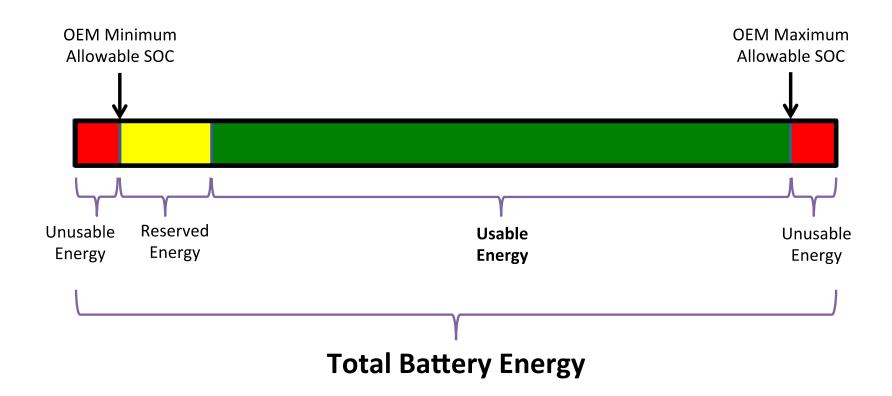
Electric Drive is four times as efficient as the Internal Combustion Engine.

12 DGE can deliver power equal to 48 gallons of Diesel



Battery Capacity Terminology

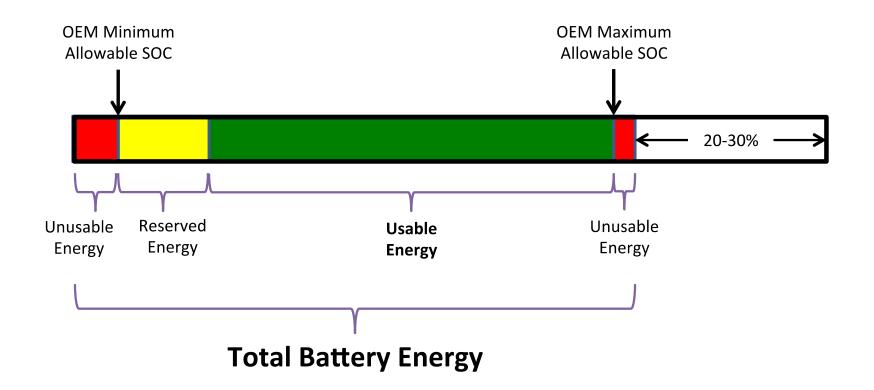
Beginning-of-Life Batteries





Battery Capacity Terminology

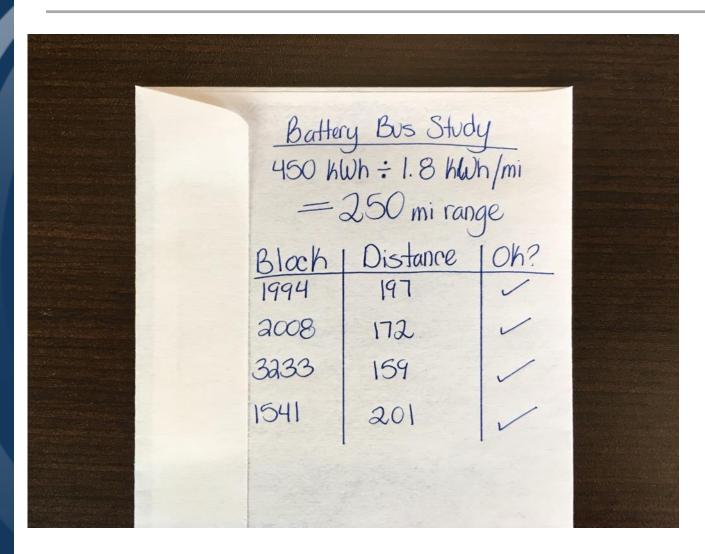
End-of-Life Batteries



Note: Batteries all lose capacity through use and aging



Naïve Method—Range

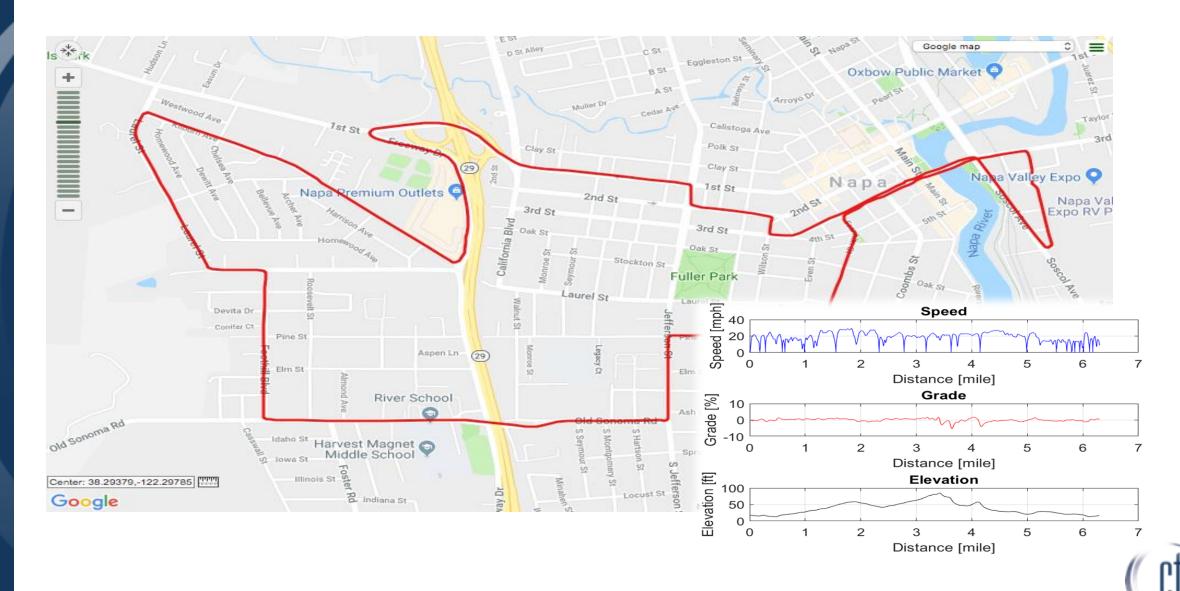


Agencies have seen a range of BEB efficiencies in service:

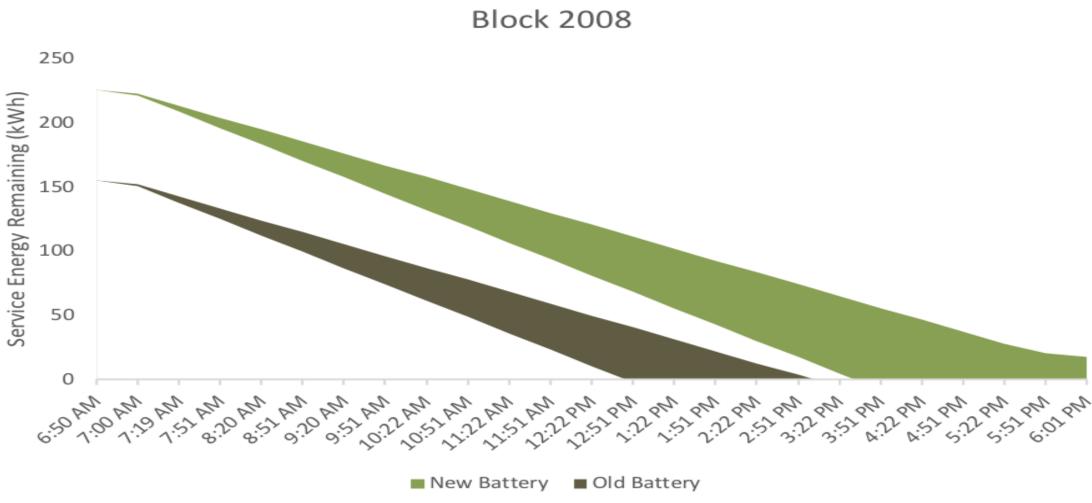
- Only 75% of Capacity is Available
- Battery Capacity decreases over time
- < 1 kWh/m to > 6 kWh/m!
- A bad driver can cost another 25%



Prudent Method—Model the Routes

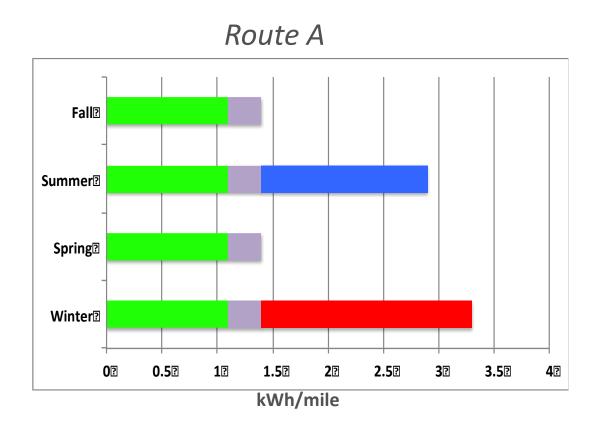


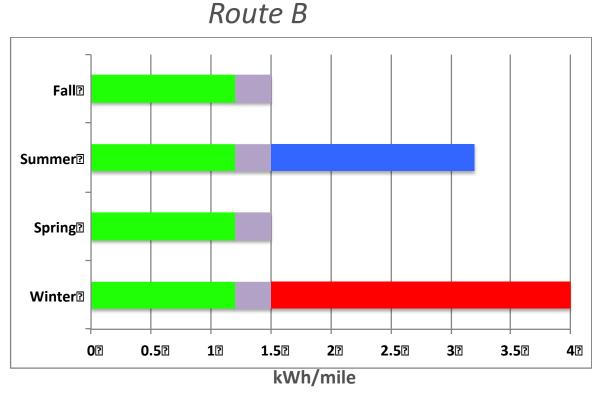
Prudent Method—Model the Blocks





Prudent Method—Include HVAC

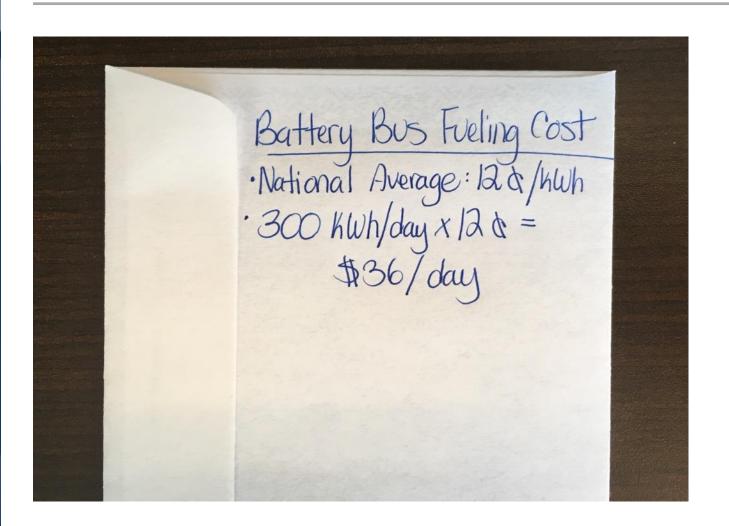








Naïve Method—Fuel Cost Estimates



Electricity costs are highly variable across the country.

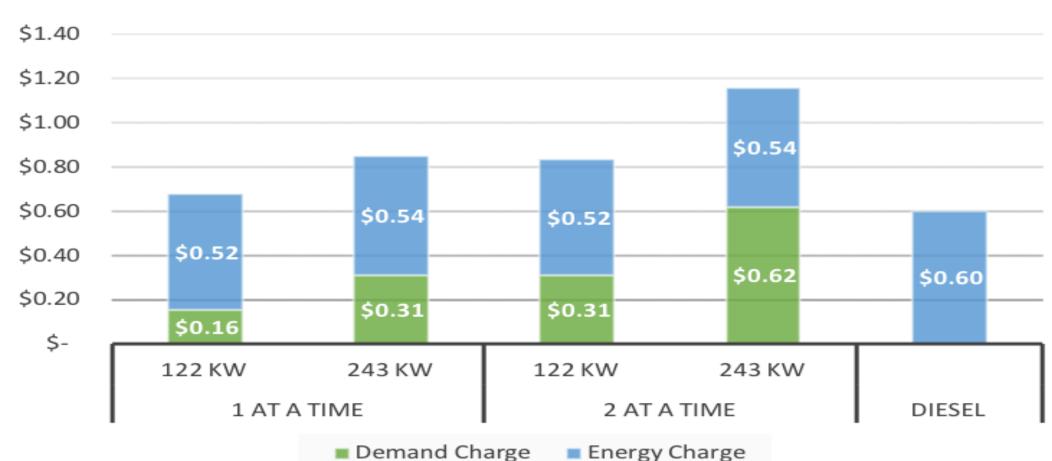
Charges can change by:

- Time of Day
- Day of week
- Season



Prudent—Charge & Rate Modeling







BEB Solicitations – What Does Not Matter (much)

- Bus-advertised range
- Bus Range Performance at Altoona
- Bus Range Performance at other transit operators
- Fuel costs at other transit operators
- Average energy costs in your area





BEB Solicitations – What Really Matters

- How will the bus perform on your route, in your climate?
- Which rate schedule will work best for you under your operation scenario and vice versa?
- What will the bus do under strenuous use cases?

End of battery life

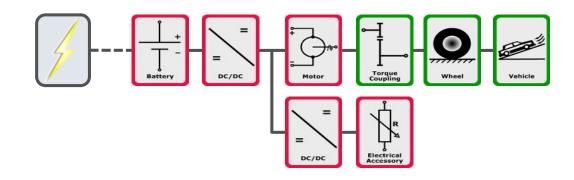
Heavy passenger load

Heavy Traffic load

Poor Driver or Driver Behind Schedule

Warmest Day

Coldest Day







Thank You!





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