



Welcome to Zero

Zero Emission Bus 101

Atlanta-Region Transit Link Authority
8/16/2019

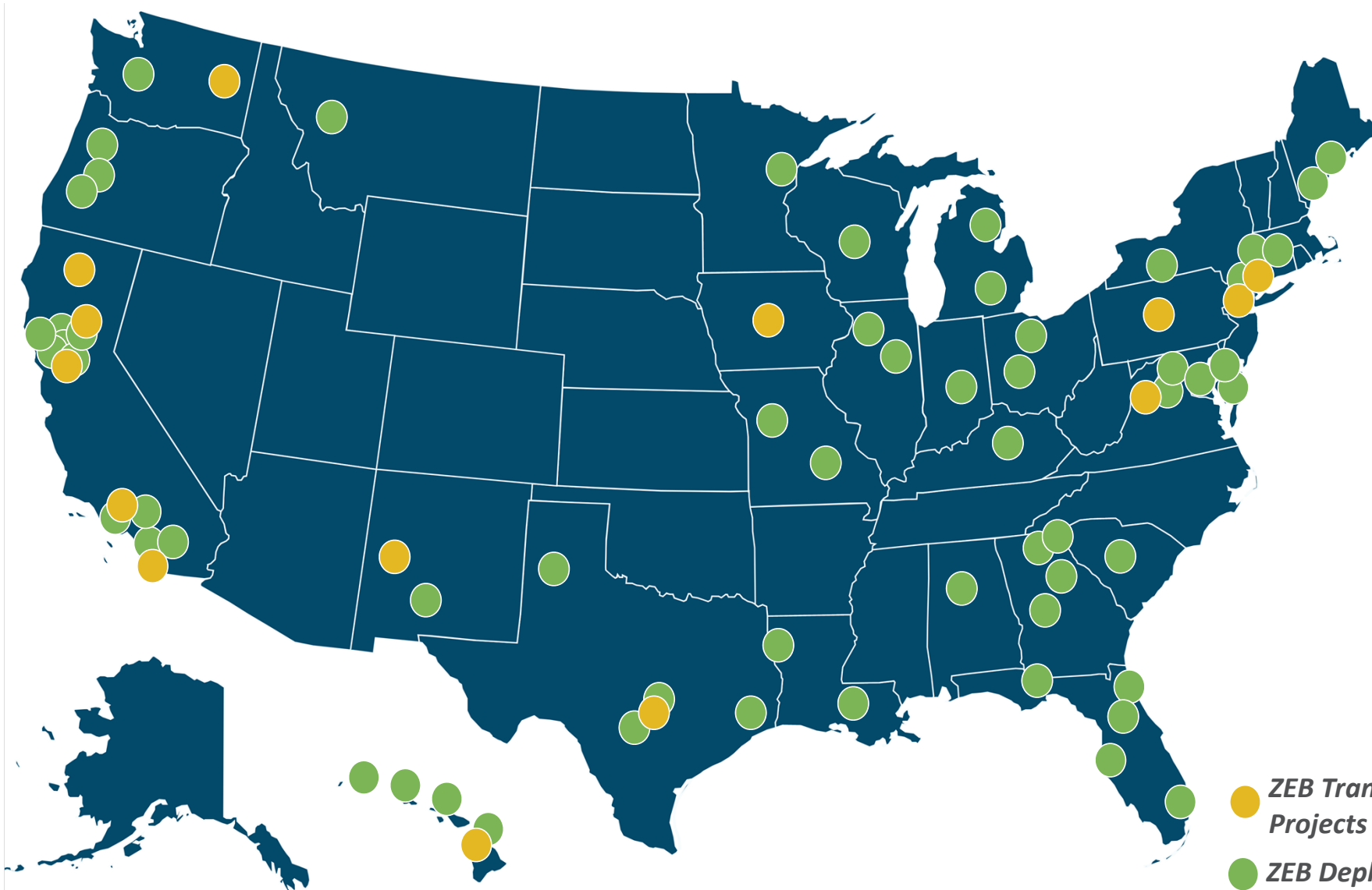
Dan Raudebaugh
Executive Director
CTE

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 - \$560 million**
 - Research, demonstration, deployment
 - 99 Active Projects Totaling over \$300 million
- **Focused on Zero-Emission Transportation Technologies**
- **National presence**

Atlanta, Berkeley, Los Angeles, St. Paul





 ZEB Transition Planning Projects

 ZEB Deployment Projects



Tesla Model S



Transit Paving the Way



1992

Toyota Mirai



2015

Transit Paving the Way

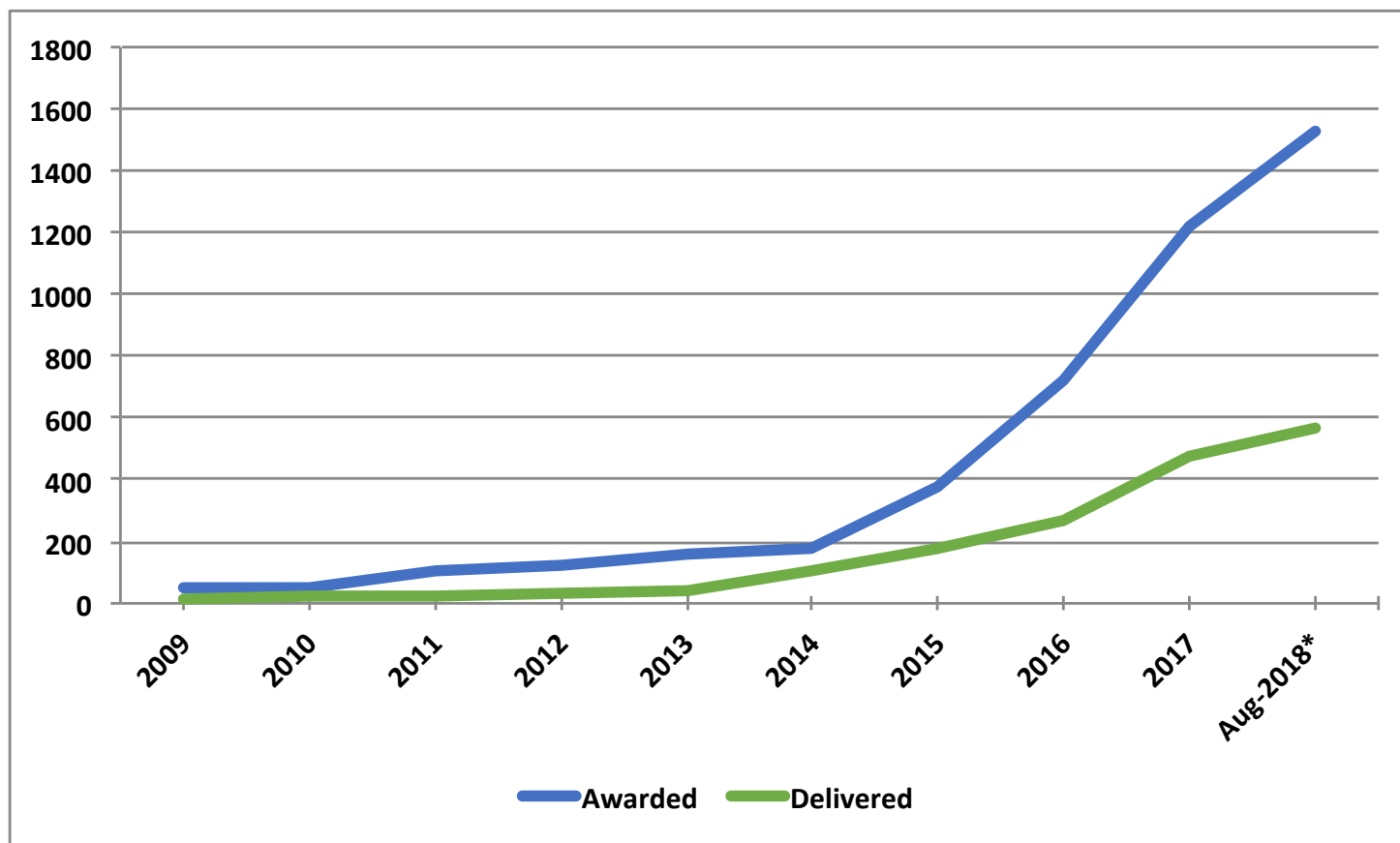


Transit Works as an Early Market

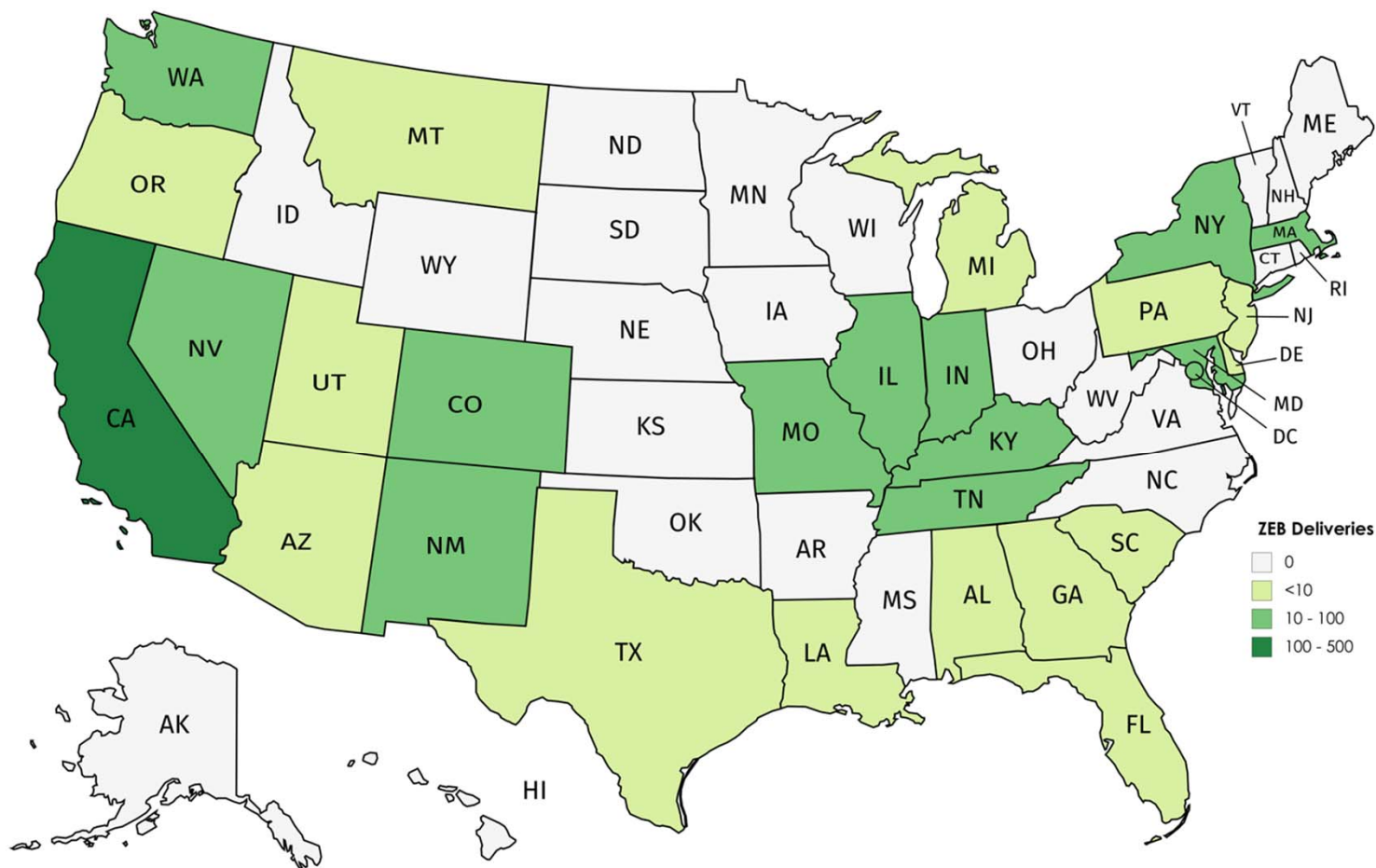
- Bounded Duty Cycle
- More Operating Hours
- Physical Bus Size
- Professional Staff
- Centrally Fueled
- Cost to End User



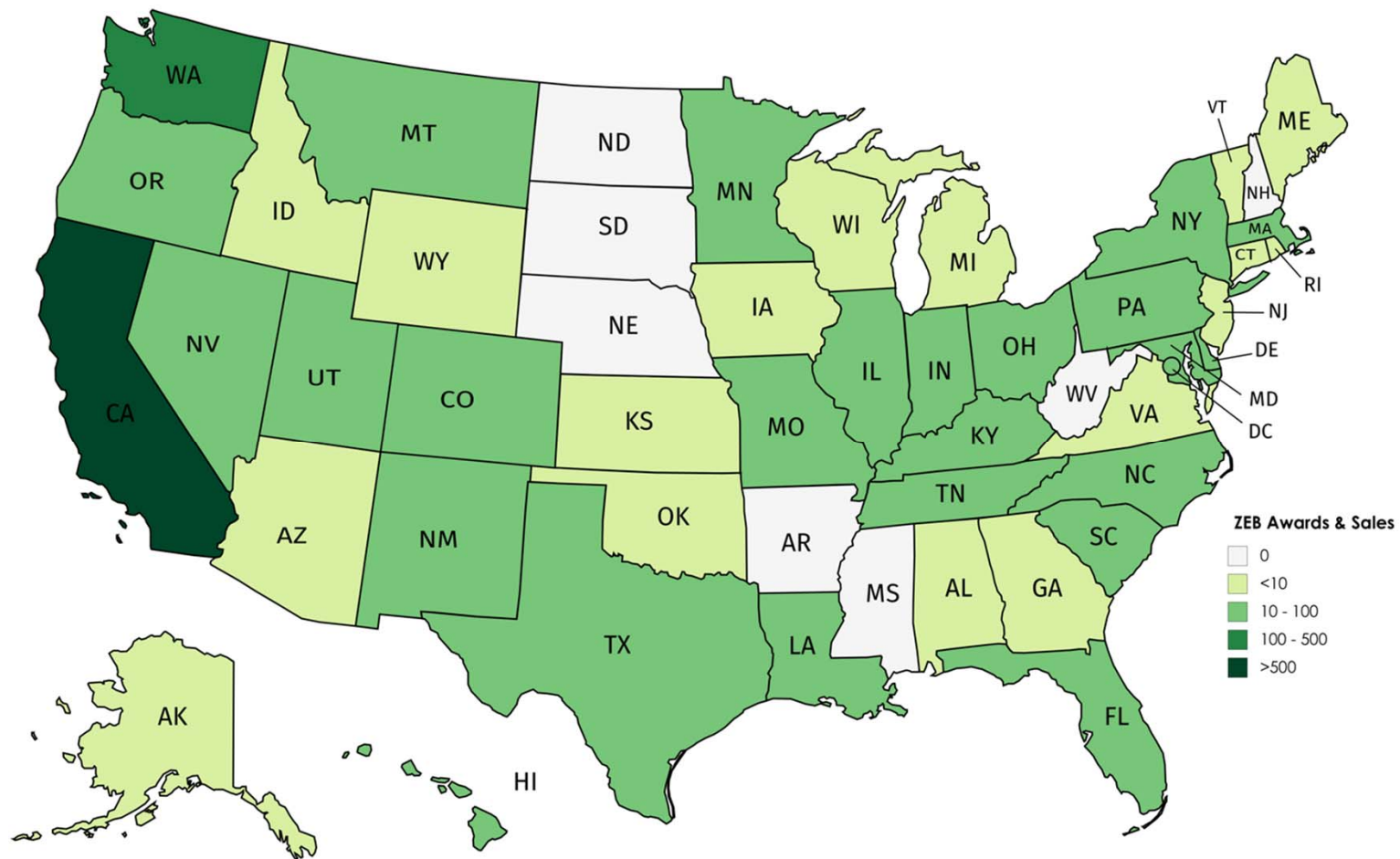
US ZEB Annual Awards & Deliveries



ZEB Deliveries



ZEB Awards & Sales



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



ZEB Models

Body Style	Length	Energy Storage (kWh)	BYD	CCW	ENC	GILLIG	GreenPower	MCI	NovaBus	Proterra	New Flyer	Van Hool	Total
BEB Low Floor	30	210 - 496	2	1			1						4
	35	94 - 440	1	1			1			5	1		9
	40	94 - 660	2	1	1	1	1		1	7	3		17
	45	320 - 323	1				1						2
	60	320 - 818	1								3		4
BEB Coach	23	134 - 134	1										1
	35	348 - 348	1										1
	40	391 - 391	1										1
	45	496 - 496	1					1				1	3
BEB Double Decker	35	170 - 170	1										1
	45	230 - 478	1				1						2
BEB Total			13	3	1	1	5	1	1	12	7	1	45
FCEB Low Floor	40				1						1		2
	60										1		1
FCEB Total			0	0	1	0	0	0	0	0	2	0	3
ZEB Total			13	3	2	1	5	1	1	12	9	1	48

- *Altoona Tested?*
- *Range vs. Passengers?*

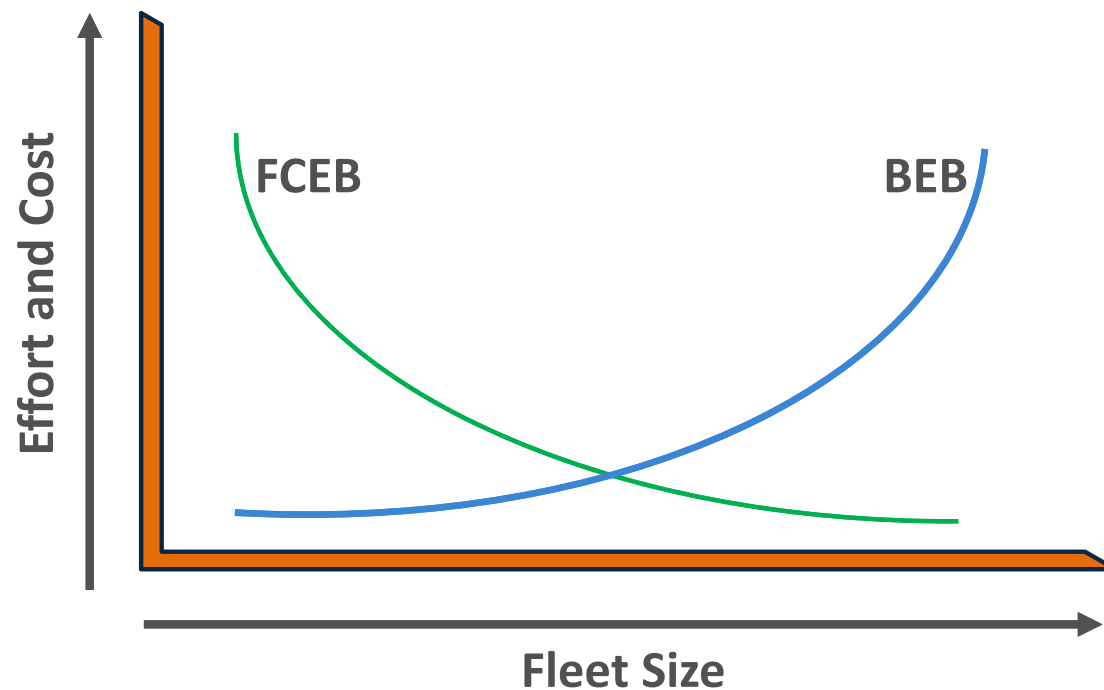
Hydrogen Fuel Cell Buses

- 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



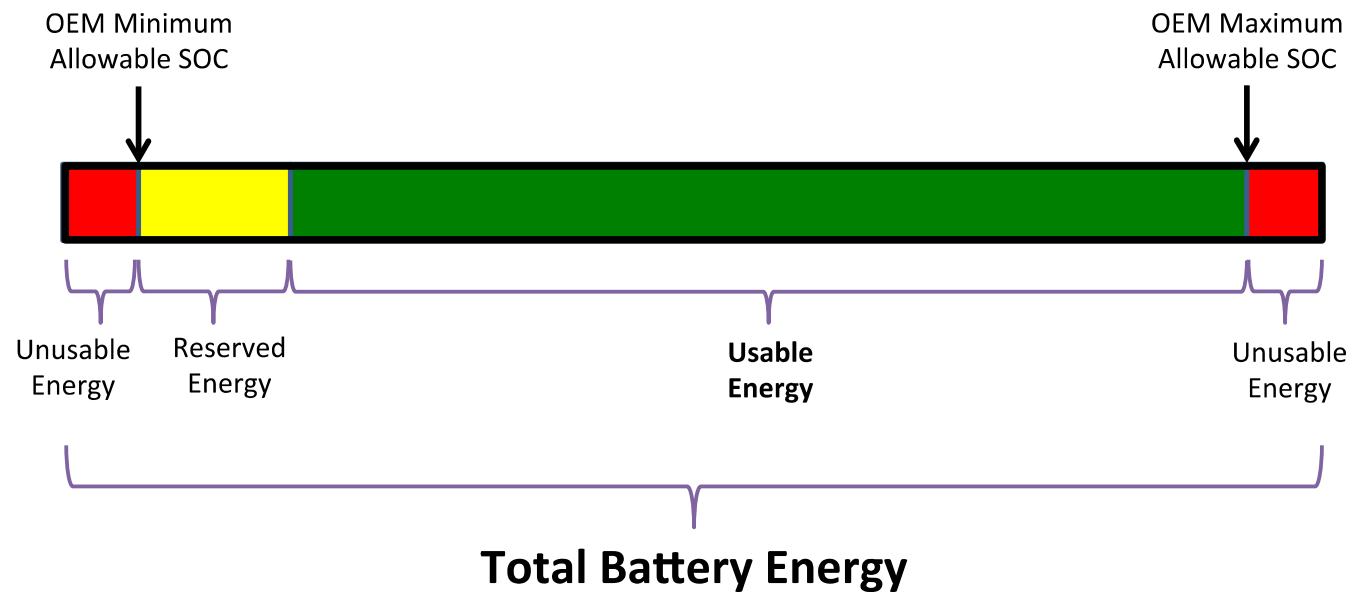
Both ZEB Technologies Will Play a Role

Infrastructure and Scalability



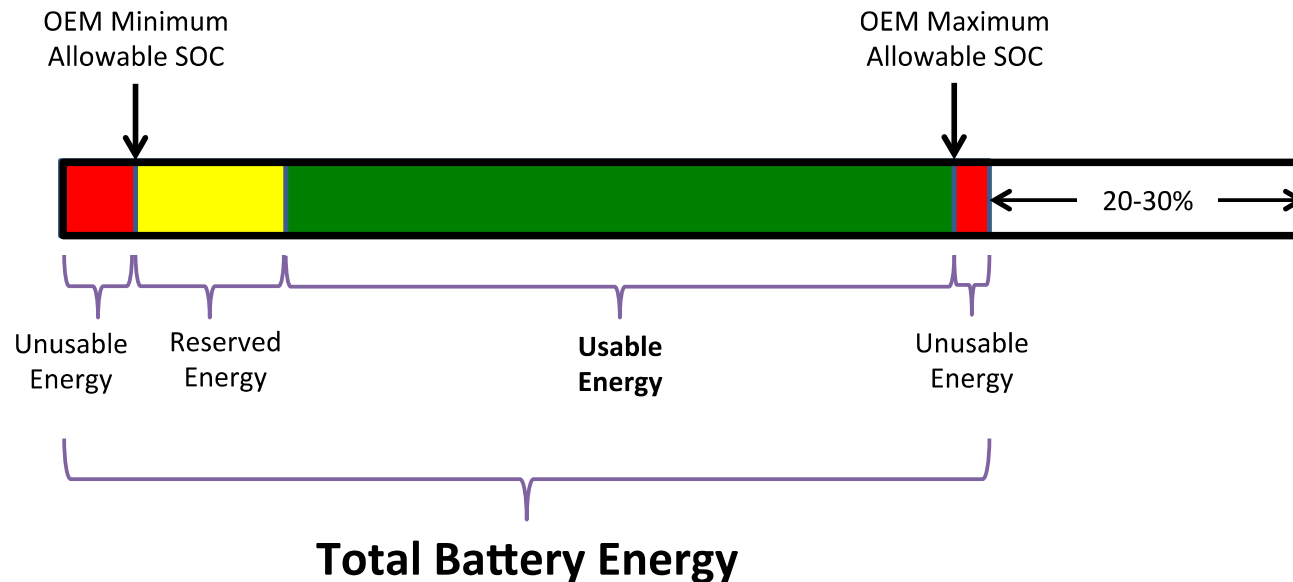
Battery Capacity Terminology

Beginning-of-Life Batteries



Battery Capacity Terminology

End-of-Life Batteries



Note: Batteries all lose capacity through use and aging

Naïve Method—Range

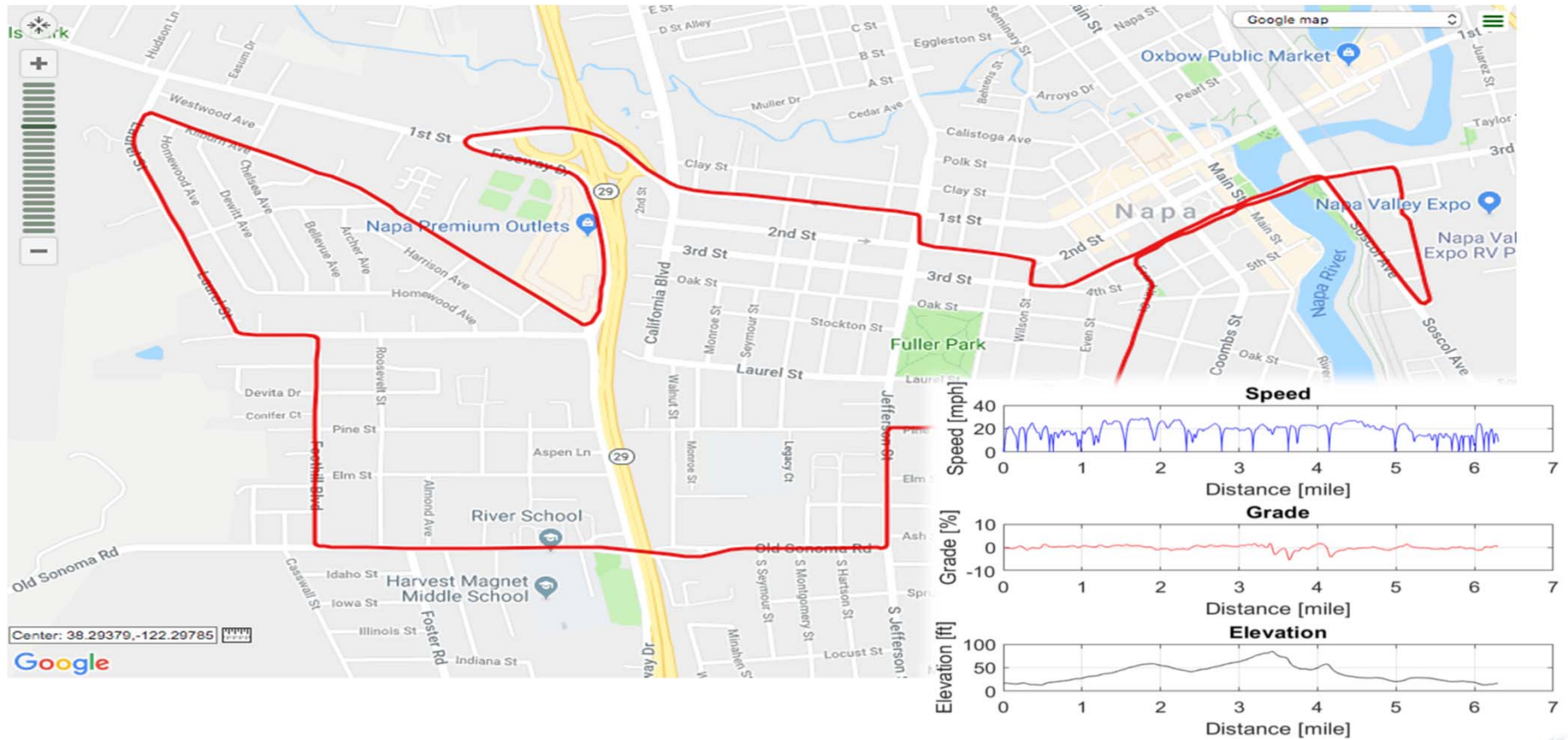
Battery Bus Study
 $450 \text{ kWh} \div 1.8 \text{ kWh/mi}$
 $= 250 \text{ mi range}$

Block	Distance	Ok?
1994	197	✓
2008	172	✓
3233	159	✓
1541	201	✓

Agencies have seen a range of BEB efficiencies in service:

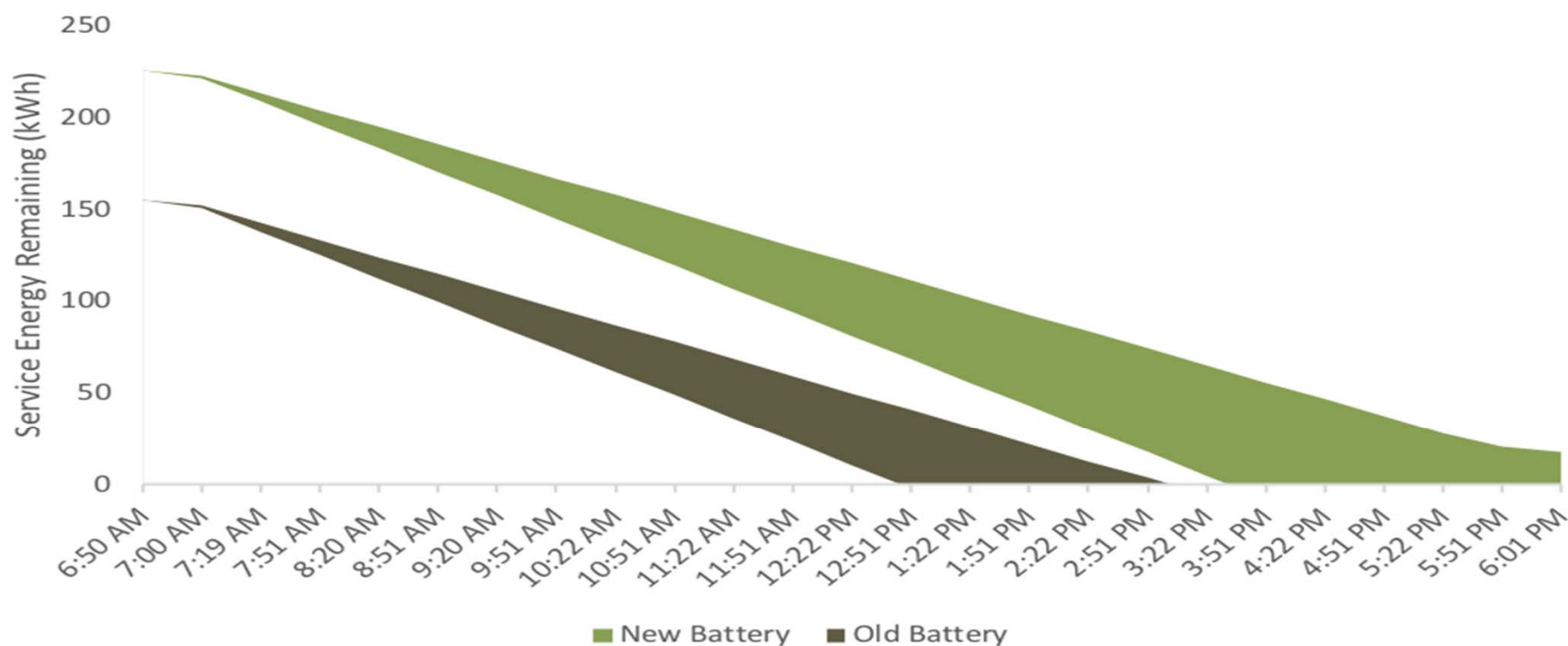
- Only 75% of Capacity is Available
- Battery Capacity decreases over time
- < 1 kWh/mi to > 6 kWh/mi!
- A bad driver can cost another 25%

Prudent Method—Model the Routes



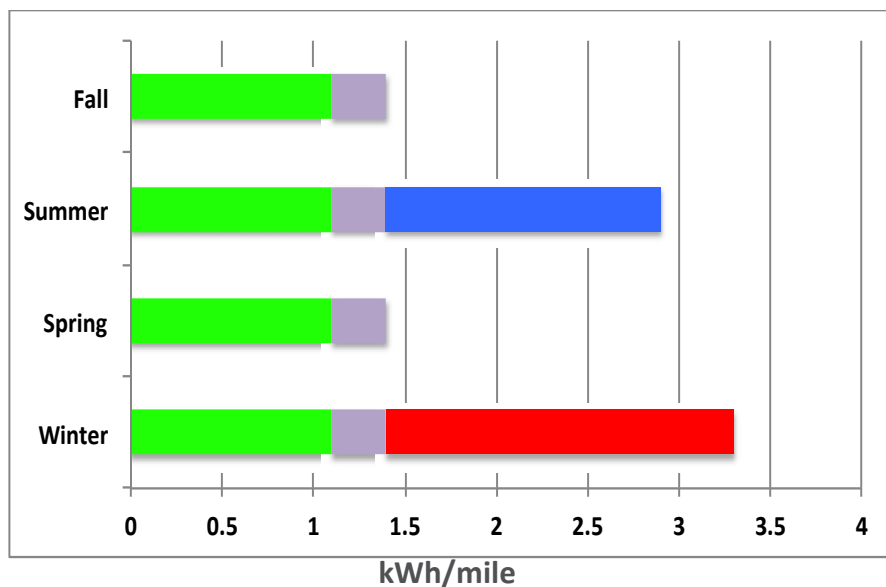
Prudent Method—Model the Blocks

Block 2008

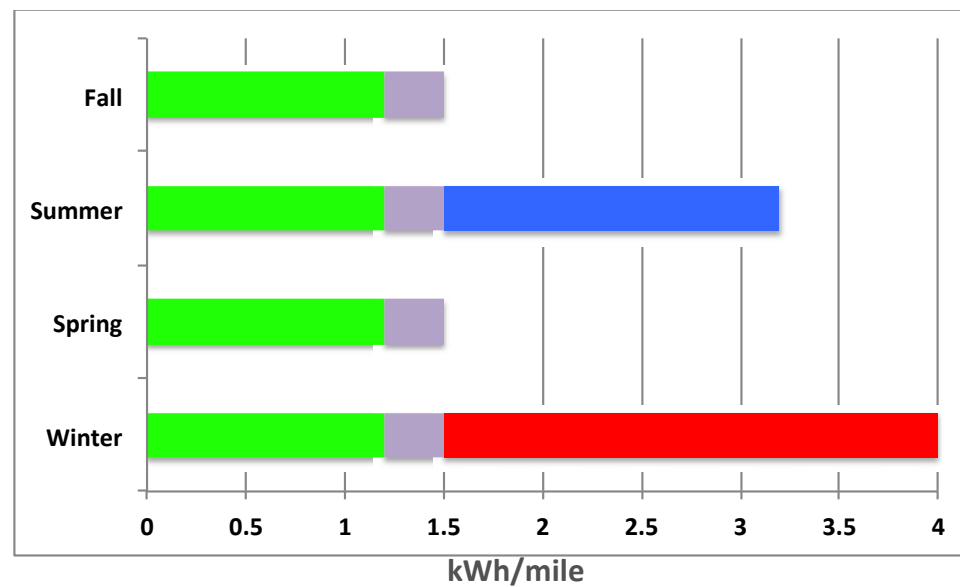


Prudent Method—Include HVAC

Route A



Route B



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

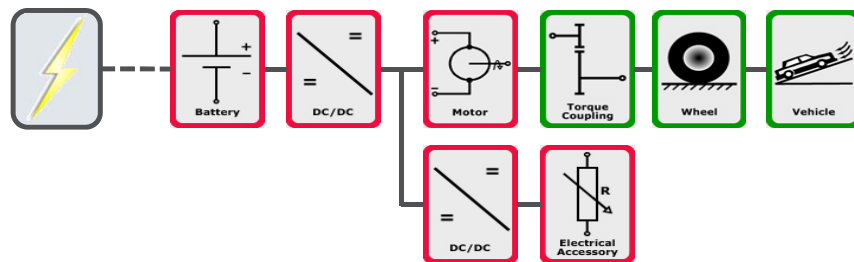


BEB Solicitations – What Really Matters

- 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



2019 International Zero Emission Bus Conference

September 26th & 27th

Conference Objectives:

- Goals: 500 Attendees & 18 Sponsors
- Raise visibility of transit as tool in climate change mitigation
- Discuss ZEB operations and fleet transitions
- Spotlights on infrastructure and bus technology
- Focus on cities and states with ZE transit goals



Unique Characteristics:

- Largest, convenes global stakeholders
- Technical Tour of AC Transit's BEB & FCEB operations



County Connection

SolTrans

TRI DELTA TRANSIT



Thank You!



25th Anniversary
1993-2018

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