Generation ZEB

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National Lead, Advanced Vehicle Programs
WSP-USA

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WHO IS WSP?

Who is WSP?
Global Engineering, Design Consulting
Formerly Parsons Brinkerhoff, founded in 1885,
50,000 employees world-wide

Why WSP for ZEB?
Over 60 ZEB projects
Comprehensive ZEB Services (Planning, Project Management, Engineering, both FCB and BEB)
Lead more ZEB planning and design work than any other USA firm

FCEB Case Study - AC Transit

Preliminary Engineering Design and Implementation Plan for 45 Zero Emission Buses (ZEBs)

45 ZEB Project

1. **Next step to AC Transit 100% ZEB fleet**
2. **BEB range is not an issue.**
   - 70 Clean Corridor Blocks serving disadvantaged communities can be served with BEBs (with Division charging only)
3. **Positions AC Transit to make most informed decision after 45 ZEBs**
   - Only transit agency in U.S. doing this at this scale
4. **Provides flexibility with emerging technologies**
   - Vehicles – Batteries – Pantographs – Charge Management
5. **Consistent with Long Range Facilities Utilization (Master) Plan**

Fuel Cell Electric Bus (FCEB)
Current Maintenance & Fueling Capacity

Division	Maintenance Capacity	Fueling Capacity
D2	30	30
D4	20	11
Total	50	41

Battery Electric Bus (BEB) Operations Modeling Results

- BEB range is not an issue
- 70 Clean Corridor Blocks can be served with Battery Electric Buses (with Division charging only)
- All routes serving disadvantaged communities

Division	# of Blocks	Recommended Blocks for ZEB Deployment	
		FCEB	BEB
2	20	16	4
4	140	74	66
Total	**160**	**90**	**70**

Current ZEBs Available to Purchase

	40-Foot	45-Foot	60-Foot
Battery Electric Bus (BEB)	Yes * ($1.14 M each)	No	Yes *
Fuel Cell Electric Bus (FCEB)	Yes ** ($1.40 M each)	No	Yes ***

* *Multiple Manufacturers Available*

** *Two Manufacturers Currently Available*

*** *One Manufacturer Currently Available*

Note that 45-foot (MCI type high capacity, luggage carrying buses) BEBs may be available by the beginning of 2020.

ZEB Equipment Procurement

ZEB PROCUREMENT SUPPORT

Manufacturer	ZEB Models	Annual Production 2017	Annual Production 2018	Deliveries of ZEBs (2009-2017)
New Flyer	XE-60, XE-40 BEB/FCEB	2,105	2,238	71
Gillig	35 ft., 40 ft. low floor BEB	1,753	1,877	4
Proterra	Catalyst FC, Catalyst XR, Catalyst E2	48	135	248
BYD USA	K7, K9, K11, C10	114	128	377
El Dorado National	40 ft. FCEB	369	236	26
Nova BUS	40LFSe, 60LFSe in dev.	1,246	1,205	0
TOTAL		**5,636**	**5,819**	**726** (6%)

Comparison of Energy Costs (H^2 @ $7/kg)

Fuel/Energy Costs	FCB	BEB	CNG	Diesel
Cost for Energy	$7.00	$0.15	$0.60	$3.00
Energy/Fuel Efficiency	8.5	2.5	2.1	3.5
Energy/Fuel Cost/Mile	$0.82	$0.38	$0.29	$0.86
1 Bus @ 40,000 miles/year	$32,941.18	$15,000.00	$11,428.57	$34,285.71

Comparison of Energy Costs (H^2 @ $5/kg)

Fuel/Energy Costs	FCB	BEB	CNG	Diesel
Cost for Energy	$5.00	$0.15	$0.60	$3.00
Energy/Fuel Efficiency	8.5	2.5	2.1	3.5
Energy/Fuel Cost/Mile	$0.59	$0.38	$0.29	$0.86
1 Bus @ 40,000 miles/year	$23,529.18	$15,000.00	$11,428.57	$34,285.71

Comparison of Energy Costs (H^2 @ $3/kg)

Fuel/Energy Costs	FCB	BEB	CNG	Diesel
Cost for Energy	$3.00	$0.15	$0.60	$3.00
Energy/Fuel Efficiency	8.5	2.5	2.1	3.5
Energy/Fuel Cost/Mile	$0.35	$0.38	$0.29	$0.86
1 Bus @ 40,000 miles/year	$14,117.65	$15,000.00	$11,428.57	$34,285.71

ZEB Fleet Mix Options

Option	FCEB	BEB	Total	Remarks
A Max. FCEB				(to maximize use of existing hydrogen fueling capacity)
New (45 ZEBs)	25	20	45	
Existing	11	5	16	
Total	**36**	**25**	**61**	Existing hydrogen fueling facilities will support an additional 5 FCEBs
B Min. FCEB				(5 of 45 new ZEBs on new Emeryville Amtrak service)
New (45 ZEBs)	5	40	45	
Existing	11	5	16	
Total	**16**	**45**	**61**	Significantly underutilizes existing FCEB fueling capacity
C All Battery Electric Buses				
New (45 ZEBs)	0	45	45	
Existing	11	5	16	
Total	**11**	**50**	**61**	Significantly underutilizes existing FCEB fueling capacity
D Equalize Quantities (between FCEB and BEB)				
New (45 ZEBs)	20	25	45	
Existing	11	5	16	
Total	**31**	**30**	**61**	Existing hydrogen fueling facilities will support an additional 10 FCEBs

RECOMMENDED

ZEB Expansion Cost (By Fleet Mix Option)

Option	FCEB		BEB		Total Bus Cost *	Total Infrastructure Cost **	% of Total for Buses
	Cost/Bus: $ 1,400,000		Cost/Bus: $ 1,140,000				
	Qty.	Subtotal	Qty.	Subtotal			
A (Max FCEB)	25	$35,000,000	20	$22,800,000	**$ 57,800,000**	**$ 12,100,000**	**83%**
B (Min FCEB)	5	$ 7,000,000	40	$45,600,000	**$ 52,600,000**	**$ 16,600,000**	**76%**
C (All BEB)	0	$ -	45	$51,300,000	**$ 51,300,000**	**$ 17,800,000**	**74%**
D (Equalize)	20	$28,000,000	25	$28,500,000	**$ 56,500,000**	**$ 13,300,000**	**81%**

*** Pursuing additional grant funds that may reduce the Option A and D Bus Cost up to $3M.**

**** Construction cost being refined. Provision for PG&E cost not included.**

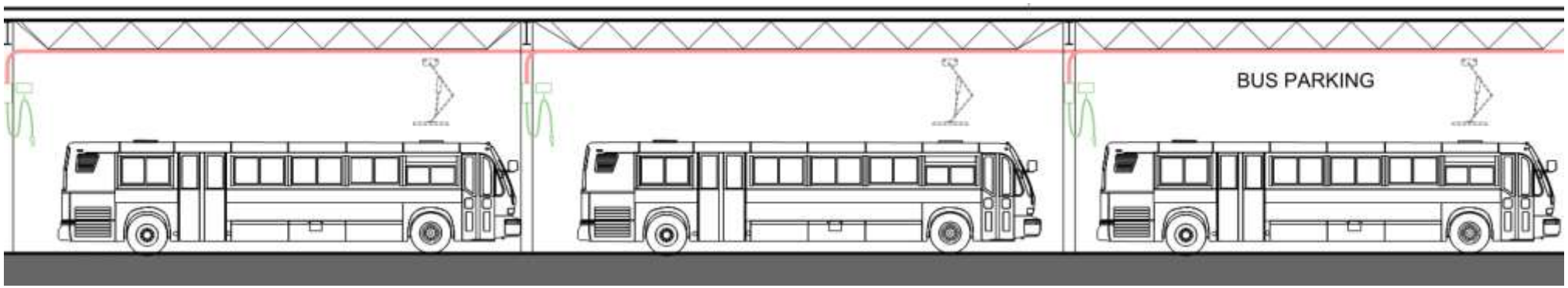
Division Charging – Overhead Charging (Recommended)

Pros

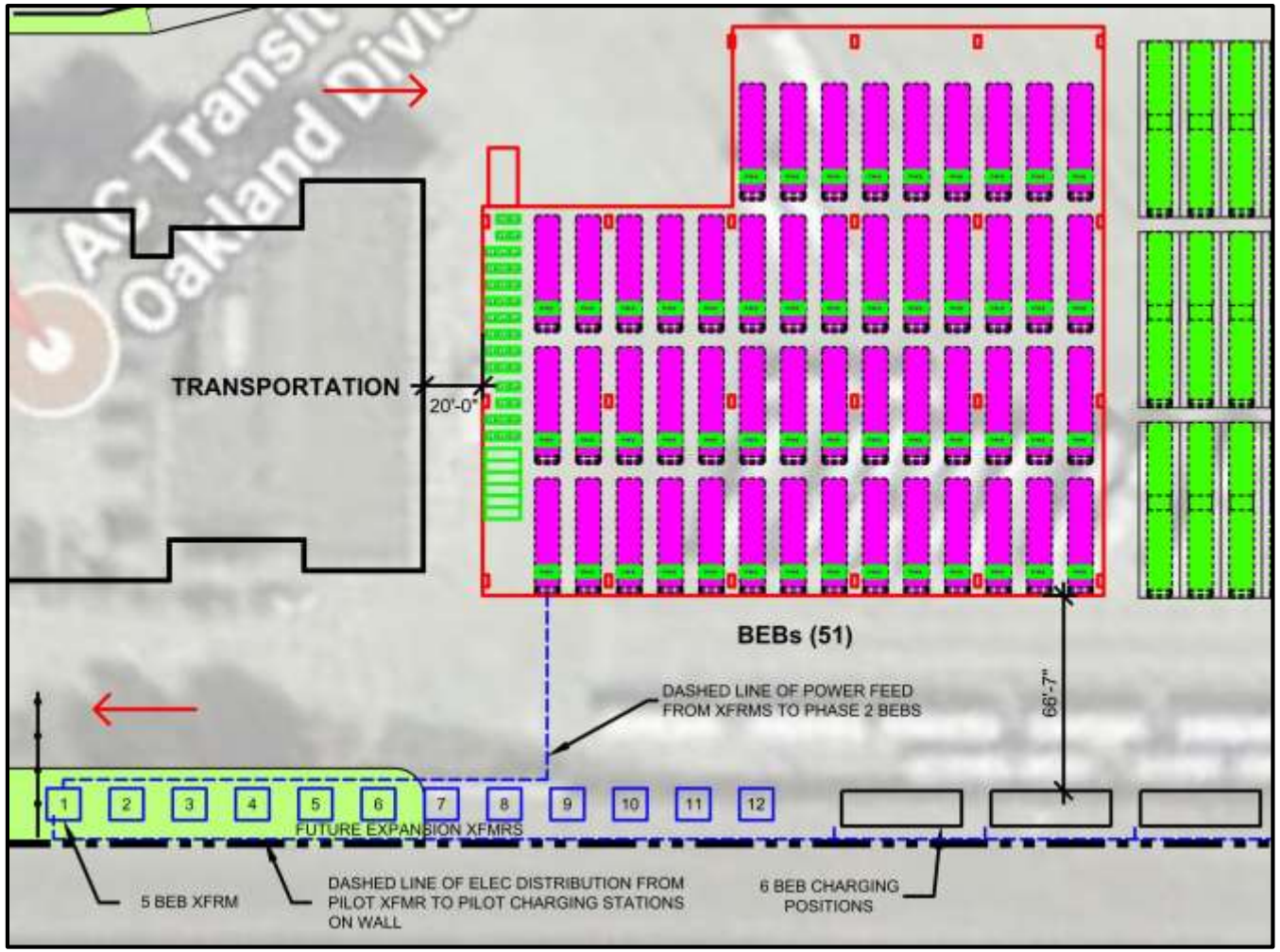
- Supports variable length vehicles if overhead support continuous
- Structure can support both overhead plug-in drops & pantograph if continuous
- Allows overhead distribution in lieu of under ground distribution
- Provides flexibility for future charging improvements
- Current pantograph 17’-0” clear allows for double deckers under structure

Cons

- Add cost for overhead structure if not shared / double utilized
- No large quantity of inverted pantograph depot installs



D4 BEB Overhead Charging



SCALABLE

Transformer 1: Installed for 5 BEBs

Transformer 2: For 45 ZEB Project (all options)

Transformer 3: For Options B & C

Transformers 4 thru 12: Future

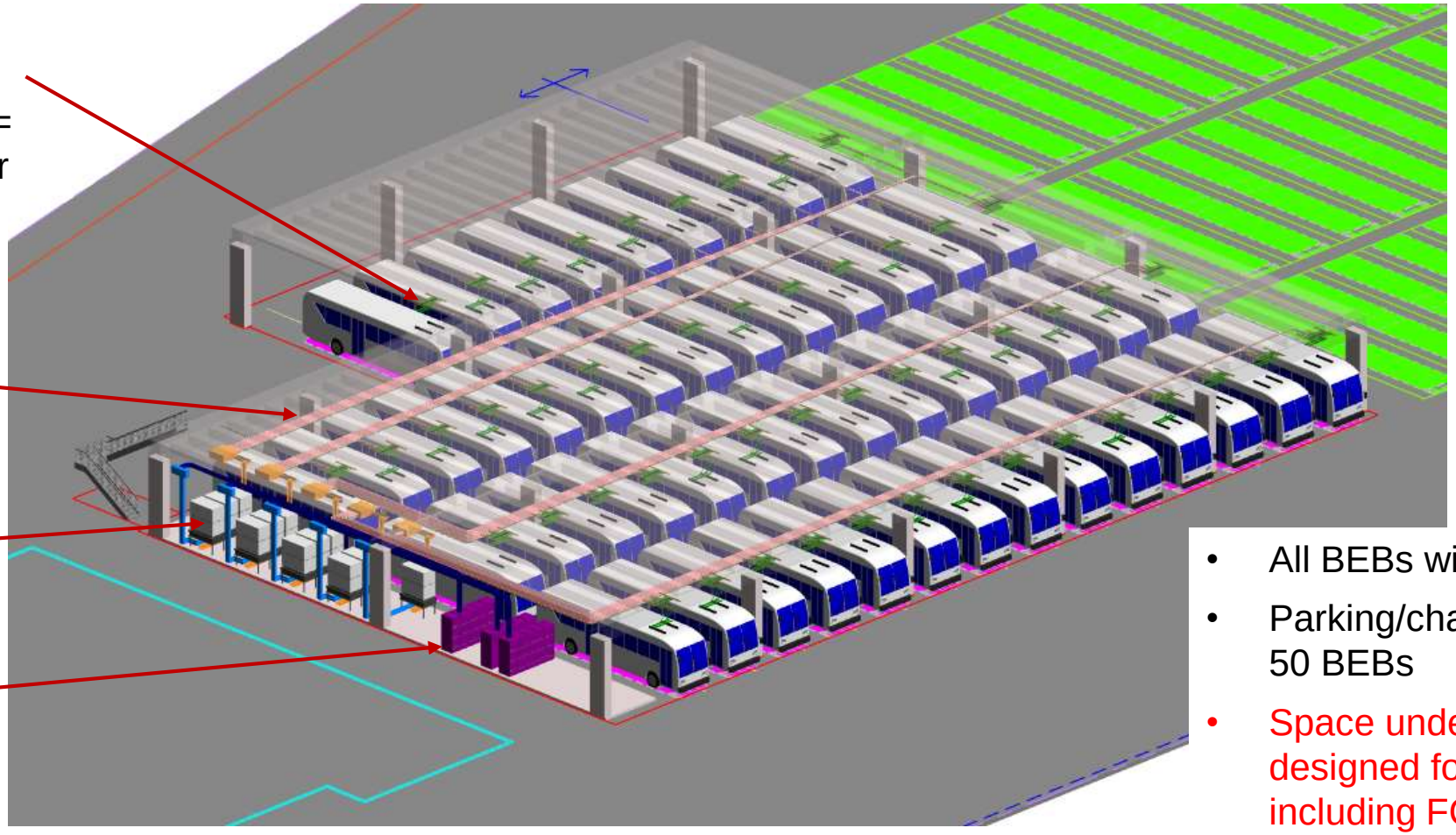
D4 BEB Infrastructure

Pantograph alternate shown (overhead drops = base bid), one per BEB

Conduit

1:2 Chargers

Switchgear



- All BEBs will park under the deck
- Parking/charging spaces for up to 50 BEBs
- Space under the deck is designed for all types of buses including FCEB

D4 BEB Infrastructure

45 ZEB Project

1. **AC Transit will be consider adopting purchase options in January 2020.**
2. **AC Transit continues to look objectively at ZE technologies, and will continue to consider both BEB and FCEB options**
3. **If recommendations adopted in January, there will be a unique opportunity to consider identical BEB, FCEB as well as conventional buses.**

Questions?

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