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Zero Emission Bus Planning

What is a Zero Emission Bus?

Battery Electric Bus (BEB)

- Propulsion occurs from electricity directly stored in batte
- Fueling occurs by recharging batteries

Hydrogen-Electric Bus

- Propulsion occurs from hydrogen stored in fuel cells that is converted into electricity for propulsion
- Fueling occurs by refilling hydrogen.

Unknown & Future Technologies?

- TBD

Transitioning to ZEB is like flicking a switch…**right?**

Biggest headaches for your peers…

Infrastructure and On-Site Spatial Requirements

- Provide grid resiliency (minimum two transmission feeds to substation, 7 figures $)
- Getting on-street infrastructure set up to enable operations
- Finding available land for large substations
- Respecting land-use planning
- Retrofitting existing garages not programmed for ZEBs
- Lack of power supply driving up operational costs

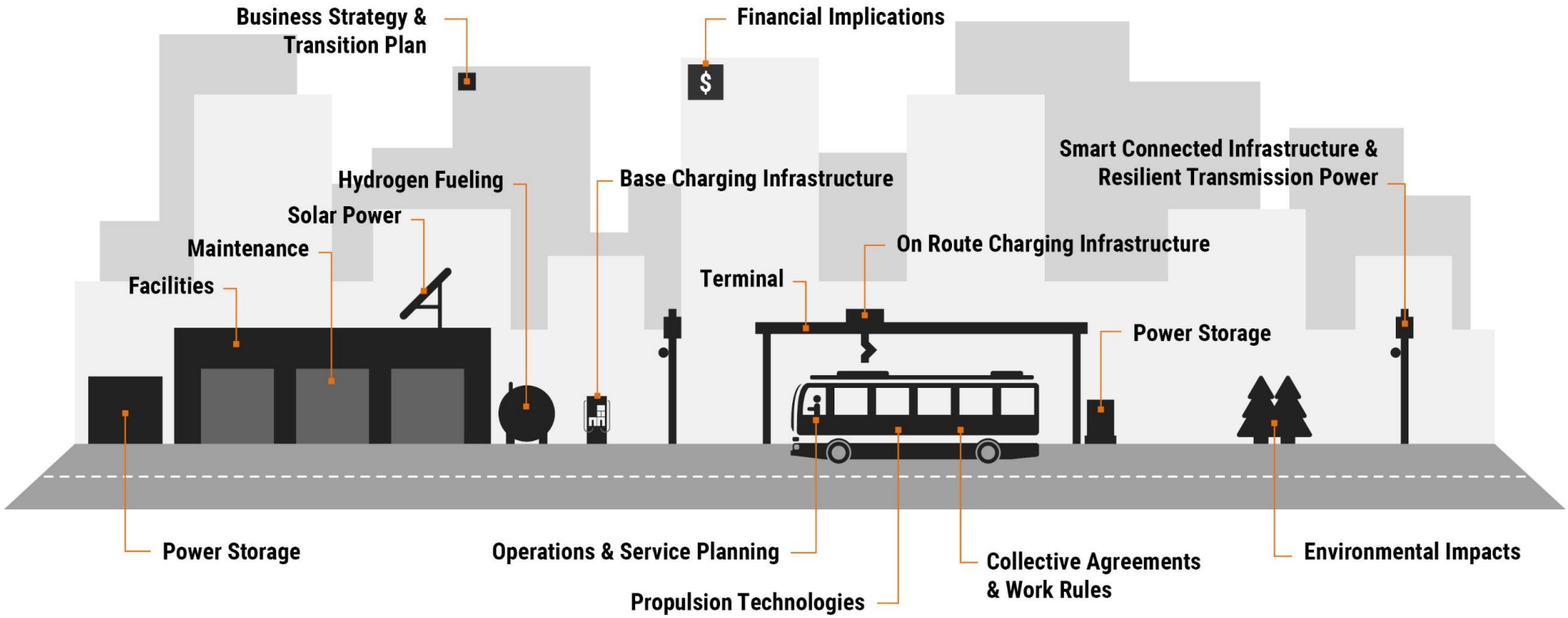
ZEB
Transition &
Implementation
Strategy

But there are others as well…

Fleet

- Complement likely to increase with ZEBs
- Aligning specific route requirements with propulsion technology
- Larger spare ratio to account for garage charging
- Anticipating “cut-over” given preexisting asset management plans
- Managing road calls – what’s repairable? what’s not?
- Developing specs and managing warranty claims
- Extreme weather (hot/cold) performance

Want Success?
Align the pieces before you start!



Cost Planning

Service Planning and Operations

- New service plans
- On-street charging vs. base charging?
- Increased labor costs
- Operator training
- On time performance issues – more recovery time to keep schedule
- Work rules & collective bargaining agreements – can we align them with new operating needs?

Capital Improvements and Training

- Start-up investment costs
- Life cycle cost analysis
- Maintenance and Repair Requirements
- Life cycle, preventative maintenance and repair estimates
- Retraining maintenance and operations staff
- Retooling garages
- Maintain operations while under construction

Fiscal Realities & Funding Sources

- **Establish the financial model and business case**
  - Potentially increased operational costs
  - Full life cycle cost of each vehicle
  - Planning and Capital Improvement costs
  - Include training in the planning costs (ops and maint)

- **Evaluate potential funding sources**
  - Local government
  - Current or potential for carbon taxes?
  - Potential utility agreements
  - State government
  - Federal government

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Scope	Phyiscal plug-in charging		Overhead arch structure with pantograph		Underslab induction charging		Overhead canopy structure with pantograph	
	Planning Assumptions	Estimated Cost	Planning Assumptions	Estimated Cost	Planning Assumptions	Estimated Cost	Planning Assumptions	Estimated Cost
	150 kW plug in charging cabinets within islands every 2 tracks		150 kW charging cabinets connected to overhead pantograph charging units every 6 tracks		150 kW charging cabinets connected to underslab induction charging units every 6 tracks		150 kW charging cabinets connected to overhead pantograph charging units every 6 tracks	
Number of Buses	252		300		300		300	
150 kW Charging Cabinet							150	
Charging equipment costs installed [1, 5]	$7							$38,250,000
150 kW Charger cabinet/controller with J1772 plug								$21,750,000
150 kW equipment/routing costs	Unc							$300,000
Overhead arch structure								$0
Overhead steel structure canopy								$8,800,000
Added Electrical Costs / Year [4]								$0
PROTECTION BELT - 24" (TBD) Raised Curbs	$20/							$280,800
PROTECTION SUSPENDERS - Bollards ($9K, each)	4							$5,400,000
SUBTOTAL								$74,780,800
CONTINGENCY & ESCALATION								$18,695,200
Cost per bus parking space								**$311,587**
Comparison to Baseline Standard (at grade every 2 tracks)	84% fewer buses than the 300 bus goal	100%	Meets 100% of the 300 bus goal	108%	Meets 100% of the 300 bus goal	153%	Meets 100% of the 300 bus goal	122%

Currently, additional per bus planning costs = $255K to $390K for on site Depot Charging . . . .

BUT

Battery technology is constantly improving which should lower initial up-front capital costs as battery storage capabilities increase.

AND

Battery ownership discussion is happening, whereas vehicle manufactures actually own the batteries, and replace/repair as a condition of the fleet procurement contract.

Notes:

1) Per-bus costs are estimated from per-unit costs for charger base + associated dispenser type + 50% for contractor installation and markups.
2) 'Pantograph down' dispenser; charger base is same as plug-in; interface is per tentative standard of J3105.
3) Not Used
4) Inductive chargers have energy-transmission loss of about 10%.
5) Costs are for charger bases and dispensers. Upstream costs for switching, transformers, substation and other upstream electrical are not included but would be similar for each model.

Planning for Success

Power, Infrastructure & Ops 1

- Develop requirements for a pilot for initial implementation, matching propulsion type to appropriate route assignments
- Charging/Fueling: Identify infrastructure needs for charging system and facility space impacts; consider operational constraints
- Evaluate ZEB fleet power requirements versus current delivery capacity
- Manage charging opportunities through software and hardware utilization to minimize peak rates
- Identify additional sources of power to support ZEB fleet requirements (grid/solar/battery)
- Review options for onsite primary and back up generation and storage
- Commissioning and “cut-over” phasing
- Develop decommissioning plan for current infrastructure

Plan to Succeed – We're Making History!

"Design-out" failure from the start

- Lots of unknowns
- Peer lessons-learned inform our approach
- Plan now, plan for the unknown, plan for planning updates!
- Contingency budgeting

Develop Transition and Implementation Strategy

- Get it right by aligning the pieces
- Define what success looks like to you

Know the Risks

- But the biggest risk is doing nothing and being un-prepared!

Be Patient

- Technology is constantly changing

ZEB Infrastructure Site Planning

The current master plan allocates space for future ZEB infrastructure equipment.

- Power Feed from Martin Way
  - ✓ Off-site sub-station(s) required
  - ✓ All on-site equipment owned & maintained by I.T.
  - ✓ Most likely feed exist. Bus Storage with overhead charging, but could also feed underground
  - ✓ Maintains safe and efficient site operation and traffic flow
- Cost Impacts
  - ✓ Additional phases of construction
  - ✓ Will affect Bus Storage parking to construct
  - ✓ Will trigger south parcel storm water improvements (if not already constructed)
  - ✓ Potentially add an Energy Management Building on site

Questions & Comments