ZEB Overview

The Conductor's Series: Electrification of Transportation

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Stephen Tofler

Stephen is a Chartered Engineer with broad experience in the transport sector, holding technical and management roles in the planning, development and delivery of transport projects.

ZEB Expertise	Zero-emission bus strategy and network integration, ZEB depot layouts, stakeholder engagement, project management
Relevant project experiences	— TfNSW minimum performance requirements (2021) — TfNSW depot layouts in Greater Sydney and ROM (2021-22) — DTP ZEB TA (2022-) — Confidential client: Ease of Technology Transition Assessments

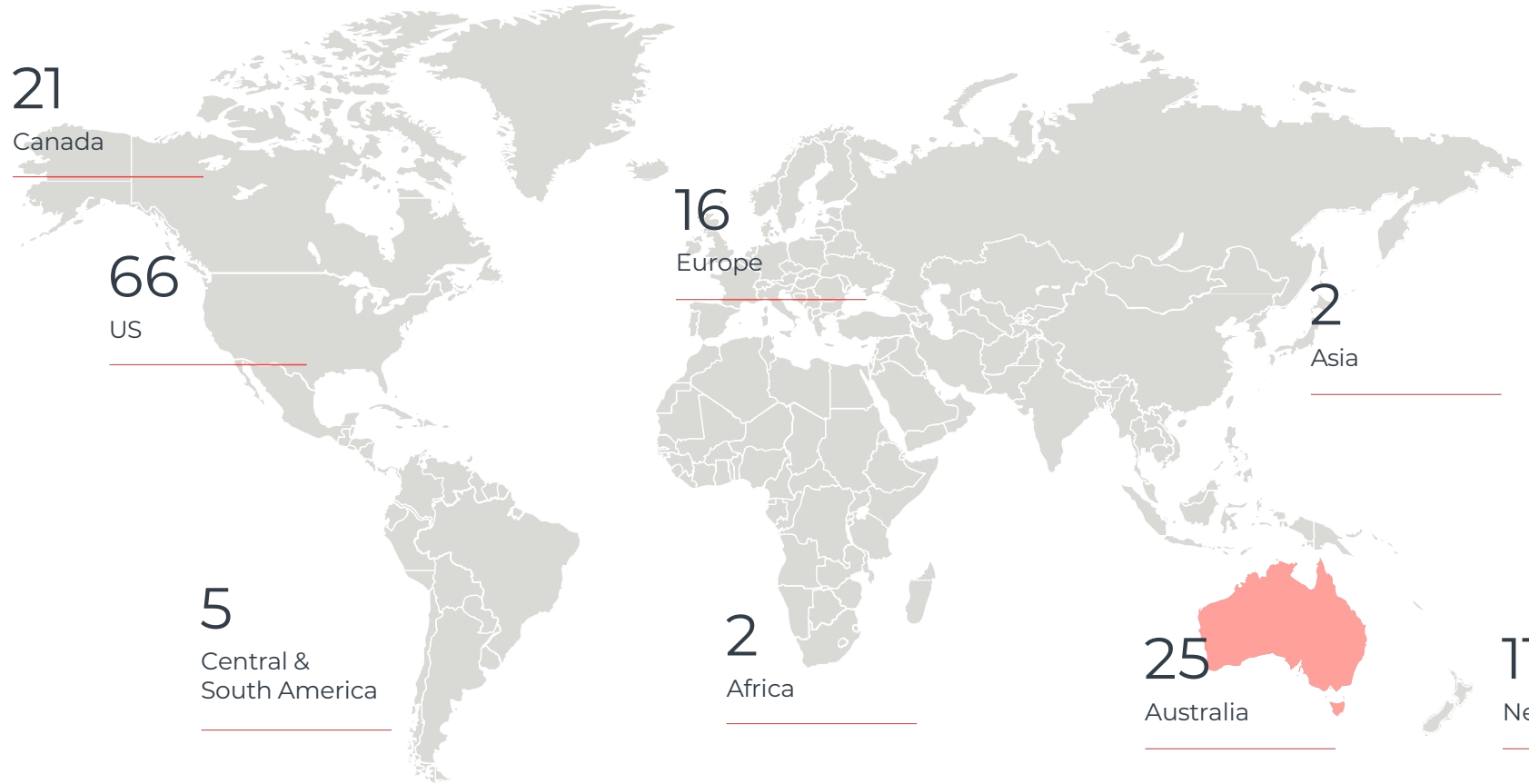
Ben Jensen

Ben is a Principal in with 22 years experience planning, designing and delivering infrastructure in Australia, New Zealand and the United Kingdom. Ben is also a Team Executive within the Infrastructure Investment Decisions, Strategic Advisory team.

ZEB Expertise	Investment case, strategic planning, commercial/procurement, project management
Relevant experience	— TfNSW ZEB Project Greater Sydney tranche 1 business case lead — Confidential client: Ease of Technology Transition Assessments — Confidential client: charger and depot technical specifications — Confidential client: funding options investigation — Electricity sector regulatory advisory and assurance services (RIN reviews, pricing reviews/support, business case development)

148
ZEB Projects Worldwide

WSP's Global ZEB Footprint (end of 2022)



ZEB Overview

What is a ZEB ?

- Buses with zero tailpipe emissions – critical for transport's net zero transition.
- Battery Electric Buses (BEBs) and Hydrogen Fuel Cell Buses (HFCBs) are most common.
- While this is a rapidly evolving space, **BEBs are best placed to support ZEB transition in the short term**
  - Green hydrogen not available at scale
  - HFCBs are currently more expensive
  - CNG depots are most easily transitioned to Hydrogen – these are not common in Australia.

Each state is at a different point in its transition

Government announcement –trial

Government announcement – transition

Intermediate target

Transition

Types of bus operations

Buses perform all sorts of roles on the network and are contracted and operated under a variety of models. Transition to ZEB will mean different things to each operation.

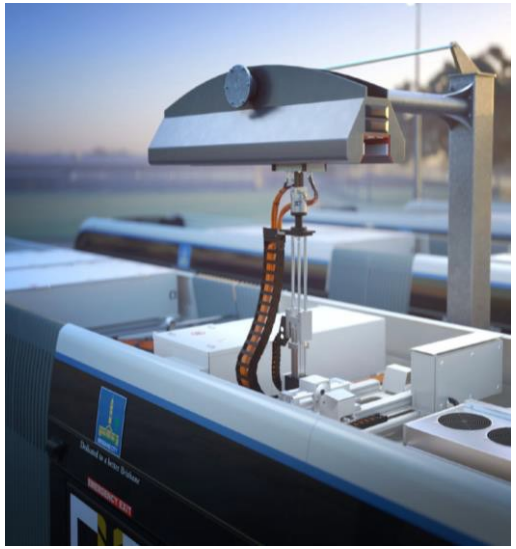
The change from diesel – Infrastructure

BEBs require charging infrastructure – this can be installed at the depot, or on road:

- In most cases buses will charge at depots – during split shifts and overnight
- On road flash charging is common in closed systems with known routes – allows for smaller light weight batteries to be used.

Examples of different forms of charging technology in Manheim, Germany

Plug-in charger at Monash University for top-up at layover – same charger as used at the depot



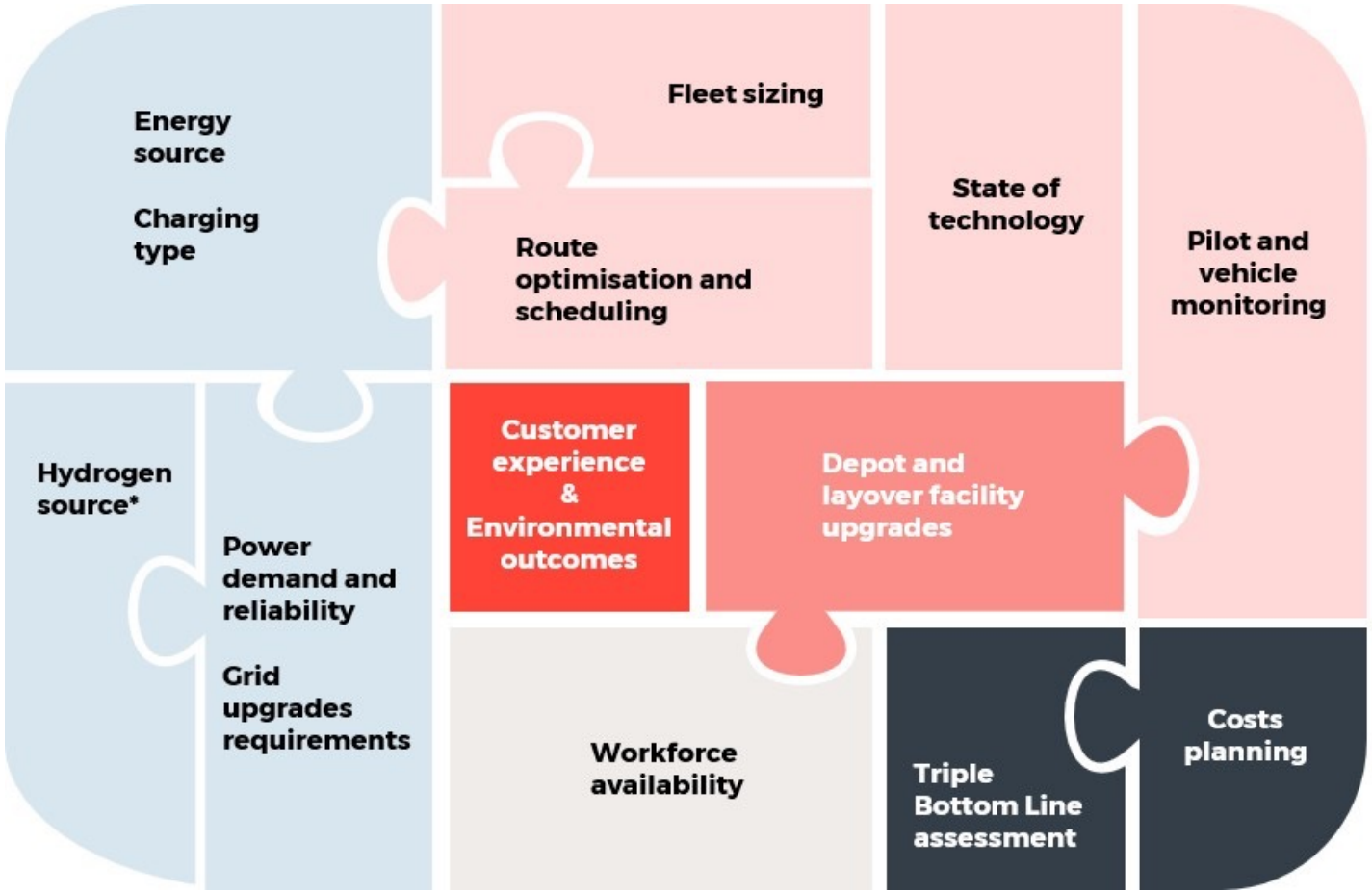
On-road 600 kw pantograph up 'flash charging' will be used for Brisbane Metro, these buses will also charge overnight at their depot

The change from diesel – Operations

- Introduction of BEB brings new operational challenges to manage:
- BEBs can be heavier, this reduces their legal passenger capacity – could require more bus services to be run
- BEBs have reduced range, and are much slower to refuel / recharge – could require more buses in fleet, managing bus scheduling (as opposed to driver scheduling) becomes more important
- Vehicles are always improving – increasing range through improved batteries and reduced weight

Vehicle		Tare Mass (weight of empty standard vehicle)	Typical range (km)	Refuel / Recharge Time
Typical Victorian Bus (SCANIA L94UB) *12.5m (L) x 2.5m (W) x (3.5m (H)*		11.9 tonnes	800-900km	10 minutes
Victorian Electric Bus (Volgren Optimus BYD K9RA) *12.1m (L) x 2.5m (W) x 3.4m (H)*		13.0 tonnes	300-350km	2-6 hrs depending on charger, and battery SOC (full charge) 10-15 minute Opportunity Charging (top-up)

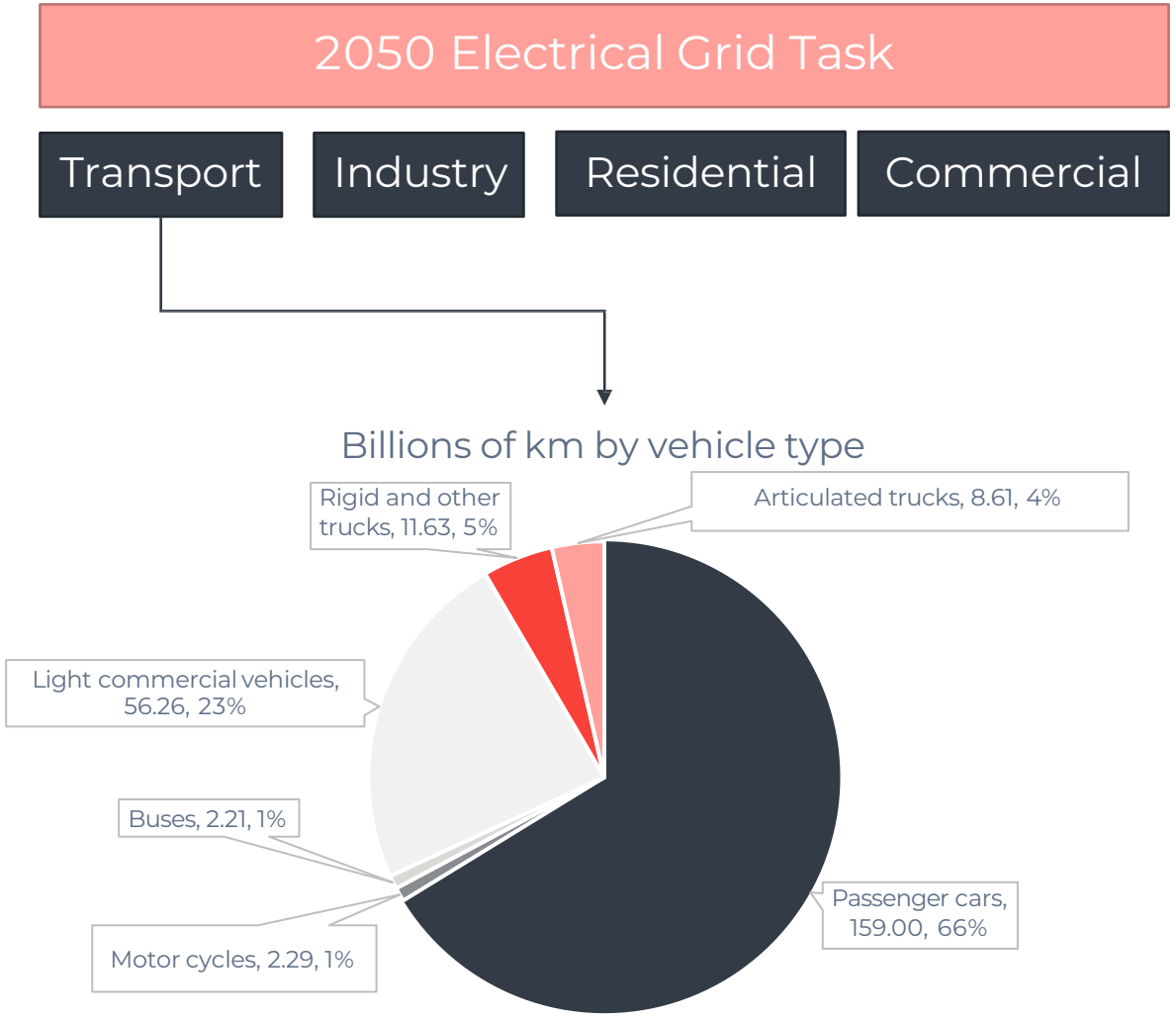
ZEB Transition involves the interplay of multiple factors — increased complexity compared to diesel buses



Challenges & Opportunities

Challenge: The scale of electrification!

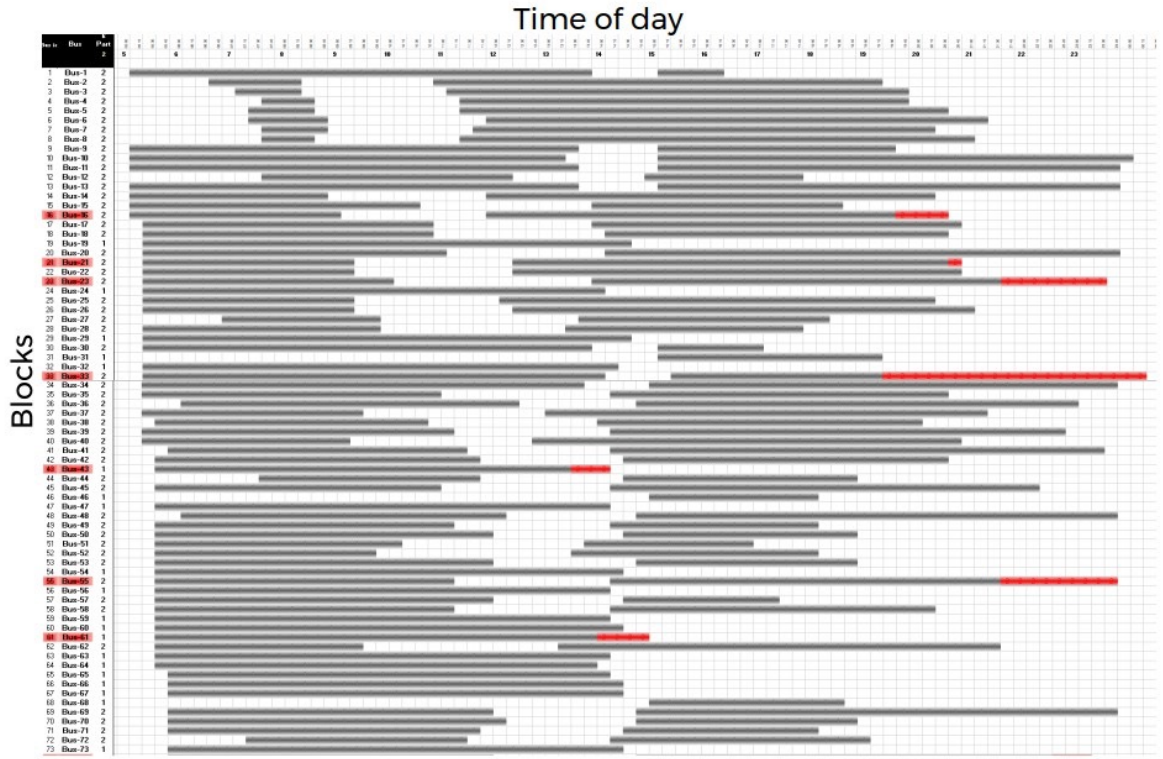
- Buses perform a highly visible, essential service, which will undergo an orderly transition to zero emissions - there is proven technology to deliver much of the bus task today.
- **How can we leverage this?**
- Buses will be a very small proportion of the electric grid task.
- **How can we ensure we don't get forgotten?**



Challenge: Powering buses with renewable energy

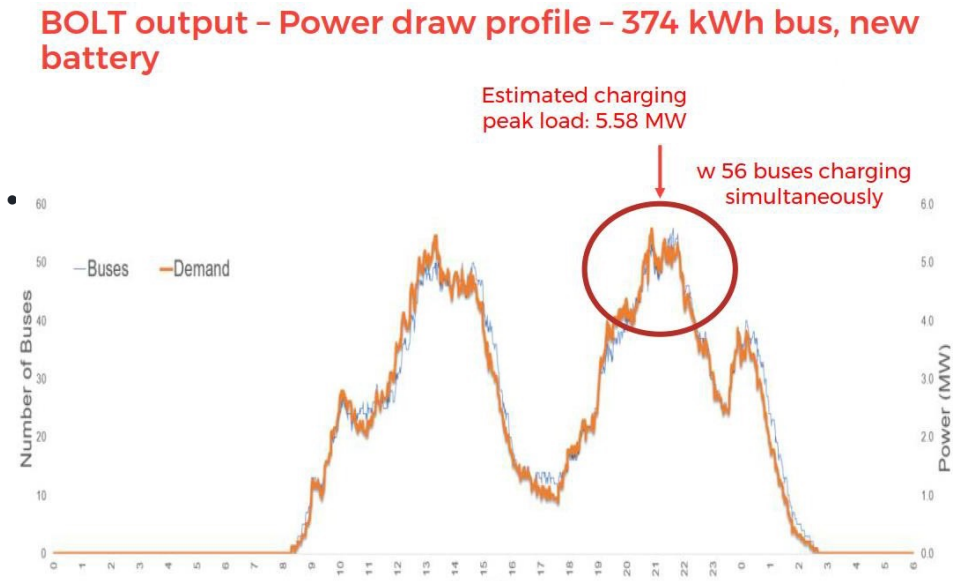
How can we achieve zero emissions by charging buses through renewable energy?

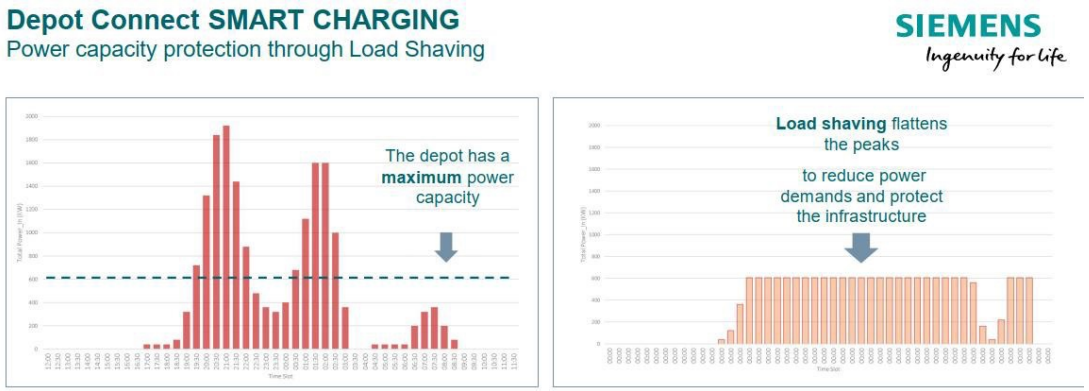
- Typical city operations are out for the day, coming back to the depot at the end of their shift in the evening.
- How to provide on-site storage for 100 buses?
- School bus operators may keep their buses parked during the day, or may use them for other uses during the day. These are typically small operations in regional areas.



Challenge: How much power do we need?

How can we ensure that bus power needs are captured in energy network planning ?





Mitigation 1: Model bus network to understand power demand throughout the day, to right size power upgrades.

Mitigation 2: Smart charging systems to manage power demand from the depot that ensures buses are charged in order ready for dispatch.

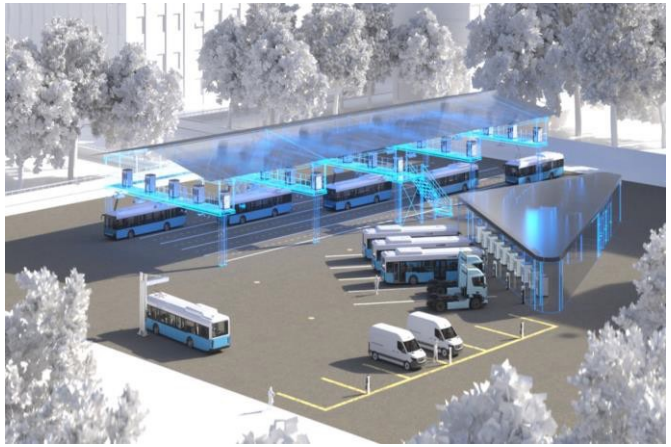
Opportunity: New delivery and operational models

- Buses are a highly visible, essential service
- To be zero emission, buses need to be powered by renewable energy
- Locations where buses charge are known / can be planned for, and overall power demand can be forecasted

- **Can the various (and new) players in the energy / charging sector identify opportunities to provide connections and energy to support a rapid and efficient transition?**
- **Can governments and bus operators identify opportunities to procure connections and energy more cheaply in the long term?**

New Model:

Shared depot concept in Leipzig where multiple user groups are using installed charger infrastructure



New Model:
Brookvale Bus depot with solar roof and microgrid in Maryland, USA.

Microgrid managed and financed by 3rd party.