Zero Emission Buses and Transition Challenges for Contracting

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Hensher, D.A., Wei, E. and Balbontin, C. *Comparative Assessment of Zero Emission Electric and Hydrogen Buses, report (including DSS),* 15 July 2021 report for BusVic.

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Summary of the current state of ZEBs in Australia

- NSW: The government has committed to the electrification of all bus fleets by 2030, with more than 50 new BEBs on the road in 2021.
- ACT: The first 90 BEBs are expected to commence in 2021 to 2022, with the remaining delivered no later than 2024.
- QLD: The Department of Transport and Main Roads (TMR) has announced that all buses purchased by 2030 will be ZEBs. New ZEB trials are being operated in South-East QLD in 2021.
- VIC: The government has committed $20 million investment in the 2021 to 2022 budget for a three-year trial of ZEBs.
- SA: The government has announced the action plan for 2021 to 2025 to start the transition to ZEBs.
- WA: The government has announced that from 2022, BEBs will start operating on certain roads.

So few ZEBs in Sydney at present (as of August 2021)

	Fleet Size	Total ZEBs in service	% of ZEB in fleet
SMBSC	4144	28	0.68%
OMBSC	1150	0	0%
Total O/SMBC	5294	28	0.53%

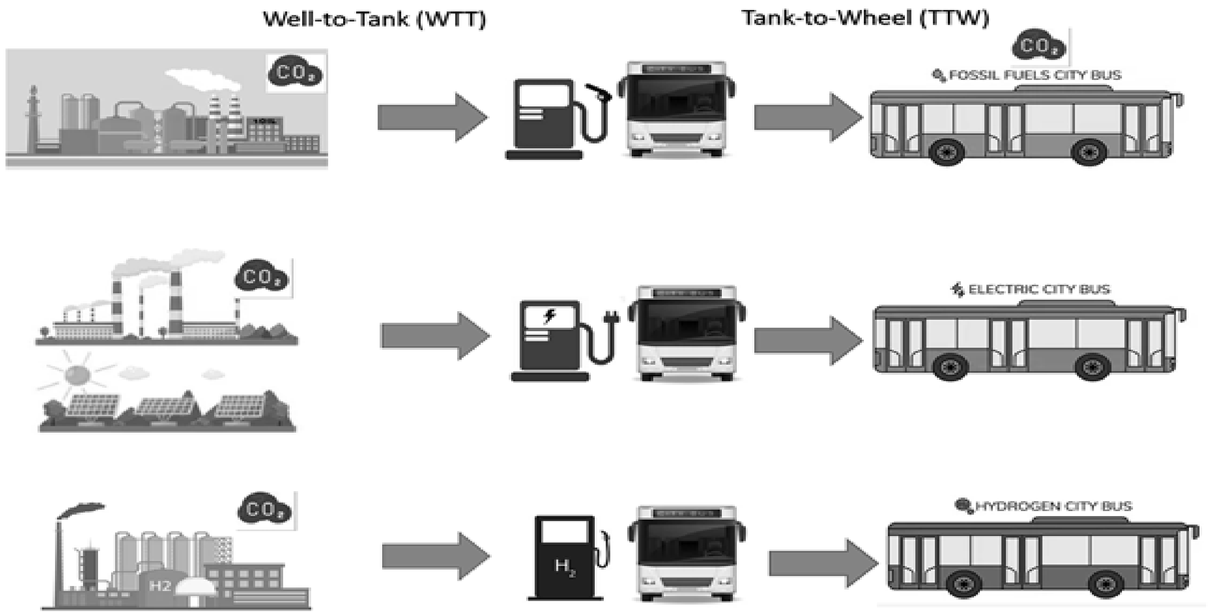
Example Trials and Commitments (being added fast)

GOVERNMENT TRIALS AND COMMITMENTS			
GOVT	OPERATOR	BUS	DESCRIPTION
VIC	Transdev	Volgren-BYD	Electric bus trials on route 246 until 2021. Bus is based at Transdev's North Fitzroy depot.
NSW	Premier Transport Group	Yutong - ABC Bus Sales	Electric bus trial for six months on New South Coast between Bombaderry Rail and Kiama Station.
	Transit Systems	Gemilang BYO	Electric bus trial on routes 431, 433, 447 and 470. Buses are based at Leichardt depot.
	The NSW Government completed an EOI for further electric bus trials in May 2020 as part of their commitment to transition its 8,000 buses.		
ACT	Transport Canberra	Carbridge toro Battery Electric	Electric bus trial completed in 2019.
	Transit Systems	Yutong	Electric bus trial for 1 year until November 2020. Bus is based at Tuggeranong depot.
Brisbane City Council	Brisbane Metro	HESS AG, Volgren, and ABB	The new Brisbane Metro project will deploy 60 trackless electric buses across two routes.
WA	Transperth	Volvo	Four Volvo electric buses will be delivered in 2021 as part of the existing 900 Bus Supply Agreement between Volvo and Transperth.

Comparison of the typical CO_2 emissions from different buses in the fleet (non-zero emissions prior to tail pipe)

Urban Bus Technology	gCO2/km (WTT)	gCO2/km (TTW)	gCO2/km (WTW or total)
Diesel Bus	162	1326	1488
Hybrid Bus	154	796	949
CNG Bus	187	1014	1201
Electric Bus	**292**	**0 (ZEB)**	292 (20% of Diesel WTW)

Conceptual illustration of WTW (WTT & TTW) emissions for diesel, BEB and FCEB



Well-to-Wheel' (WTW) includes all the emissions involved in the process of extraction/creation, processing and use of fuel in a vehicle to gauge the total carbon impact of that vehicle in operation. **'Well-to-Tank' (WTT)** only includes all the emissions associated with fuel up to the point that it enters a vehicle's fuel tank or energy storage device. **'Tank to Wheel' (TTW)** covers the emissions associated with fuel combustion in the vehicle, i.e. from the tailpipe.

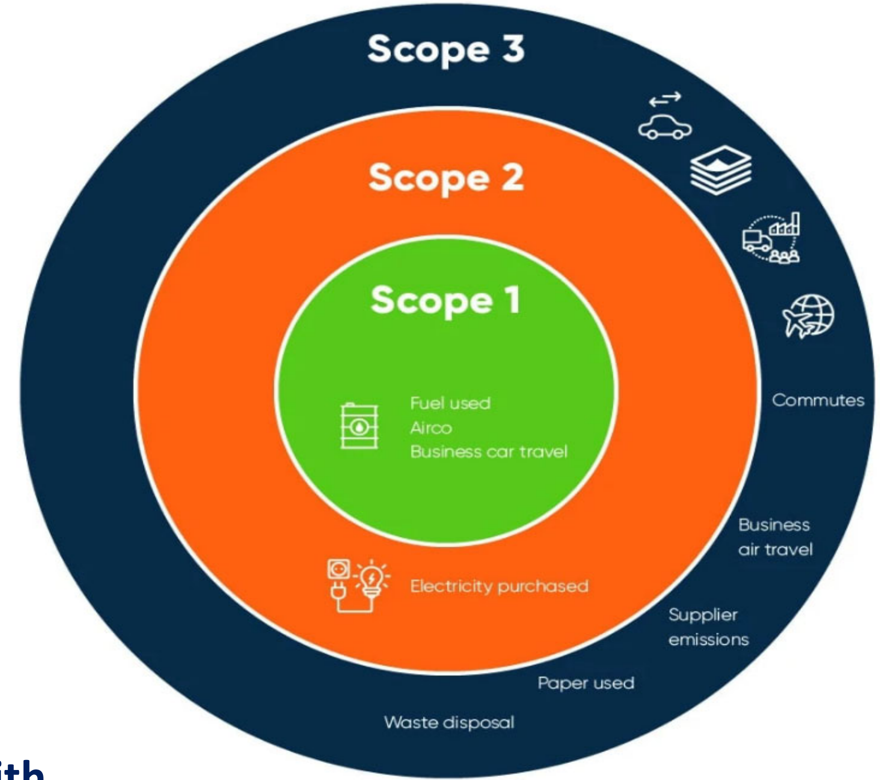
Renewable energy penetration by state (Source: Clean Energy Council 2021)

Gigawatt hours (GWh), is a **unit of energy representing one billion (1 000 000 000) watt hours,** equivalent to one million kilowatt hours

State	Total Generation (GWh)	Fossil Fuel Generation (GWh)	Total Renewable Generation (GWh)	Renewable Proportion of Generation	Renewables as Proportion of Consumption
Tasmania	10,956	90	10,866	99.2%	100.0%
South Australia	14,285	5,763	8,523	59.7%	60.1%
Victoria	**49,390**	**35,705**	**13,685**	**27.7%**	**28.4%**
Western Australia	19,171	14,528	4,643	24.2%	24.2%
New South Wales	68,158	53,846	14,312	21.0%	19.1%
Queensland	65,426	54,537	10,888	16.6%	18.0%
National	227,386	164,469	62,917	27.7%	27.7%

Clarifying Definitions : Direct and Indirect Emissions

– Emissions can also be categorised as direct and indirect.
– **Direct emissions** are emissions from sources that are owned or controlled by the reporting entity.
– **Indirect emissions** are emissions resulting from the activities occurring at sources owned or controlled by other entities.
– In defining the direct and indirect emissions, a definition of three scopes of emissions are often mentioned.



'The Grid – gorilla in the room' Neil Smith

Indirect emission factors for consumption of purchased electricity or loss of electricity from the grid (Source: Department of Environment and Energy 2017)

(Victoria is worse in Australia, but look at Europe, Poland excluded!)

State or Territory	Emission factor kg $CO_{2\text{-}e}$/kWh
New South Wales	0.83
Australian Capital Territory	0.83
Victoria	1.08
Queensland	0.79
South Australia	0.49
Western Australia	0.70
Tasmania	0.14
Northern Territory	0.64

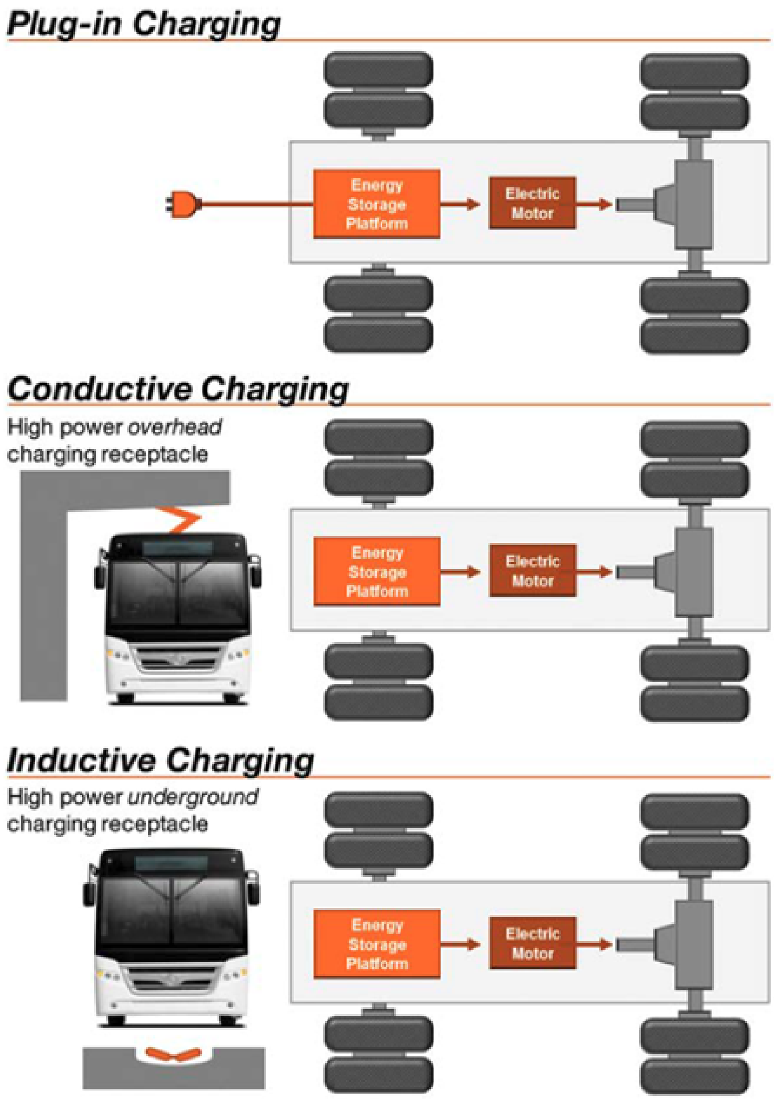
State or Territory	Emission factor kg $CO_{2\text{-}e}$/kWh
Norway	0.019
Sweden	0.012
Denmark	0.209
Nordic countries	0.075
Italy	0.327
Poland	0.846
EU	0.294
US-avg.	0.432
China	0.555
Japan	0.506

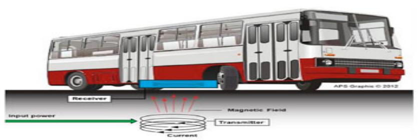
Source: Lie, K.W., Synnevåg, T.A., Lamb, J.J., & Lien, K.M. (2021). The Carbon Footprint of Electrified City Buses: A Case Study in Trondheim, Norway. *Energies*, 14,770, 1-21.

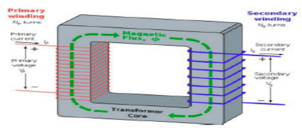
Comments on Various Fuel sources

- The emissions that BEBs cause, when charged from the grid are indirect emissions.
- **A diesel bus** will generate on average 1.3 kg/km CO_2 emissions.
- If a bus is **an electric bus**, then to run 1km, 1 to 1.4 kWh electricity is required from the grid.
- An Example: Let us make it simple with 1km for 1kWh:
  - **Electric Bus:**
    - The actual level of CO_2 emissions from an electric bus running 1km is about
      - 1kg CO_2 if charged from a coal-powered station **(~80% of current energy)**, and
      - 0.5kg CO_2 from a gas-powered station;
    - hence the **actual life cycle emission reduction can be as low as 26% if electricity is produced from coal** and 63% if electricity is produced from gas.
  - If **hydrogen** is produced with carbon capture and storage (CCS), the emission rate is about
    - 0.28 kg/kWh, plus some extra for compressing and transport;
    - hence the emission reduction will be less than either coal or gas generated electricity charged EVs and electric buses, calculated as a 75% reduction in the life cycle emissions.
  - If electricity or hydrogen are produced from renewables (e.g., solar, wind) and then used to power BEBs and FCEBs,
    - the life cycle CO_2 emissions will be close to zero or very low.
  - For example, in the above case, if BEBs are adopted in Tasmania, where electricity has a very low carbon density, BEBs can truly be called ZEBs.

The charging methods: it matches fast charging with conductive charging, and wireless charging with inductive charging







The three leading charging technologies are:

1) lower power charging through cable and plug-in (e.g., AC or DC charging using charging system (CCS) or CHAdeMO systems);

2) higher power charging through conductive charging with physical connections (e.g., using fast charging equipment like a pantograph); and

3) fast charging through inductive/wireless charging using a magnetic field for fast charging (UITP 2019).

Besides these three methods, BEBs also include an **on-board regenerative braking process that may recharge up to 40% of the electricity back to the battery during operation**, especially in a metropolitan bus with many stops and starts.

Overview of Emissions, Energy and cost Savings

	Diesel	Battery Electric			Fuel Cell Electric (Hydrogen)		
		Plug-in charging	Conductive charging	WPT/IPT (Inductive)	Grey Hydrogen (best case)	Blue Hydrogen (best case)	Green Hydrogen
Life cycle emission ($g\ CO_2/km$)	1350 (0.5 ltr/km)	656 (1 kWh/km)	682 (1 kWh/km)	650 (1 kWh/km)	850 (0.1kg/km)	71 (0.1kg/km)	0 (0.1kg/km)
Emission percentage relative to diesel (per km)	100.00%	**48.59%**	**50.50%**	**48.15%**	**62.70%**	**5.26%**	**0.00%**
Fuel efficiency per 100 kms	40 to 60 litres	90 to 150 kWh			9 to 10 kgs	9 to 10 kgs	9 to 10 kgs
Unit cost	$1.50/litre	$0.25/kWh			$2.20/kg	$3.02/kg	$3.88/kg
Energy/Fuel cost per 100 kms (low end) $2021	**$60.00**	**$22.50**			**$19.80**	**$27.18**	**$34.92**
Energy/Fuel cost per 100 kms (high end) $2021	**$90.00**	**$37.50**			**$22.00**	**$30.20**	**$38.80**
Cost saving relative to diesel (best case) (high end)		**75.00%**			**78.00%**	**69.80%**	**61.20%**
Cost saving relative to diesel (low end) (per km)		37.50%			63.33%	54.70%	35.33%

Procurement Considerations

What is required is not a myopic, blind pursuit of a *process* goal (of a contract specification) often driven by dogma and ideologism, but a better appreciation of nuance in ensuring that context-specific institutional structures are put in place, guided by clear *end* goals.

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Key factors to consider when purchasing and operating electric buses

Operation	Charging Infrastructure	Maintenance
• Route length, topography & electric range Passenger capacity • Operation day length of the bus • Flexibility of operational base/term of contract • Depot space to facilitate charging at night • Driver training to optimise efficiency and range • Fuel cost savings • Integration of e-buses across the whole organisation • Requirement for additional buses to cover e-bus downtime	• Number, type of charger & locations • Peak vehicle requirement • Availability of power • Power capacity at charging site • Managing peak demand • Optimising route scheduling with bus charging • Maintenance contract for infrastructure	• Lower frequency in brake pad replacement • No requirement for engine oil filter changes • Components likely to require replacement lithium battery, traction motor and power electrics • Manufacturers typically offer five-year warranty periods • Extra cost for extension beyond warranty periods • Tailored packages to support the vehicle life are available

1. Vehicles – weight, range, capacity
2. Infrastructure – fueling, equipment
3. Depot size
4. The Grid – gorilla in the room
5. Mixed fleets
6. Supplier concentration

Contract Risks:

1. Daily experience!
2. Grid – unmanageable for an operator
3. Time frame – contract length, long life assets
4. Depots: Design and Location
5. Finance: Availability, second-hand values
6. "Energy price" – predictable?

1. An inevitable upheaval of the industry
2. A decade of uncertainty ahead – technology, costs, contracts, capital
3. Conflicts between jurisdictions – energy regulation, land-use planning, depot location
4. 'Bias to big (operator)' may kill innovation

Key Issues I would like to share – The Transition Plan

– The broad objective(s) of government should be to provide
  – *"a good quality, integrated and continually improving service for a fair price, with reasonable return to operators that gives value for money under a regime of continuity and community obligation"* (based on Hensher and Stanley 2008).
– This is an important context in which to assess transition and the challenge is
  – **how best to share risk without risking denuding the market of players going forward**
– What we have through the green initiative is effectively
  – a relatively immature market where we have much to learn about how best to transition into and deliver post-transition a cost efficient and cost effective bus service.
– I would suggest that we are in transition essentially working with a management contract
  – all asset risk carried and covered by the regulator.
– To do this effectively it is best to not overlay it with tendering on what is left over for operator to bid to provide
– **This is a good argument for negotiation (at least in transition) rather than tender.**

Key Issues I would like to share – The Transition Plan

- Competitive tendering is a high-powered regulatory scheme, and under uncertainty, if risks cannot be reduced, it will increase the cost of capital.
  - A lowered powered incentive scheme, such as a negotiated contract (or rate of return regulation in the regulatory literature) may be optimal in this scenario, at least for a transition phase until uncertainty is lower.
  - This would transfer risks to the government or users (depending on who assumes the financial consequences of unexpected cost changes) and implicitly assumes that governments (or users) are better able to absorb these risks, as they should given that it is their policy commitment being implemented.
- We see great value in removing, temporarily at least, the direct competitive element of the procurement process for bus operators
  - preferring coopetition through negotiated contracts with all of the incumbent bus operators until such time as the transition is complete, and then to consider reviewing the market delivery options.
- That could be some time.
- One not insignificant concern is that if we proceed down a path of large operators working closely with government under a tendered model (as appears to be the case in some countries and States),
  - blocking out knowledge sharing to the broader bus sector, where government increasingly covers, in the short term at least, many of the additional costs of depot upgrade and ZEB purchases,
  - we risk the loss of many smaller and efficient operators from the market and an increased risk of regulatory capture closing the door in the future for these many smaller operators.
  - **With fewer bidders the contract price will increase.**

But maybe we need a totally new procurement model (Tendered or Negotiated) which is more than for the Transition?

Looking beyond Transition

- Under a green transition, it is reasonable to assume that no one bus operator, let alone a regulator, can claim that they are the best agent to manage the risk, or indeed the experts advising each operator and govt.

- Whatever the likely technology landscape may look like, it is clear that the road to a green outcome will be best travelled through
  - A trusting partnership between all the key stakeholders in the value chain,
  - of which the regulator and a committed the bus operator are the main participants, BUT working closely with bus manufacturers, energy suppliers and depot reconfiguration specialists etc.
- **We call this a *Supply Chain Partnership Contract (SCPC)***
  - Collaborative Contracting ***– see next slide***
  - Sound Familiar – like a PPP for infrastructure projects.
  - Like subscription based models

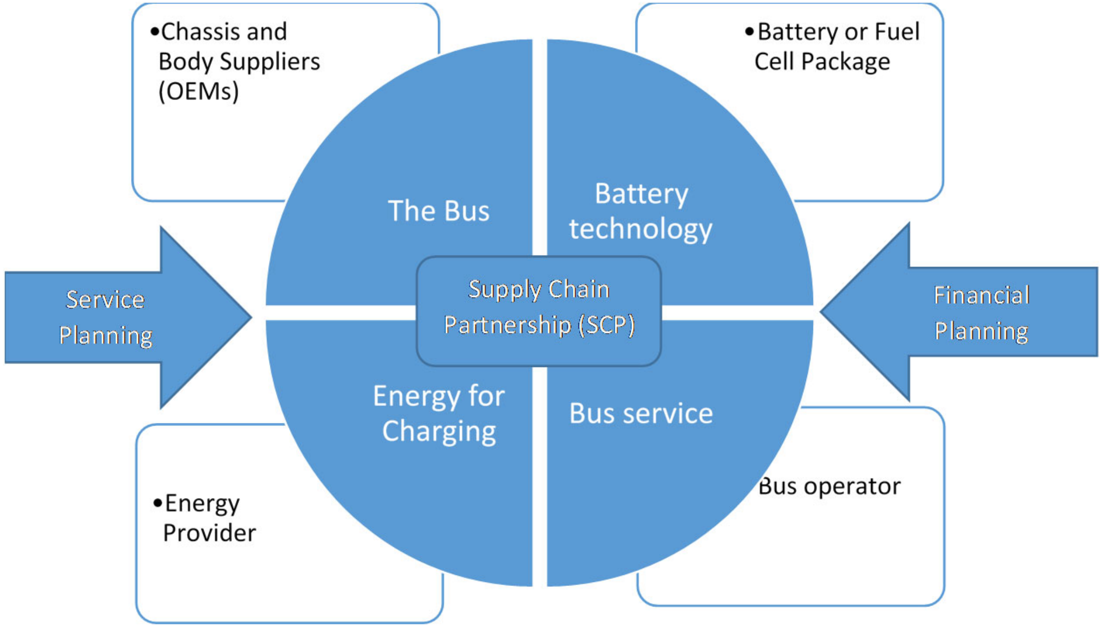
Things that must be said

Whilst collaboration is important, trust goes beyond legal/commercial specifications in a supply/value chain and enters the domain of unwritten or unquantifiable factors which decide success.

The hype and rhetoric associated with many technologies means that a ‘level head’ is necessary, avoiding the technological deterministic mindset so as to ensure that technologies are not implemented for technologies’ sake, but rather leveraged to ensure societal advantage.

Many of the present new mobility services, technologies and businesses cannot be regarded as ‘disruptive’ since they still try to earn revenue in traditional ways by transporting people. Real disruption would only occur when the core principles of travel taking time and travel being a derived demand are challenged. For instance, autonomous technologies might mean that the travel time budget conception is altered, whilst collaboration with other sectors (e.g., property developers, retailers) might change the revenue model fundamentals of transportation companies.

A Supply Chain representation of the Procurement model for Bus Contracts: Collaborative Contracting
Supply Chain Partnership (SCP) – Similar to the idea of PPPs.

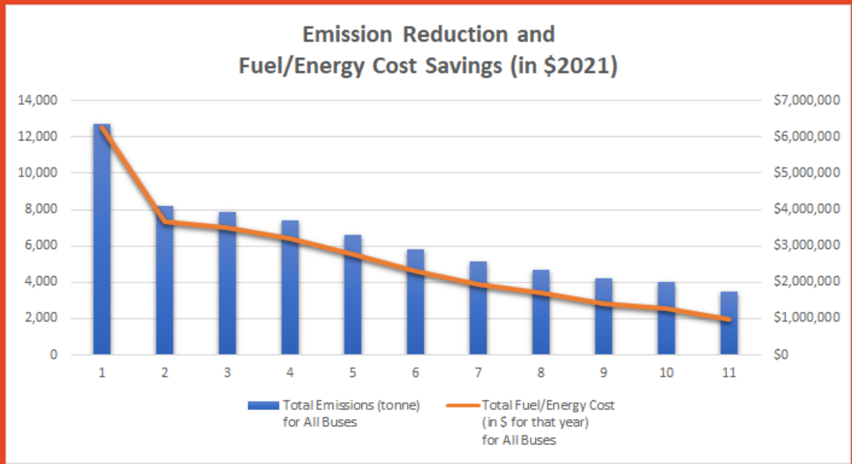


In many jurisdictions the trend is de-risking on both sides of the operator in the value chain: on the manufacturer side with vehicles-as-a-service (VaaS) and the ever advancing (digital) capabilities of buses with many defects/maintenance requiring the expertise of the original equipment manufacturer (with links to new technologies like autonomous and electric); and on the government side with the government ownership of assets and management contracts.

In some markets (e.g., Singapore, which modelled itself on Perth and London), government manages the hiring and training of bus captains (through the Ministry of Manpower and Singapore Bus Academy). In Darwin, the government even undertakes crew scheduling and development of rosters for their contracted bus operators.

Bus operators can therefore become, or are becoming, no more than an organiser of labour to operate buses and are vulnerable to being squeezed out of the transport ecosystem (e.g., imagine a bus manufacturer putting drivers on their products and suddenly being able to take the role of a bus operator).

Decision-Support System (DSS)



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Decision Support System

The purpose of this Decision Support System is to provide an evidence-based forecasting tool for bus operators to forecast outcomes of emission reductions and fuel and energy cost savings when transitioning from a diesel bus fleet to a zero-emission bus (ZEB) fleet.

The DSS allows different numbers of buses in the bus fleet and includes both battery electric buses (BEBs) and fuel cell electric buses (FCEBs) using hydrogen. Treating 2021 as the starting base year with your chosen number of buses in a bus fleet, the DSS allows users to explore the financial and emission implications of a selected electrification plan over a ten year period from 2022 to 2031. Users can assign different numbers of BEBs and FCEBs for each year, and make a selection related to fuel consumption, charging strategy, battery type, and other choices relating to BEBs and FCEBs. The DSS also allows users to change the price for diesel, electricity and hydrogen to reflect market prices.

The summary worksheet provides the overall yearly and accumulated total CO2 emission reduction, fuel/energy cost saving and capital investment associated with a ZEB procurement plan.

	Total Numbers of Diesel Buses/BEBs/FCEBs			
Years	Number of Battery Electric Buses (BEBs)	Number of Fuel Cell Electric Buses (FCEBs)	Number of Diesel Buses	Extra Diesel Buses
2020	0	0	2300	
2021	0	0	2300	0
2022	0	0	2300	0
2023	0	0	2300	0
2024	0	0	2300	0
2025	0	0	2300	0
2026	0	0	2300	0
2027	0	0	2300	0
2028	0	0	2300	0
2029	0	0	2300	0
2030	0	0	2300	0

	Annual Shift to BEBs
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
Total	0

	Annual Shift to FCEBs
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
Total	0

Reset Defaults and 0s for BEBs and FCEBs

Starting Number of Bus

2300

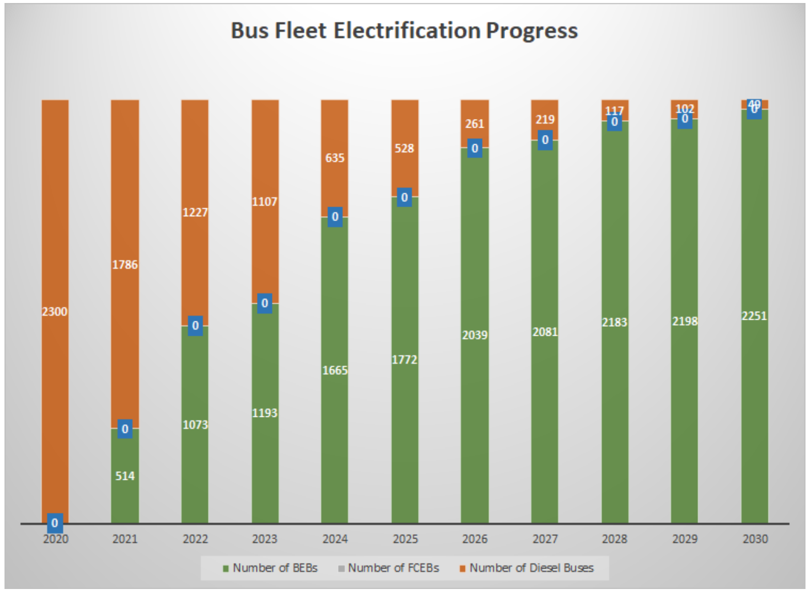
Now that you have entered your transition plan, you can either go straight to the summary tab where we provide estimates of costs and emissions based on assumptions we have made, or you can go to the year tabs and change the various items associated with our assumptions

The assumptions relate to

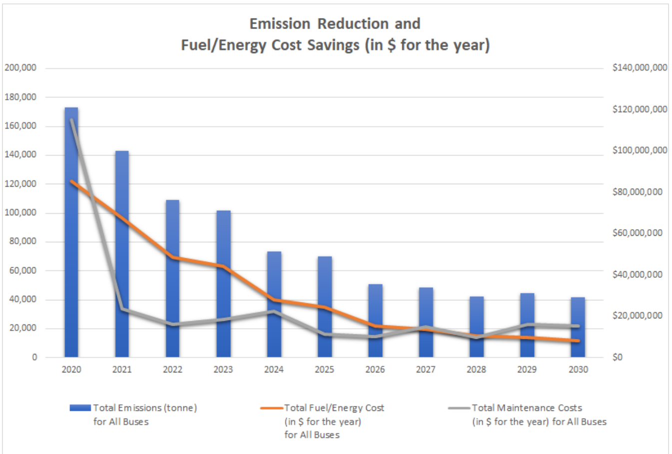
Annual bus kms
Passenger occupancy percentage
Diesel fuel efficiency (litres/100km)
Cost of diesel ($/litre)
Fuel consumption of BEBs in KwH/100kms and FCEBs in Kg/100km
Percentage of charging at the depot
Braking charge energy saving percentage
Percentage of charging time that is off-peak
Battery type mix (percentage)
Price per KwHr for LFP battery (all other prices are relative to this)
Price of NMC battery over LFP battery (higher in %)
$/kWh (electricity)
$/kg (hydrogen base price)
BEB Bus Value / BEB Battery Pack Value (Times)
Prices for Diesel bus and FCEB
Maintenance costs for BEB, FCEB and diesel buses

Reset to Base Defaults	BEBs	FCEBs	Diesel
Number of Buses	514	0	1786
Annual Kms Per Bus	66,400	66,400	66,400
Annual average occupancy rate per bus (%)	50%	50%	50%
Fuel Consumption (100 kms)			
Diesel (litre/100kms)			42
BEB (kWh/100kms)	97		
FCEB (kg/100kms)		10	
Annual Consumption (diesel in litre)			49,807,968
Annual Consumption (kWh of electricity)	11,586,999		
Annual Consumption (kg in hydrogen)		0	
Charging (BEB only)			
Depot charging %	100%		
Opportunity charging (Fast) %	0%		
Braking charge energy saved			
Braking charging save energy up to %	30%	30%	
Charging Time (BEB only)			
Off-peak hour charging (e.g., 11pm to 4am)	50%		
Battery Type and Price (BEB only)			
LFP Battery (e.g., in BYD, Yutong BEBs) %	88%		
NMC (e.g., in Proterra BEBs) %	12%		
LFP Battery Size (kWh per bus)	345		
NMC Battery Size (kWh per bus)	425		
Price per kWh for LFP battery	$200		
Price of NMC battery over LFP battery (higher in %)	40%		
Electricity mix (BEB only)			
% renewables & others	9%		
% of Coal	68%		
% of CNG	23%		
Hydrogen Type			
Grey Hydrogen %		90%	
Blue Hydrogen %		5%	
Green Hydrogen %		5%	
Cost for fuel/energy			
$/litre (diesel)			$1.33
$/kWh (electricity)	$0.124		
$/kg (hydrogen base price)		$5.38	
Price for New Diesel and Hydrogen Bus		$1,000,000	$450,000
Distance-Based Charge (cents/km)	0	0	0
Total Emissions (CO_2 in tonne)	8,751	0	134,482
Total Energy/Fuel Costs	$1,430,994	$0	$66,244,597
Total Battery Costs for BEB	$38,550,000		
Total Capital Costs to Purchase New Buses	$308,400,000	$0	-$2,570,000
The numbers of diesel and ZEBs changes for 2021	514	0	-514
Resale Value of Diesel Bus (per bus)			$5,000
BEB Bus Value / BEB Battery Pack Value (Times)	8		
Distance-Based Charge ($)	$0	$0	$0
Maintenance Costs Per Bus	$4,000	$46,000	$12,100
	Total Emissions (CO_2 in tonne of Three Types)	143,233	
	Total Energy/Fuel Costs of Three Types	$67,675,592	
	Total Capital Investment for 2021	$305,830,000	
	Total Distance Based Charge	$0	
	Total Maintenance Costs	$23,666,600	

	Number of Diesel Buses	Number of BEBs	Number of FCEBs	Annual Increased New ZEBs	Total Emissions (tonne) for All Buses	Total Fuel/Energy Cost (in $ for the year) for All Buses	Capital Investment ZEBs (in $ for the year)	Distance-Based Charge (in $ for the year)	Total Maintenance Costs (in $ for the year) for All Buses	Total Fuel/Energy Cost (in PV$2021)	Capital Investment ZEBs (in PV$2021)	Distance-Based Charge (in PV$2021)	Maintenance Costs (in PV$2021)	Emission Reduction Over Base %	Fuel Cost Saving Over Base % (in $ for the year)	Maintenance Cost Saving Over Base % (in $ for the year)
2020	2300	0	0	0	173,184	$85,309,392	--	--	$115,000,000	$87,015,580	--	--	$117,300,000	--	--	--
2021	1786	514	0	514	143,233	$67,675,592	$305,830,000	$0	$23,666,600	$67,675,592	$305,830,000	$0	$23,666,600	17.29%	20.67%	79.42%
2022	1227	1073	0	559	108,820	$48,497,976	$332,605,000	$0	$16,316,600	$47,547,036	$326,083,333	$0	$15,996,667	37.17%	43.15%	85.81%
2023	1107	1193	0	120	101,622	$44,381,136	$71,400,000	$0	$18,498,800	$42,657,762	$68,627,451	$0	$17,780,469	41.32%	47.98%	83.91%
2024	635	1665	0	472	73,309	$28,188,230	$280,840,000	$0	$22,588,000	$26,562,399	$264,641,804	$0	$21,285,177	57.67%	66.96%	80.36%
2025	528	1772	0	107	69,926	$24,517,381	$63,665,000	$0	$11,312,000	$22,650,270	$58,816,619	$0	$10,450,539	59.62%	71.26%	90.16%
2026	261	2039	0	267	50,874	$15,357,410	$158,865,000	$0	$10,244,000	$13,909,680	$143,888,925	$0	$9,278,306	70.62%	82.00%	91.09%
2027	219	2081	0	42	48,355	$13,916,516	$24,990,000	$0	$14,862,300	$12,357,468	$22,190,405	$0	$13,197,297	72.08%	83.69%	87.08%
2028	117	2183	0	102	42,236	$10,417,202	$60,690,000	$0	$9,668,000	$9,068,801	$52,834,297	$0	$8,416,576	75.61%	87.79%	91.59%
2029	102	2198	0	15	44,632	$9,902,597	$8,925,000	$0	$16,196,400	$8,451,771	$7,617,402	$0	$13,823,471	74.23%	88.39%	85.92%
2030	49	2251	0	53	42,014	$8,084,326	$31,535,000	$0	$15,248,600	$6,764,602	$26,387,077	$0	$12,759,346	75.74%	90.52%	86.74%



Summary	
Average Annual Emission Reduction %	58.14%
Average Annual Fuel/Energy Cost Saving %	68.24%
Average Annual Maintenance Cost Saving %	86.96%
Total Emission Reduction (in tonne)	1,006,824
Total Fuel/Energy Cost Saving from 2020 to 2030 ($ for the year)	$582,155,554
Total Capital Investmentfor Purchasing ZEBs ($ for the year)	$1,339,345,000
Total Fuel/Energy Cost Saving from 2021 to 2030 (PV$2021)	$523,979,462
Total Capital Investmentfor Purchasing ZEBs (PV$2021)	$1,276,917,314
Total Distance-Based Charge (PV$2021)	$0
Total Maintenance Costs Saving from 2021 to 2030 ($ for the year)	$991,398,700
Total Maintenance Costs Saving from 2021 to 2030 (PV$2021)	$907,002,772
Total Costs Savings Including Fuel and Maintenance 2021 to 2030 ($ for the year)	$1,573,554,254
Total Costs Savings Including Fuel and Maintenance 2021 to 2030 (PV$2021)	$1,430,982,234



Decision-Support System (DSS)

Switch to excel application if time

See Background Tab for all assumptions (and shown for BEBs in previous slide)

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THANK YOU

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