DISCUSSION PAPER

Zero Emissions Bus Forum

Virtual Event, 1 October – 19 November

UITP INTERNATIONAL ASSOCIATION OF PUBLIC TRANSPORT AUSTRALIA / NEW ZEALAND

ZEB Forum
Zero Emissions Bus Forum

ARUP

Credits

This discussion paper could not have been produced without our interviews. We would like to thank the following people for their time and willingness to participate:

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Contents

Foreword

Firstly, I would like to thank Michelle Batsas and Angé Anczewska and the rest of the UITP team for their tireless effort pulling the Zero Emissions Bus Forum together; and to acknowledge the support provided by the team at Transport for NSW to get this off the ground and running.

For our inaugural event we have drafted this discussion paper to first provide a brief state of play, but more importantly discuss the insights and thoughts on the transition towards zero emission buses from the people who are directly involved in the planning, operations and delivery of Australia and New Zealand's bus system.

I would like to thank all the people and their respective organisations for participating in the 12 interviews we held, and the open and honest conversations with our team. The interviews were structured to be very open and explore and discuss key ideas, thoughts and priorities participants had around the transition.

In reading the report we ask that you take it purely as the perspectives of people at a given time in a field that is rapidly evolving. We hope that you as the reader seek to ask further questions at the forum, or spark discussions on points of interest that you might agree or not agree with. By bringing people together to discuss and share knowledge we hope to grow the number of champions and leaders across industry and Government to help make headway towards a zero emissions future for our on-road public transport system in Australia and New Zealand.

One big question we are putting to industry and Government is whether we should begin considering the development of the zero emissions bus ecosystem as a nation building exercise requiring a significant and coordinated investment? We know the transition will require changes across the ecosystem to realise the significant economic, social and environmental benefits. This includes supporting next generation jobs and manufacturing, redefining the 'bus' customer experience, reimagining our roads and streets, energy resilience and of course cleaner air for our communities. In essence, transforming our bus system could be the catalyst for wider economic change towards a sustainable future.

Lastly, thank you to the team here at Arup who have supported in pulling this paper together, especially Franziska Korte and Joey Schaasberg. We're (Arup) proud to be a gold sponsor and part of the organising committee for this game changing event. I look forward to meeting you at the forum and working together to realise a zero emissions future. Feel free to reach out to me via LinkedIn or by email: *mark.rowland@arup.com*.

Kind regards

MARK ROWLAND
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ADVISORY LEADER

Key Talking Points

The following summarises key talking points and insights obtained through developing this discussion paper:

Outcomes & Opportunities

Emissions & Clean air
The role of ZEBs in reducing greenhouse gas emissions and improving local air quality is seen as the key driver for the transition.

Energy Security
Early engagement with the energy sector is needed regarding the role of ZEBs to ensure there is network capacity for recharging, support energy resilience, and ensure clean energy generation to support the transition to zero emissions.

Jobs & Economy
The transition to ZEBs has the potential to catalyse next generation jobs and stimulate the Australian and New Zealand economies, especially if the entire vehicle is designed and manufactured here.

Customers & Community
ZEBs could improve the customer experience, satisfaction and overall perception of buses. Combined with the improved environmental performance ZEBs have the potential to contribute to better streets and places, as well as improving an operator's social license to operate.

Policy & Planning

Vision & Certainty
Industry has a lot of uncertainty around the transition towards ZEBs. Governments could address this uncertainty through a clear vision, integrated policies and strategic roadmaps, with clear targets, that engage stakeholders around the benefits and potential pathways.

Growing Champions
Strong leadership in the ZEB space is needed now, underpinned by trials and growing our industry and Government 'Champions' knowledge and clarity particularly around ZEB technology, operations, ownership, risks and energy grid implications.

Transition & Technology

Operational Readiness
While electric bus technology is ready to be deployed widescale, unclarity remains around operational readiness. Moving towards larger scale trials will help jurisdictions get operationally ready and reduce risks in relation to charging, depots, the grid and upskilling.

Role of Hydrogen?
Views around the role of hydrogen, its performance, the cost and the maturity of technology in comparison to electric buses are diverging. There is a need to work through the different use cases for battery electric and hydrogen vehicles.

Ownership & Operations

Fleet as a Service
The idea of procuring ZEBs under a fleet as a service concept could allow Government more flexibility to purchase services rather than holding assets, to achieve greater public value.

Ownership, affordability, funding
How can we improve the affordability of ZEBs? There are potential solutions ranging from changed ownership structures and procurement models.

GLOBAL

17% electric buses globally in 2020

Global market is expanding rapidly

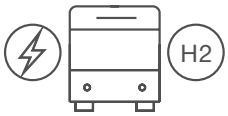
32% increase of global e-bus sales in 2019

27% Expected growth in units until 2027

Europe

electric buses growing exponentially as older fleets are retired

3000 battery electric buses in operation



<100 hydrogen powered buses

Biggest drivers for the transition to ZEBs

local air pollution reductions in the cities

climate emergency and compliance with GHG emission reduction targets

aim to increase attractiveness of buses

AUSTRALIA

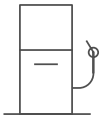
100,473 buses operating in public and private sectors

80% of them are diesel buses

1500 annual local bus building capacity

1300 annual new buses registered

6700 litres annual average fuel usage for diesel bus



NEW ZEALAND

70+ years electrically powered buses have operated in Wellington

Targeted goals

By 2025

Auckland Transport to procure only ZEBs

By 2023

100+ electric buses in Wellington and New Zealand

By 2040

100% electric buses fleet for Auckland Transport

Setting the Scene

Our approach

To help inform and generate conversations for the UITP Zero Emissions Bus (ZEB) Forum in October and November 2020, we (Arup) have drafted this discussion paper for attendees and other interested stakeholders. Our overall approach was to engage people from Government and industry who are actively involved in the transition towards ZEBs to gain their insights and thoughts on the matter.

In preparing this discussion paper we have relied heavily on what we heard from the 15 interviews held with bus operators, transport authorities, vehicle manufacturers and technical experts. We have overlaid these discussions to create meaningful insights and inform discussion at the Forum. The insights have been grouped into four key themes:

- Theme 1: Outcomes & Opportunities
- Theme 2: Policy & Planning
- Theme 3: Transition & Technology
- Theme 4: Ownership & Operations

A list of the participant organisations and people interviewed are listed in Credits.

Note:
With most of the interviewees based in Australia, the paper has a strong flavour towards the transition here. The insights provided by New Zealand participants provide a unique perspective given the deregulation of the bus system there and the larger individual deployments of ZEBs.

So, what are we talking about?

What became clear from the first interview is that industry and government are confusingly using similar terms. 'Low emission' and 'zero emission' sometimes mean the same thing, and other times it includes low emission diesel engines. For the purposes of this paper we have used zero emissions to mean zero tailpipe emissions. Participants spoke about the importance of using 'Well-to-Wheel' emissions, also known as lifecycle analysis and cradle to grave. 'Well-to-Wheel' is essentially the environmental impact from the original energy source and energy production through to the energy consumption – this is important in Australia where there is a high rate of coal generated energy.

The forum presents a good opportunity to better define what is 'low emission' and what is 'zero emission'. In doing so it would help jurisdictions in the future set expectations around transport objectives, vehicle standards, emission and energy targets and whether specific fuel types or the way they are generated are excluded.

State of play

In Australia and New Zealand, Government sets targets and sends policy signals on the types of buses and the associated infrastructure it expects to procure in the coming years. Currently low emission bus procurement targets are not business as usual in either New Zealand or Australia. Last year, the Australian Federal Government delayed the implementation of Euro 6 fuel standards (introduced in 2015) until 2027. Though New Zealand adopted it in 2018, they have a large number of second-hand imported vehicles.

To date, the UK, EU and China have started to decarbonise their bus fleets through setting aggressive national targets, which has included all new buses being 'low emission' by a certain year and then all buses by a targeted year. It is acknowledged that in a number of these locations, the government owns the assets and, in several cases, directly operates the services.

Wellington (NZ) has operated a large fleet of electric buses for well over 70 years, with the trolley bus system replaced by battery-electric buses in recent years. Prior to the abolition of trolley buses, modern vehicles were able to travel for short distances using onboard batteries. By mid-2023 Wellington is expected to have around 110 battery electric buses on the road (25% of the fleet). Auckland Transport targets a full zero emission bus fleet by 2040, with all buses to be procured as zero emission vehicles from 2025.

Throughout Australia several cities are planning or have begun ZEB trials on a smaller scale. While initial results are generally perceived as positive, discussions highlighted the need to be better at sharing insights and results across boundaries: *'How can we demonstrate that the technology is past its infancy and is ready for wider scale deployment?'* We discuss this further under the section 'What we heard'.

For Australia, transport is the second largest source of greenhouse gas emissions. Over the past decade transport emissions have grown by 10%, with emissions from buses growing nearly 100% over 2005 levels. Recent media reporting suggests Australia's emissions are expected to be 8% higher than 2005 levels by 2030, while our commitments under the Paris Agreement require a 26% reduction by 2030. Excluding emissions from the agricultural sector, transport is the greatest contributor to New Zealand's greenhouse gas emissions. It is one of the few countries worldwide to have a zero emissions goal enshrined in law (Zero Carbon Act). However, the Act does not introduce policies to cut emissions, rather it sets a vision and provides tools for further action.

Peak medical bodies such as the Royal Australian College of General Practitioners and Doctors for Environment Australia have called for tougher standards on air quality, including particulates such as PM 2.5 and PM 10, and nitrox compounds. They argue there is no 'safe' threshold or cut-off below which there is no health harm. Children exposed to long-term nitrogen dioxide, nitrogen oxide and PM2.5 from traffic air pollution are at an increased risk of developing poor lung function and asthma.

Potential Challenges and Issues

The following summarises some of the key challenges and issues previously identified in facing the transition towards ZEBs:

Vision and strategy

- Lack of a cohesive national vision, targets and champions
- Regulation, policy and standards around procurement, technology and targets either missing, contradictory or not fit for purpose

Ownership and collaboration

- Unclear charging infrastructure and depot ownership structures
- Lack of formalised partnerships and competition between operators reducing collaboration opportunities

Technology and knowledge

- Limited availability of trial data and monitoring of emission reductions
- Difference in bus standards for width, weight and mass restrictions
- Misinformation about disbenefits of clean bus technology
- Need for better information and training of people in the industry for promotion and operation of ZEBs
- Understanding grid capacity and charging impacts on generation requirements

Finance

- Risk of unforeseen whole-of-life costs including electricity grid upgrades
- High price of hydrogen, fleet and the indirect price on carbon
- Lack of clear and robust business case(s). This includes the case for low emission zones (LEZs) and the business case for bus operators to commit to change.
- High cost and low availability of zero emission bus fleet
- Need for incentives, funding and financing of the transition
- Lack of information about associated infrastructure and their financial case

What We Heard…

In developing our list of questions, we aimed to keep them very broad and open to allow participants to explore their thoughts, priorities and challenges regarding the transition towards zero emission buses. Having reflected on what we heard, four key themes have been identified.

THEME 1

Outcomes & Opportunities

Through the interviews it became apparent that the transition to ZEBs globally is being driven by different objectives. The case for change can be quite different depending on the local political landscape and community concerns.

So, considering the transition to 'Zero Emission On-Road Public Transport' as a strategic response, we have outlined and described the outcomes and opportunities people raised through the interviews. Of course there will be more and outcomes will need to align with the respective transport plans. Also, acknowledging local priorities and drivers for each jurisdiction, some outcomes and opportunities may be more important than others.

Climate change and emission reduction

Nearly all respondents discussed the role of ZEBs in meeting climate change commitments. Some felt the efforts in the bus sector are more of a gesture, and that efforts should be focussed on the biggest contributor – private vehicles. Also, with various jurisdictions either working towards long-term 2050 net zero emissions targets or having Acts that didn't tie them to actual short-term targets, it was easy to continue business as usual.

Some people felt it was important to not get caught in the hype or just doing it because we think it's a good thing.

One person asked: *"If the objective is to reduce CO_2 emissions wouldn't we be better to get more people out of private cars and onto low emission diesel buses? We need to remain agnostic and consider what is the appropriate response(s) to achieving the desired policy outcome."* However, on the other hand someone commented: *"It could become hard to justify the green credentials of an old diesel bus if someone can just as easily drive around in a modern electric car powered by renewable energy."*

Several participants raised the possibility of Australia becoming a market *"for where old technology diesel buses are sent"* as bans on diesel kick-in. Some indicated a stronger public commitment by Government to immediate climate change goals were required for industry to scale up and increase investment. Refer to 'Social Licence to Operate,' page 11.

Cleaner air

We heard that one of the main drivers for shifting towards ZEBs in the UK and Europe was around improving air quality. More and more cities are implementing 'Low Emission Zones' to improve air quality and the health of their citizens. There are now more than 250 such zones in place in the EU. At least 10 local governments in the UK are in the process of implementing Clean Air Zones, and in turn are creating a very strong incentive to transition towards ZEBs.

A subject matter expert pointed us towards the UK's greenerjourneys.com for case studies and developing the investment case for ZEBs. In the EU they are going beyond just clean air zones and now fine breaches in world health standards, such as nitrogen dioxide levels (NOx) and 16 global C40 cities have signed up to congestion free zones including Auckland (NZ), helping to fast track ZEB rollout.

We weren't made aware during the interviews whether any Australian or New Zealand jurisdictions were actively implementing LEZs.

One person mentioned though *"it's estimated a lot of people die each year (estimated to be 3,000 in Australia), but our air quality is generally rated as good, therefore the imperative to change isn't as strong in the communities' mind.*

The whole light rail business case in Sydney began with an effort to remove loud and dirty buses from the city centre. As buses were unable to be moved from diesel or gas, light rail became the product to solve that problem."

Another mentioned: *"If you truly accounted for the externalities of a diesel bus over its lifetime, it could add another $1m to the cost of the vehicle. When people talk about low emission diesel buses and Well-to-Wheel calculations they often assume that the vehicle is maintained in a good working order...we need to consider the amount of poorly performing diesel buses."*

Do we need to create stronger awareness of air quality issues in our cities?

Energy resilience and security

There was a bit of conversation with interviewees around the opportunity of rethinking the role of ZEBs and bus depots in relation to the energy system – discussed further in 'Key Theme 4' and in 'Reflections', pages 19 and 21. As we rely more on intermittent renewable electricity generation, storage is becoming an important element of the energy system, and in particular, to ensure buses are charged at an affordable rate for the next day's operation.

Participants highlighted the need to engage the energy sector early. This was not just about ensuring that there was capacity in the network for charging buses but asking what the role of ZEBs and the depots could be in supporting energy resilience. For example, a bus depot with 200 fully charged electric buses would be holding the equivalent energy needed to power 50,000 homes. This solution may involve on-site storage solutions (e.g. flow battery, liquid air) to collect energy during solar hours and trickle charge buses at night, or even potentially provide electricity back to the grid. Or provide the basis for an emerging hydrogen distribution grid.

Lastly, one person commented *"the pandemic has made us rethink energy security and self-reliance. Should we be 100% reliant on imports for fuel (diesel) to power our transport network?"*

How do we ensure better coordination and an agreed way forward with the energy sector?

LEGEND

Forum Question

Next generation jobs

It was common to hear comments and insights around using the transition to ZEBs to catalyse next generation jobs and stimulate the economy. For this reason, we have reflected on this further under the section '*A Nationally Significant Investment?*'. Key points raised included:

- Design, build and manufacture the entire vehicle in Australia, including the battery pack
- Restarting large scale vehicle manufacturing in Australia
- The research and technology could potentially cross to other fleets, for example rubbish trucks, airport vehicles, freight vehicles, other passenger vehicles
- University partnerships to develop and design software and battery technology
- Given ZEBs are modular in design, assembly could take place locally in each jurisdiction
- Establish an export industry for New Zealand and Australian made buses
- Encourage a shift towards next generation jobs, whether that is in vehicle design, advanced manufacturing or technology
- Financing and construction of new supporting infrastructure
- A more attractive and equitable industry to work in, given its clean environmental credentials

How important is it to consider the next generation jobs and manufacturing sector when pursuing a ZEB agenda?

A new product or service offering?

We have used a question mark for this heading as opinions differed quite widely from "*a bus is a bus*" through to the view that ZEBs present an opportunity to "c*ompletely reimagine the customer product offering.*" When respondents were asked about the key justifications for transitioning to ZEBs, around half started off with the customer experience.

A subject matter expert highlighted that previous ZEB trials they had been involved in saw passenger numbers increase, while all other routes saw declines. They had to have a customer engagement strategy in place to advise passengers when they were using diesel replacement buses due to the dissatisfaction with them.

In one interview we pondered whether electric buses could have the same type patronage bump, as we see when metro rail systems shift from diesel to electric, as was the case in Auckland and Perth.

An operator reflected that given buses move a significant amount of public transport users in Australia and New Zealand, switching to zero emission buses could significantly improve the experience and change the view people have towards catching the bus.

Another operator suggested it was time to reconsider the whole design of the bus given it is possible to remove the motor and powertrain: *"Could we showcase an entire route of what the future could be: modern stops, re-designed vehicle, extensive bus priority measures, branding, a real customer centric focus?"* It was mentioned that electric buses could potentially achieve higher passenger loadings through weight reductions (up to another 15 passengers) and faster boardings and alightings through a third door.

Another mentioned: *"Do zero emission buses change the business case for bus priority measures and increased priority across the network?"*

It was suggested *"electric drivetrains can have computer managed acceleration and deceleration curves that make the whole experience much smoother and safer for passengers."*

How could we be reimagining the whole-of-journey experience on a bus of the future?

Social Licence to Operate

Several interviewees either mentioned or alluded to their social licence to operate (SLO). Given the growing desire by the community to act aggressively on climate change and what people are starting to see achieved overseas with ZEB deployments, there is a real and growing risk that the current approach will no longer be acceptable to the community. We heard there was already vocal criticism occurring to new diesel bus purchases, as one

person mentioned *"it seems counter to State Government direction and legislation around renewables and reducing emissions."*

It is important to acknowledge that SLO is created and maintained slowly over time as the actions taken by the provider builds trust with the community it operates within. However, loss or damage to the SLO can happen over a very short period, *"In order to protect and improve our social license, we need to first be doing the right things and then be seen to be doing the right thing."*

It was mentioned how important it is to consider the entire supply chain, including waste management, battery recycling, and other aspects to ensure they were achieving the environmental benefits over the entire lifecycle. Another interviewee highlighted the need to *"ensure we don't forget about the existing supply chains and people involved in them from chassis builders through to diesel mechanics."*

Maintenance and operations

One of the key benefits people explained were not fully realised, are the significant maintenance and operational benefits of ZEBs. For example, the simplification of the mechanics means:

- a lot less things to go wrong
- a significant reduction in maintenance hours
- less need for costly parts throughout the life of the bus

Regarding operations it was noted how much cheaper electricity was than diesel on a per km basis. It was argued that focusing on operational expenditure over the lifetime of the bus, rather than the initial capital expenditure, would make ZEBs a very compelling offer.

A couple of people mentioned that people who maintain ZEBs have said they are much cleaner, easier and quicker to maintain resulting in less downtime, and produce less environmental wastage (for example through oil and diesel leaks). One person said, *"it may actually help to attract more people from diverse backgrounds to consider roles in maintenance and mechanics"*, given both the clean reputation and vehicle maintenance requirements.

Reimagining our streets and places

There was commentary around the potential for ZEBs to be considered as a key intervention in reimagining our streets and places. ZEBs could be better integrated into the streetscape and support the vision of the place rather than severely impacting on the public realm. *"We've all encountered the bus street: rumbling noisy bus, dirty, screeching brakes, people waiting over the footpath, it's a place you want to get through as fast as possible."* Do ZEBs enable the place vision to be achieved?

Someone mentioned, *"Could an electric bus, on a lower frequency route and limited to 30 km/h safely and comfortably share the same (dedicated) lane with cyclists?... Could we look at having electric bus sizes more applicable to the need, for example smaller buses for outer suburban centres and much larger buses with 300 passengers along key corridors in the city? This would mean less expensive vehicles and less batteries needed."*

Another asked, *"Will all ZEB's be full size, do you have small ZEBs operating on demand in some areas?"* From these comments we've reinterpreted this to think through both re-sizing the vehicles for the use case and thinking more about the human scale.

It was posed, *"we might see less resistance by residents to a bus stop near their house, as they'll be much less engine noise and plumes of smoke?"* and *"We see significant uplift in property values along light rail corridors, could we achieve value uplift if we treated an entire corridor with electric buses and new modern infrastructure?"*

THEME 2

Policy & Planning

Coordination and certainty

In Australia and New Zealand governments set targets to achieve public value and send policy signals to industry on the requirements and future demand for procuring buses. A common insight that came through is the considerable uncertainty industry has around the vision and policy direction for ZEBs nationally in Australia. It tends to be clearer for New Zealand, acknowledging that each jurisdiction is going to set their own mission in the ZEB space. Though some are pursuing an aggressive agenda, including the banning of diesel bus purchases or larger scale trials, others are cautious about being the first cab off the rank given the technology is still evolving and the risk of potentially making a significant investment in the wrong transition pathway.

It was discussed that a coordinated roadmap or transition pathway would help provide industry with more certainty and a clear direction, to enable operators, manufacturers and the broader supply chain to make the transition and take key investment decisions. It was felt by some that the core focus of Government should be on setting policy goal/outcomes and the procurement of services to create the right innovation and response from the market. Someone suggested whether it was possible to get commitment for a minimal number of ZEBs across New Zealand and Australia (for example 150 new ZEBs per year) in the near term to help spur the supply chains along.

Though it was acknowledged it may be difficult to get one overarching plan, the coordination activities could simply be a collation of the plans from jurisdictions centred in one location to help pull together commitments on proposed buying plans. As part of this coordinated 'roadmap' the following could be considered:

- Outlining the role of Government in coordination and regulation of the market, supply chain, procurement, standards and ownership of infrastructure to name a few
- Linking ZEB policy into wider policy initiatives and strategies around better health and liveability outcomes (such as clean air policy), city mobility and placemaking targets, as well as energy supply and demand strategies – especially emerging federal and state hydrogen strategies
- Assist Government planners and policy makers on various mechanisms available to achieve widescale ZEB penetration, such as new generation contracts, bus design standards, emission targets and innovative ownership/funding models
- Clearly outlining key milestones, targets and requirements to be achieved during the transition, including when certain fuel types will no longer be purchased
- Developing 'the why' for transition and business cases, including better appreciation of wider economic benefits of developing a ZEB industry in our region

Who is best placed to help coordinate and disseminate information nationally?

Better Question:
Would adoption of ZEB be spurred by national policies on fleet mix, emissions, supply chain and with certainty of support during transition?

Growing our champions

Several participants highlighted the need to significantly grow the number of champions of ZEBs from politicians through to bus drivers. *"Relying on just one leader or doing it because it's a good thing to do remains a barrier to the transition."* It was suggested to grow the leadership in this space to better understand the *"Why should we change?"* and better articulate the case for ZEBs.

Anecdotally, in the UK the main push towards low emission mobility by leaders, has been through the introduction of low and ultra-low emission zones. However, given our differing political priorities, we need to help our champions be in a better position to articulate the opportunities and benefits of transitioning towards ZEBs in our region. This could include creating next generation 'clean' manufacturing jobs through to redefining the customer experience.

To improve the knowledge of our champions, it was suggested further clarity is needed around:

- the vehicle range under varying operational geographical conditions
- charging and depot infrastructure requirements and ownership
- the current and predicted life span of the vehicle and battery
- the costs and benefits over the lifecycle
- risks and uncertainties in a widescale deployment of ZEB fleets
- impacts on the energy grid, upgrades needed and whether renewable energy is available
- Perhaps recast, to avoid electric bias, availability and certification of low emissions fuelling for ZEB fleets

Accounting for time horizons

The challenge of election, franchise and fleet replacement cycles was mentioned several times. For example, elections are held every three to four years, franchises seven to ten, and bus fleet replacements can be anywhere up to 25 years.

The other element discussed is the operational lifecycle of a bus. For most jurisdictions this was indicated to be 20-25 years, and even at that point they may go on to charter and school services for another ten years. Therefore, a diesel bus purchased today could potentially be still on the road past 2050. Jurisdictions will have legislated net zero targets by then.

Given the length of a franchise period (average eight years) can be for only a third of the life of a bus, it has several ramifications, including that operators may need to depreciate the value of the vehicle faster to make a return on investment sooner. This means capital expenditure can be valued more than operational expenditure over the life of the bus.

People suggested the following questions needed to be worked through:

- How do we break the cycle of focusing on short-term capital expenditure over longer-term operational benefits, and factoring in major externalities in the purchasing business case?
- The existing supply chains are set up to build diesel buses to last 25 years in Australia. Will ZEBs currently being deployed survive as long?
- How do we better transfer risk and achieve longer-term benefits?
- Would buses be more affordable if we adopted an 18-year end of life, similar to Singapore and Hong Kong? *"It may mean the buses are less expensive to manufacture and may not require a mid-life overhaul."*

Remaining agile

Though many commented that battery technology is ready for wide scale deployment, there was commentary, *"We aren't ready to commit to a particular path just yet...we need to remain technology agnostic...don't lose sight of the end goal."*

One person mentioned, *"though the time might not be ready to choose a path, we need to start planning to move beyond trialling a few buses to transitioning a whole depot."* It became clear that there was a need for knowledge sharing between jurisdictions, especially regarding trial findings and operator insights. Some felt in a competitive landscape it was difficult to get information on what was happening nationally, and how vehicles were performing. *"We're hearing a lot of talk but not getting much hard data...we'd heard there were brownouts (grid issues) when they plugged all the buses in at once during the evening peak – did that happen?"*

It was highlighted that given Melbourne and Sydney are tendering out some of the largest bus franchises in the region, people are looking to the respective transport authority to drive the agenda. *"These franchises will define the future of the country's bus fleet."* This last statement highlights the potential need for the franchise contracts to enable agility and flexibility to transition ZEB fleets into operation – see Theme 3.

To remain agile in a changing landscape, there were the following suggestions and ideas:

- Begin converting lower mileage routes today to ZEBs, and cascading diesel buses to other longer routes at other depots.
- Would it be possible to future-proof battery electric buses to enable a conversion to fuel cell?
- Investigate or future-proof contracts for third party providers. This could include undertaking market sounding activities alongside the franchise tendering.
- Understand existing depot capabilities, begin the planning and investment case(s) for dedicated ZEB depots/fleets.
- Actively engage and support the transition of the local ZEB supply chain.
- Understand grid resilience and what is required to maintain it if demand is changed, potential location(s) for new ZEB depots, and whether depots could act as energy storage locations.
- Look at the role of enroute and opportunity charging, including ownership and usage.
- Take an operational readiness approach today, such as bus driver training, upskilling mechanics, preparing depot space for charging infrastructure.
- Secure fuel supply chains of renewable energy.

THEME 3

Transition & Technology

Buses are the easy bit…

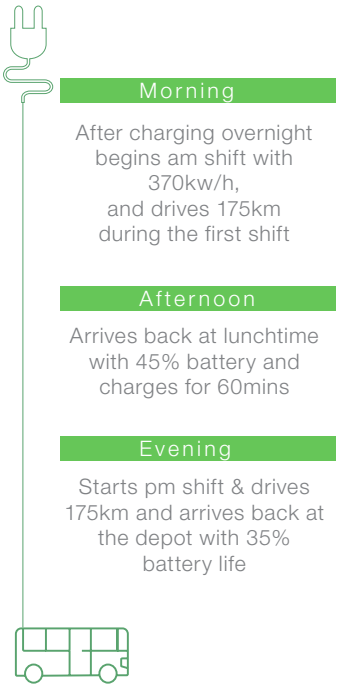
We heard from several people that battery electric bus technology is ready to be deployed widescale, and they have relatively easy access to buying the vehicles, but the major barrier is starting the transition towards ZEBs.

It was acknowledged that there was a need for trials not so much to understand whether the technology works but to showcase ZEB technology, increase awareness and help identify what needs to be done to get operationally ready. As part of this operational readiness it would help iron out any issues and risks, such as space needed at depots, impacts on the grid, and driver training.

The real-life case study provided to us (right) shows a typical day for a battery electric bus operating in Sydney: on a 30-degree day, with an average speed of 30 km/h, and up to 40 passengers per trip. Noting under this scenario it is likely to gain around 30-40 kWh from regenerative breaking and use another 6-8 kWh for air conditioning:

Enroute and fast charging

It was noticed how few interviewees spoke about the opportunities of enroute charging or 'opportunity charging.' When people were prompted, they mentioned it was difficult to know who would own the infrastructure outside of the depot, and if it would potentially become redundant as technology improves or we move to longer range fuel cell buses (hydrogen). Real-life case studies are showing what can be successfully achieved and alleviate range anxiety.



It was acknowledged that there would be special case studies for enroute charging of vehicles like the under-construction Brisbane Metro and the recently completed Newcastle Light Rail which charges at stops when passengers are boarding. Someone mentioned the possible return of the trolley bus where vehicles would operate on wires along key corridors and then on batteries for other sections. There was mention of the impact of the charging equipment on the street environment and supporting infrastructure needed.

There were thoughts from participants around the future of fast charging batteries. Some felt if we could get to the point of a 30-40-minute fast charge then the operational and scheduling characteristics could be like that of existing fossil fuelled fleets.

Hydrogen

In developing this paper, we were aware early on that we could write an entire paper on the virtues of hydrogen. Though we generally didn't ask specific questions unless that's where the conversation went, there was a lot of commentary. We want to highlight below is not a 'for or against' but rather a reflection of what we heard.

The biggest attraction of hydrogen powered buses are the performance and operational characteristics which closely mimic existing fossil fuelled buses. *"They'd be no change in our operations, our existing re-fueller could re-fuel the buses in the same amount of time…also we'd potentially not lose that much space (in the depot) in comparison."* The latter quote highlights the risk of losing depot space due to charging infrastructure for battery-electric buses.

Most people commented that they felt hydrogen still needed more time before being deployed widescale, and one person said it is *"a classic chicken and egg situation. If our diesel pumps break down, we can drive around the corner and fill up at any petrol station…the supply chain for hydrogen has a way to go."*

It was flagged that the capital expenditure is a key barrier for the adoption of hydrogen buses, *"a hydrogen bus currently costs around $1.5-2m each, then the onsite hydrolyzer, re-fuelling equipment could easily be another $10-12m. Hydrogen buses at scale are not even close to affordable at the moment…yes, the cost of buses, availability and access to hydrogen needs to be solved, but what are the standards that will be adopted in NZ and Australia for hydrogen infrastructure?"*

Community concerns are another key barrier, *"don't forget what the residents would say about having a hydrogen plant in their backyard!"*

One person claimed that hydrogen fuelled buses *"will always require 2 to 4 times as much energy as electric buses. Given how much power is needed each day for a bus we need to be very careful of the energy inefficiencies."*

What we understand from this quote is that they believe there is significant energy lost as energy moves from wire to gas to wire, while for a battery electric bus energy is transferred wire to vehicle. According to BMW, around double the energy is needed, therefore on their assertion to deliver 100W to the drive motor of a hydrogen bus would need 250W to be originally generated compared to 125W for a battery bus.

It was noted, *"with two thirds of our energy (Australia) coming from coal we need to make sure we're not generating brown hydrogen. We could make things worse from a carbon emissions point of view."* While another mentioned *"Australia has an oversupply of solar PV availability in the daytime, that could easily be harnessed to run hydrolysers at zero emissions, producing green hydrogen."*

While another comment was that it is important to stop focusing on hydrogen versus batteries, it is rather the use cases that hydrogen would need to play to support the transition towards zero emissions that should be in focus, such as, *"areas that are going to get very hot and will need strong air conditioning, like Western Sydney, up to 50 degrees!"*; *"Places where you have abundant and cheap renewable energy supply (i.e. inefficiencies don't matter); "Very long routes that need to operate across the day without re-fuelling"; "Or where hydrogen infrastructure has been established for other purposes, there is an off-shoot for buses, or vice-versa."*

One person mentioned that they thought *"hydrogen will play a significant role in achieving net zero carbon emissions in replacing (natural) gas in industrial, domestic heating, long haul freight and even the airline industry….Given the significant role of hydrogen in the future will it be an appropriate use for metro bus routes given they can easily run on batteries?"*

There were conversations around the existing CNG bus fleet and supporting infrastructure, *"Could we repurpose CNG infrastructure for hydrogen?"* Though an interesting idea, there are several flaws.

What are your thoughts on the comments made regarding hydrogen? What would be the most appropriate use cases?

What would be needed, and by whom, to encourage the transition to hydrogen?

Trials to transition

"Trialling electric buses is less about proving the technology, but rather helping get people ready and hopefully ironing out issues."

It was raised that though small-scale trials are important for growing awareness and support for ZEBs, we need to begin planning for larger scale deployments such as converting an entire route(s) and then an entire depot. These larger deployments would essentially start the transition process. One of the biggest areas raised was the retraining and upskilling of the industry. One participant from New Zealand outlined the education opportunities to upskill in the field of ZEBs.

Gaining knowledge and building redundancy in the local workforce was deemed required to de-risk the transition and achieve operational readiness.

How can we effectively upskill the industry without causing widescale angst and opposition?

THEME 4

Ownership & Operations

Moving towards a Fleet as a Service?

"Regardless of how we [the Government] currently structure it, we are essentially buying the bus. The question is if we actually want to own the bus at the end of the contract?... Given the significant investment we are making in the fleet through Government subsidies, should we be seeking to increase our return on investment?" This statement shines a light on the complex relationship of bus ownership and how they are procured in some jurisdictions.

It was explained in several jurisdictions that "*it is typical that the government procures the fleet via payments to operators and retains the fleet should the operator go into receivership. However, the operator manages the fleet for its life. The operator can buy the vehicle out at the end of the lease and put it into its non-public transport fleet for charter or sell on the vehicle whereupon it is removed from the government asset register...The question is if this model continues to work in a ZEB world?"*

Comments were made that it is easier for Government-owned fleets to transition to ZEBs, while it will be too difficult with private ownership. However, it was argued that it is a misconception that a Government-owned fleet makes it easier to transition to ZEBs. New Zealand, with a deregulated bus industry, will potentially be running up to 200 ZEBs by 2023.

To put it in perspective, Sydney has approximately 5000 buses. To completely renew the fleet over the next 20 years would require 250 buses to be purchased each year. If they were all battery electric the cost would be $188m ($750,000 per bus), compared to $125m for diesel buses ($500,000 per bus).

A person commented that "*given the significant investment we are making wouldn't we be better to treat electric buses like trams (light rail), we wouldn't expect operators to have their own depots and vehicles...The depots need to be strategically located and the right fleet purchased for the service requirements."* Another view questioned why we don't look towards other industries, *"in the airline industry, they lease the right plane for the job and, the banks even own the engines, airlines don't have a whole fleet of jumbo jets and just fly them on every route regardless! They pick the right plane for job to ensure maximum efficiency."*

Several interviewees suggested a greater role for the private sector as the market could:

- be in a better position to re-allocate limited and expensive resources/assets
- take a longer-term approach to investment decision making
- take on more of the purchasing, technology and operational risk
- even drive down the cost of buses through purchasing power

They suggested this market approach could allow the Government more flexibility to purchase services to achieve greater public value. For this paper we are describing this as *'Fleet as a Service*'. Under this banner we highlight two of the several ideas people put forward below:

- **Depot + Fleet**: under this scenario, a 'third player' would create dedicated ZEB depots, and procure the appropriate fleets. This would be over a 20-year period (handed back to Government after) and made available to operators over their defined franchise periods (e.g. 8-10 years).
- **Battery + Charging**: under this scenario, the bus manufacturer would provide the vehicle at cost parity of a diesel bus, the battery and charging equipment would remain under the warranty and ownership of the manufacturer. The battery equipment would be charged out on a per kWh used basis, over the life of the battery (usually 10 years). All risk with battery and charging remains with the manufacturer.

What other models are available that can achieve both greater public value and be attractive to financing?

Maintaining a competitive market

Following on from the points above, it was highlighted that for jurisdictions where operators maintain their own depots and fleets, it becomes tricky as to how the transition will occur. Given the expense of supporting depot infrastructure and the initial capital cost of the bus it can potentially create a significant barrier to entry.

Imagine a new operator trying to find an appropriate depot location, size and power grid capacity. Given a long-term investment is needed and the contract durations can be as little as five years, it is possibly unfeasible to make this upfront investment.

It was noted that, "*the NSW Government already has fleet and depot as a service. They effectively own them (fleet & depot) in trust, and lease em' back to the operators, then pay the operator to lease them. Transport Asset Holding Entity is the ultimate owner. If a contractor does not win the franchise bid, the whole fleet and depot shifts to the new owner.*"

Some key questions discussed:

- *"How do we enable the roll-out of this new technology and ensure the market remains competitive to operate services?"*
- *"Do we try and maintain the existing business model, by assisting operators to transition their existing depot to ZEBs?"*
- *"If we don't own anything how do we ensure the investment isn't wasted and are we getting value for money over the long term?"*
- *"Should we be intervening that much, or should we just set the outcomes we want and leave it to the market?"*

Driving affordability of vehicle procurement

Following on from what has been discussed above, several comments were made around what people thought could help drive the affordability of procuring ZEBs:

- Increase purchasing power, for example pipeline of committed orders, enabling larger orders, new business models.
- Standards and requirements, for example aligning Australian and New Zealand bus design standards with Europe (specifically vehicle width and rear axle loading). Could Austroads play a greater role in the harmonisation?
- Consider a lower bus life expectancy from 25 years to closer to 18 years. This would help make buses more affordable to manufacture in the first place.
- Ensuring ZEBs continue to be manufactured in a modular form.
- Consider making a strategic investment in developing and building ZEB batteries locally.
- Consider transitioning an entire depot at once to ZEBs.
- Aligning fleet specifications with route requirements, *"given the batteries are modular - could we reduce the number of battery packs needed for certain routes by up to a half?"* and *"Often we can re-fuel a bus every day and it doesn't do more than 100km but drives around with a full tank of diesel with a range of 700km."*
- As the European, Chinese, US, Korean and Japanese markets grow for ZEBs this will potentially help drive down the purchase price of ZEBs.

What other models are available that can achieve both greater public value and be attractive to financing?

Reflection

A Nationally Significant Investment?

It became clear that the transition of ZEBs goes far beyond simply reducing emissions. The investment in ZEBs could be viewed as a significant nation building exercise under Infrastructure Australia's nationally significant investment priority list. The investment would see an entire supply chain created, new investments in depot infrastructure and fleets, and transform the energy sector. The benefits of this national upgrade program would sit across the economic, social and environmental dimensions:

- Economic: significantly increasing our productive manufacturing capacity, enabling Australian-built vehicles to be globally competitive, upgrades of bus depot and electricity grid.
- Social: improving the quality of life for our streets and places, increasing employment through designing and building new vehicles, improving access to services through high-quality public transport provision. The most vulnerable in society are the most reliant on bus services, such services offer many a way out of social isolation.
- Environmental: significantly reducing greenhouse gas emissions, waste creation, noise pollution, visual intrusion, and more.

How can we coordinate between Federal and State Governments to realise this nationally significant opportunity to create next generation jobs, transform our public transport system and de-carbonise the transport system?

What would convince the National Cabinet that a ZEB transition is worthy?

Taking a Systems Thinking Approach to the Transition

Through conversations with stakeholders we discussed complex environment ZEBs. The transition requires changes across the ecosystem and throughout the system's lifetime, from manufacturing to operating, financing to training and infrastructure planning to end-of-life design.

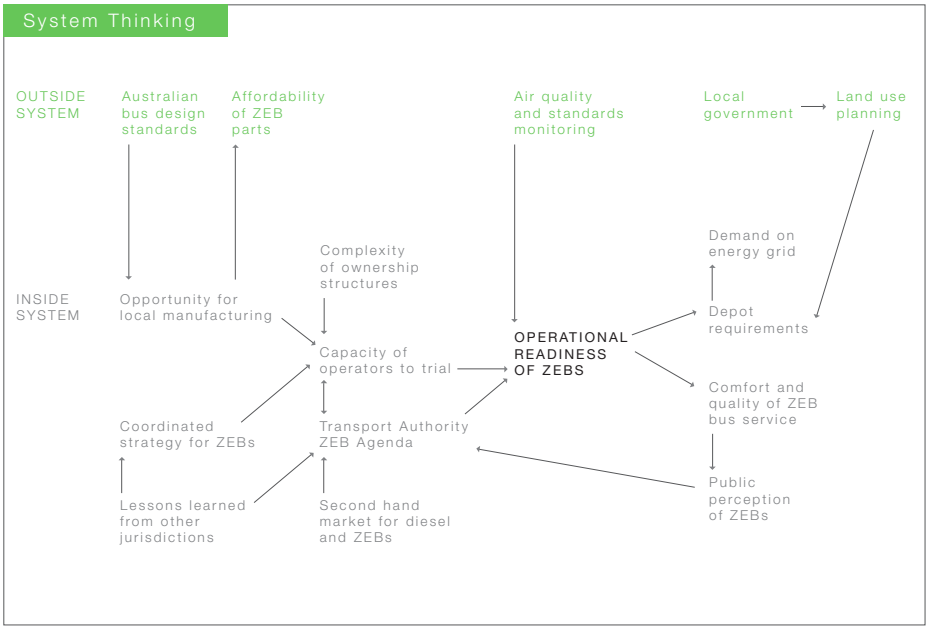
Systems Thinking is a multidisciplinary approach to complex problem solving providing oversight into the complexity of the system, its elements and relationships between them. It can help to understand the consequences of decisions and identify challenges and opportunities that might otherwise not be apparent.

Early adopting jurisdictions and operators of ZEBs will likely face high upfront costs and technology uncertainties.

It will be important for stakeholders across the system to collaborate in order to enable innovation, optimise infrastructure investments and accelerate adoption to meet climate goals.

Possible actions jurisdictions could consider:

- Program BC – what are the costs and benefits and models for this?
- Develop lifecycle analysis frameworks for vehicle and battery businesses
- Incentivise manufacturers to design products with end-of-life solutions in mind
- Provide consistent regulation and industry standards for vehicle deployment, infrastructure implementation and energy system upgrade
- Increase system interoperability to build users' trust and support system resilience



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