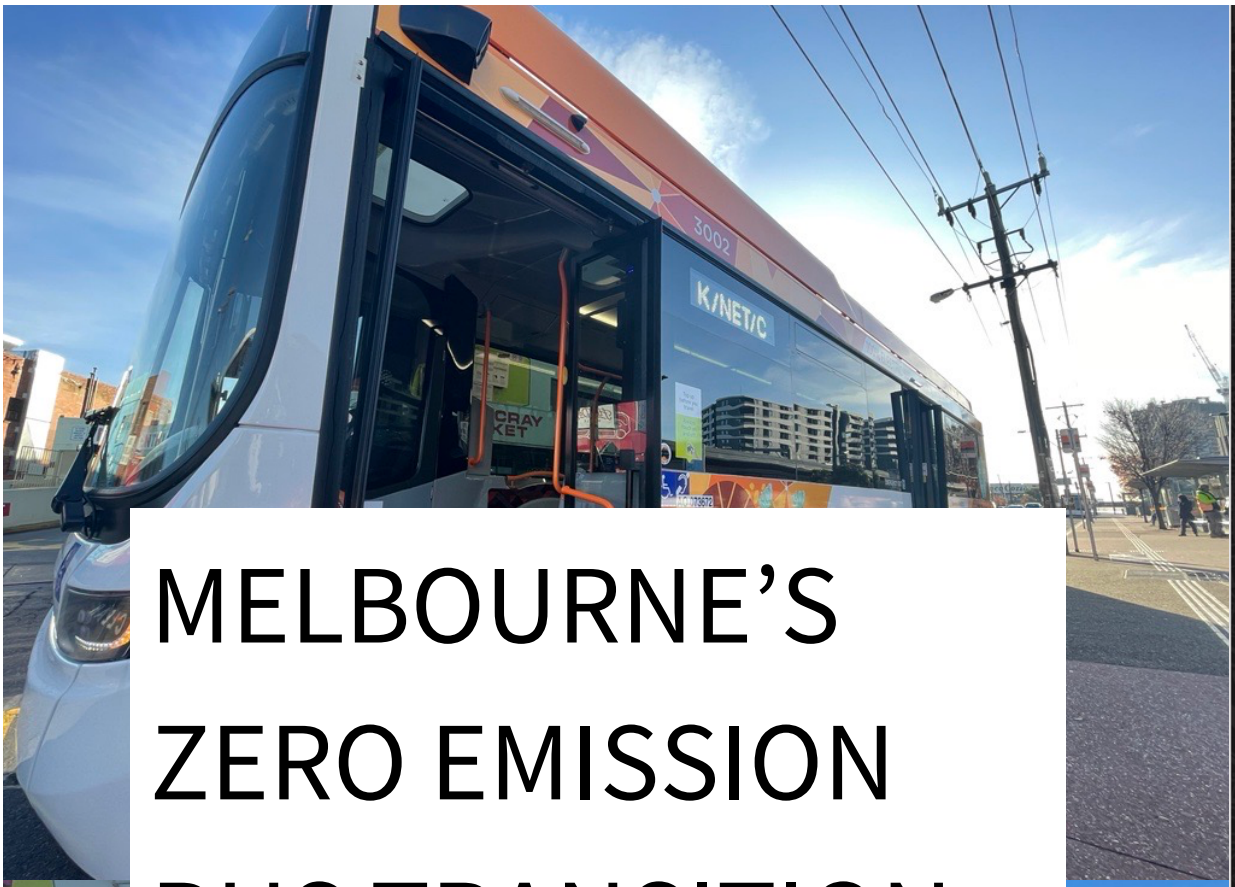

MELBOURNE'S ZERO EMISSION BUS TRANSITION

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THE UNIVERSITY OF MELBOURNE

Melbourne Centre for Cities

MELBOURNE'S ZERO EMISSION BUS TRANSITION

IAIN LAWRIE, NATASHA MANAWADU, and JOHN STONE

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INTRODUCTION

Governments across the world are rapidly decarbonising their cities as the effects of climate change intensify. The transport sector contributes approximately a quarter of all global greenhouse gas (GHG) emissions (World Resources Institute, 2020). Tackling the sector's emissions is instrumental to reducing global emissions. Transitioning to zero emissions buses[1] (ZEBs) is an important way for cities to reduce their carbon footprint, provided that renewable energy is used to generate the required electricity (Department of Transport (DoT) & ARUP, 2021).

Chinese cities dominate this transition, with 98% of all ZEBs operating in China (Song, Liu, Gao, & Li, 2020). European and North American cities are also accelerating their adoption of ZEBs (American Public Transport Association, 2019; European Union, 2021). Beyond the climate imperative, a rapid drop in price and advances in battery technology have accelerated the transition (United States National Renewable Energy Laboratory, 2020).

Although the transition to ZEBs, and EVs more broadly, represents a fundamental technological step-change which will decouple transport's reliance on diesel and petrol, the ZEB transition goes beyond just technology and operations. A smooth transition to ZEBs will require policymakers, operators, and other stakeholders to adapt current institutional processes–such as contracting–which have been built around the specific technical requirements of the diesel bus.

The ability for ZEBs to significantly reduce emissions is limited in cities, like Melbourne, where buses handle only a small share of overall travel. Policymakers and planners will need to act boldly to make buses a stronger part of a public transport system that offers a more competitive alternative to the car.

This paper is focused on the challenges and opportunities associated with transitioning the urban bus fleet in Melbourne. However, much of the analysis is relevant for other Australian cities. It is informed by a literature review and the results of guided discussions with an expert working group of bus industry professionals. The paper is designed to assist policy makers seeking to optimise implementation of various state-based targets. We first establish Melbourne's context by outlining existing efforts to transition to ZEBs in relation to international trends. We then outline the need for changes in bus operations

and maintenance required for the ZEB transition and highlight the current contractual barriers to making these changes. New considerations for ZEBs, such as changing infrastructure and energy requirements, are also explored. We conclude by outlining the critical considerations in Melbourne's ZEB transition and offer our recommendations for policymakers and industry.

[1] The Victorian government uses the term 'Zero Emission Bus', but it is not entirely accurate. Non-exhaust vehicle emissions from brakes and tyres are significant and arise irrespective of the powertrain. Some electric buses also incorporate diesel-powered heating systems. There may also be emissions associated with displacement of emissions from the vehicle to somewhere further up the energy-supply chain. 'Zero Exhaust Emission Bus' is more precise. (See UK Air Quality Expert Group, 2019)

BACKGROUND

The paper begins with a review of the academic and grey literature, which identified a growing body of work examining the challenges of a ZEB transition. Technical assessment of the two most promising approaches to ZEB deployment dominates the academic literature. These are battery electric buses (BEB) and hydrogen fuel cell buses (FCEB). While we do not underestimate the engineering difficulties of refining an emergent technology, our analysis of the breadth of both grey and academic literature suggests that BEBs are increasingly a mature offering. FCEBs, while technically understood, remain more costly. Hydrogen appears to offer promise for heavy line-haul applications and thus may play a role for long-distance coach operations. However, rapid advances in range, reliability and reductions in cost mean BEBs appear poised to usurp traditional diesel buses in most urban bus markets. So, our focus in this paper is on BEBs rather than FCEBs.

We have identified some vital questions about the ability of BEBs to fit into the existing institutional structures which deliver route-bus services.

- Can BEBs be deployed under contract arrangements currently operating in Victoria?
- Are there contractual barriers to BEB deployment within pre-existing service contracts?
- Can BEBs be 'drip fed' into existing operations, or must entire depots be electrified in one go?
- Is there sufficient space or grid capacity at those depots to handle full electrification?
- If the overall objective of a ZEB transition is to reduce carbon emissions, are there higher order questions to be asked of how our urban bus networks are structured, serviced, and organised?

Very little academic or grey literature addressed these collective challenges, particularly in the Australian urban context.

To answer the questions raised in our literature review, we assembled a working group of five Victorian bus industry experts. Their expertise covered bus operations, contracting, network planning and technology. Regular meetings were convened to address a series of research questions. Further experts were drawn in to provide insight to specialist issues, including battery and bus manufacturing, bus safety and energy supply. We also conducted a series of one-to-one meetings with individuals from the core group and other industry specialists. These provided deeper insight in specific areas. Both the group and individual meetings were held by video conference.

MELBOURNE'S ZEB TRANSITION IN ITS NATIONAL AND INTERNATIONAL CONTEXT

Public transport operations in Victoria comprise regional rail and coaches, and metropolitan tram, train, and bus services. Apart from the regional V/Line rail operations which remain as a state-owned corporation, all services are operated by private companies under a variety of franchises and contracts with the Victorian State Government. Metropolitan train and tram services—currently franchised to MTM and Keolis Downer respectively (Public Transport Victoria (PTV), n.d.)—represent privatised operations of formerly government owned and operated services under the Public Transport Corporation and its separate state-owned rail and tram forbears (Victorian Auditor-General, 2005). Historically, most Melbourne's bus services were initiated by private companies and have remained so throughout their existence. This has resulted in a sense of ownership of their routes by these private companies, even though they only remain in operation through state subsidy (Victorian Auditor-General, 2009). Other bus routes, now contracted to the private sector, were previously operated by state agencies. The result is a heterogenous bus industry comprised of both multinationals and small family-owned operators.

Approximately 30% of metropolitan Melbourne's bus routes have been competitively tendered since 2013 under the Metropolitan Melbourne Bus Franchise (MMBF). These routes dominantly, but not exclusively, represent bus routes operated by the former state-owned Tramways Board. The remaining 70% of Melbourne's bus routes are provided through 27 separately negotiated contracts.

Melbourne's public transport services operate in a highly car-dependent city. At the 2016 Census only 13.4% of work journeys were made using public transport (Australian Bureau of Statistics, 2016). Of Melbourne's three key public transport modes, buses have much lower patronage, with 122 million annual boardings in 2018/2019 compared to 205 and 243 million for trams and trains respectively (Public Transport Victoria, 2020). This is despite bus services being the only public transport option available for much of the city's middle and outer suburbs. Melbourne's buses suffer from a poor reputation - perceived as more unreliable, uncomfortable and infrequent compared to other public transport modes (Roberts, 2020). Consequently, to increase their utilisation and maximise the benefits delivered, any bus service improvements in Melbourne—including a ZEB transition—must address the key factors which have led to this low public perception and ridership.

THE NATIONAL AND REGIONAL CONTEXT

Compared to leading examples in China, Europe and North America, Australian cities have been very cautious in their ZEB transition. Despite Commonwealth institutions possessing the potential to drive change through mechanisms such as common standards for vehicle emissions, Australia's ZEB transition has been led by the states and territories.

NSW has the most ambitious policy settings, committing to transition its entire bus fleet to ZEBs by 2030. Transport for NSW has also released a ZEB transition strategy for public consultation, signalling the government's commitment to proactively lead the process (Transport for NSW (TfNSW), 2021). The

ACT government has also made a similar commitment to fully transition its bus fleet to ZEBs by 2040 (UITP, 2021). ACT has made significant strides, completing and publishing the results of its ZEB trial conducted over 12 months in 2019 (see ACT Government, 2019). Based on learning from their trial, the territory government has established an active market process to procure over 120 BEBs as part of its fleet renewal (Transport Canberra, 2021). Across the Tasman, Auckland, New Zealand has announced that all new buses will be ZEB by 2025, with a full transition by 2040 (Auckland Transport, 2020). Auckland's transition has been underpinned by the NZ government's commitment to emissions reductions, supported by localised demand for emission free buses in support of climate change mitigation efforts (ARUP & UITP, 2020).

While in its infancy compared to leading global cities, Melbourne's ambitions for the ZEB transition are comparable to NSW. The Victorian government recently announced that, from 2025, all new buses purchased in Victoria will be ZEBs. This commitment is reflected in the new Victorian Bus Plan (Victorian Department of Transport, 2021c). The Victorian Department of Transport (DoT)—Victoria's overarching transport agency—has also announced an AUD$20 million ZEB trial. A bidding process is underway with an award expected in early 2022. While The trial, and the recent announcement of the deployment of a small number of ZEBs through Kinetic's successful bid for the large Melbourne Metropolitan Bus franchise (see below), are designed to pave the way for a full ZEB transition.

It remains unclear how the overall ZEB transition will occur. Victoria's policy, unlike NSW, ACT and Auckland, does not specify a timeframe for the full transition.

INTERNATIONAL EXEMPLARS

China is leading the global ZEB transition, with 98% of the world operating ZEBs and two of the world's largest BEB manufacturers, BYD and OEM Yutong (Bloomberg, 2021; Song et al., 2020).

Shenzhen—a major city in south-eastern China—is also the first city globally to fully electrify its fleet, reaching this milestone with its 16,000-strong fleet in 2017 (World Bank, 2021). Such a rapid transition was enabled by strong policy leadership and vertical and horizontal coordination between national and local departments. At the national level, the Ministry of Industry and Information (MIIT), National Development and Reform Commission (NDRC), Ministry of Science and Technology (MOST), and Ministry of Finance (MOF) collaborated closely on policy to prioritise the electrification of bus fleets, establishing a program from 2009-2012 to deploy at least 1,000 'new energy vehicles' (NEVs) in Shenzhen and nine other cities (World Bank, 2021). Locally, the Shenzhen municipal government established a multi-departmental working group to promote NEV development and implement national NEV policy (World Bank, 2021). In addition to establishing transport electrification as a policy priority, national and local governments subsidise multiple elements in the BEB value chain, including vehicle and battery manufacturing. Subsidies and public-private partnerships (PPPs) also play a significant role in providing Shenzhen's extensive EV and BEB charging infrastructure (Li et al., 2020). To reduce the high upfront capital costs and risks associated with procuring a new fleet of ZEBs, state-owned third-party financial leasing companies were established to purchase the ZEBs and lease them to operators (Li et al., 2020). The maintenance of vehicles and batteries are also decoupled, with ZEB manufacturers and charging infrastructure operators responsible for maintaining their respective assets (Li et al., 2020).

While Shenzhen does not have a directly comparable urban structure or governance to Melbourne, Shenzhen's example highlights the need for government to lead and facilitate the ZEB transition across diverse and disparate operators, and the need for innovative institutional arrangements, whether in procurement, financing or contracting. China's explicit intervention in the industry has resulted in BYD and OEM Yutong now established as major global players in international bus markets.

Figure 1: Electric buses in Shenzhen (Source: CleanTechnica, 2020)

Although not as advanced in ZEB transition as China, Europe's more comparable governance and institutional structures provide transferrable lessons for Melbourne. European cities benefit from strong climate leadership and EU cooperation on the ZEB transition. For example, since 2016, the European Commission has organised the European Clean Bus Deployment initiative, committing participant cities to an accelerated roll-out of ZEBs and establishing a deployment platform and expert group for public transport stakeholders to share information (European Commission, 2017). The European region also benefits from other European Union (EU)-funded ZEB programs, such as the Zero Emission Urban Bus System (ZeEUS) research program coordinated by international public transport association, the UITP (ZeEUS, n.d.). Significantly, the European Parliament passed a Clean Vehicles Directive, binding EU member states to procuring only zero emissions vehicles (ZEVs)—including ZEBs—from 2026 (European Commission, 2019). Collectively, these initiatives have provided the policy certainty for technology investment, driving down costs to ensure European bus manufacturers remain competitive alongside Chinese firms in the global ZEB bus market. The Netherlands appear to be the leaders in the pursuit of the EU Directive.

Outside the EU, London is a signatory to the C40 Cities Fossil Fuel Streets Declaration and Clean Bus Declaration of Intent (C40 Cities, 2015). Through these declarations, London has pledged itself to procure only ZEBs from 2025 and ensuring that large parts of the city are zero emission by 2030 (C40 Cities; 2015).

In a structure partially adopted in Melbourne, London's buses are operated by private firms regulated through performance-based contract management (Transport for London (TFL), 2015). London's transition thus offers transferrable lessons for Melbourne. A subsidiary of Transport for London (TfL)—London's overarching transport agency—manages the bus fleet by planning routes, setting service levels and monitoring service quality across the private operators contracted by TfL to operate bus services (Transport for London (TfL), n.d.). Of the over 9,000 buses managed by TfL, 485 are BEBs, 2 are FCEBs and 3,884 are hybrid buses (Transport for London (TFL), 2021a).

London's ZEB transition has been guided by the sustainability commitments of successive London mayors, who have paired public transport incentives with private car disincentives to encourage people to shift their travel to more sustainable transport modes (Logan et al., 2020).

Figure 2: London's Ultra Low Emission Zone (Source: ABC News, 2019)

Transport planning in London is guided by an ambitious goal articulated in the Mayor's Transport Strategy 2018. The target is for 80% of all trips in London to be made by active and public transport by 2041 (Mayor of London, 2018). The Transport Strategy also reinforces London's commitment to ZEB-only procurement from 2025 and a complete fleet rollover by 2037 (Mayor of London, 2018). Other programs, such as London's Ultra Low Emission Zone, further bolster London's transition to ZEBs (Transport for London (TfL), 2021b). London's emerging ZEB transition is thus linked to both a defined political commitment on climate imperatives and tangible policy settings on transport outcomes. In turn, private operators have clear guidance and certainty as to future conditions (Argyriou & Barry, 2021). London's policies are supported at a national level, where the UK government has recently launched a £3bn National Bus Strategy, poised to deliver 4,000 British-built BEBs and FCEBs across the UK (Department for Transport (DfT), 2021).

Both Shenzhen and London's experience highlights the need for strong political commitment and a policy mandate with clear targets. It also signals the need for a steering body with strong regulatory oversight that is backed by funding commitments from government.

Overseas experience indicates that many challenges inherent to the ZEB transition have been accompanied by contractual and financial innovations. Drawing from a previous example, Shenzhen's ZEB transition saw the introduction of new players and new contractual and financial arrangements. Crucially, the leasing and maintenance of buses and batteries were decoupled, representing a significant departure from previous contracts to operate diesel buses. Shenzhen's case is not uncommon; a study of 22 cities across the Americas, Asia-Pacific and European regions found that 7 of the 22 cities implemented innovative contractual arrangements during their ZEB transitions (Li et al, 2018). For example, Bogota has similarly decoupled the leasing of buses and batteries, and the city explored alternative contracts for maintaining the fleet and training staff. Hybrid bus manufacturers in Bogota had contracts to not only maintain the buses for an initial 5-year period, but to also train the operator's mechanics so that they would be able to take over once the manufacturer's maintenance contract ended (Li et al., 2018, p. 475). In Gothenburg, energy companies are investing in BEB charging infrastructure (Li et al., 2018, p. 475). These examples highlight not only the need for governments to re-invent their contractual arrangements for bus services, but to also consider new players in ZEB operations.

The following section identifies some of the key technical shifts associated with the ZEB – and specifically BEB - transition. We then place those shifts in context of Melbourne's existing bus contracting arrangements, identifying areas which are likely complicate the uptake of ZEBs in Melbourne.

ZEBS REQUIRE A SEISMIC SHIFT IN BUS OPERATIONS & MAINTENANCE

The transition to BEBs requires a seismic shift in how bus operations occur in Australian cities. Our discussions with industry operatives and review of the emerging literature identify several operations and maintenance challenges of the ZEB transition. We outline these below.

SKILLS AND RETRAINING

Maintenance requirements for BEBs differ significantly from ICE buses. Existing skillsets in maintaining internal combustion engines, relevant for decades despite incremental technology improvements, will become redundant. While a small range of maintenance skills may remain relevant, new skillsets related to electric propulsion will be required. Uncertainty in transition timing makes it difficult, particularly for smaller operators, to prudently invest in these new skills, or to know when to continue investment in status quo skills development, such as diesel mechanic apprenticeship programs. Skills acquisition and retraining will emerge as an industry-wide challenge. Government will clearly have a role to play in guiding labour reskilling through TAFE and other higher education programs. With longer durations expected between major overhauls, it may be prudent for governments to invest in centralized BEB maintenance facilities, rather than the status quo depot by depot arrangements. This will, in turn, affect contractual arrangements and will require negotiations with unions. These changes–while delivering operational and maintenance efficiencies–will have significant near-term impact on operators and their ability to effectively price their operations.

CHARGING STRATEGIES

While the battery capacity of BEBs procured beyond 2025 are likely to manage the full daily shift of a typical urban bus route (European Bank for Reconstruction and Development, 2021), differing approaches to re-charging present new operational and procurement dilemmas. Each approach has limitations, with a preferred method yet to clearly emerge in the Australian urban context. We discuss the differing methods and challenges briefly below.

Inside depots, buses can be trickle charged overnight on cheaper, standard voltage plug in chargers. This requires deployment of equipment to each bus layover space. Alternatively, fewer fast chargers could be deployed, necessitating 24-hour depot operations to rotate buses through their charge cycle and seamlessly shuffle vehicles that will start and end service at various times. Both approaches are likely to reduce depot capacity.

Some BEB manufacturers are combatting these issues by offering overhead gantry recharging infrastructure for depots, allowing all bus parks to recharge through tram-like rooftop pantographs. However, the approach is rather inflexible since buses will not be able to rotate between routes unless all buses and depots are similarly configured. The approach potentially risks a technical 'capture' that limits future bus procurement to the initial supplier.

An alternative to universal depot charging is 'opportunity' charging infrastructure in public streets. This may provide additional flexibility to depot charging. However, it must be done with care: charging at a terminus introduces problems with on-time running since the vehicle must lay idle for a certain period to re-charge before re-entering service. A delayed outbound trip will consequently delay all further trips for that vehicle.

'Flash' charging, where the bus is provided a rapid charge at selected stops, imposes a short but usually acceptable delay on the vehicle. But this requires substantial electrical capacity, which if not available

in locations which suit bus operations will incur expensive grid upgrade costs. Locations must also provide dedicated road space. Further, it is operationally difficult to share 'flash' charging equipment on higher frequency routes, since following buses will be delayed awaiting a previous bus to complete its charge cycle. Nevertheless, flash charging operations may increase depot efficiency by allowing buses to enter daily service with only partially re-charged batteries.

Further technological solutions are emerging in response to these challenges. 'In-motion' charging involves overhead trolley wires being installed along select sections of route, enabling buses to re-charge while in service and without operational delay. With the benefit of such broader recharging support, buses may be able to have smaller, lighter batteries. 'In-motion' charging may prove more economic than single, high capacity 'flash' charge points, but introduces additional visual infrastructure to the urban street and reduces route flexibility. The overall cost, benefit, and operational efficiency of standard, fast, gantry, flash or overhead in-motion recharging approaches remains an unexplored aspect of the Australian BEB transition. In a rapidly evolving technical landscape, risks are manifold, particularly those around interoperability of technology and risks of procuring what may become stranded assets.

Figure 3: Opportunity 'flash' charging pantograph (Source: OppCharge, n.d.)

NEW MARKET PLAYERS

These technological challenges are largely beyond the expertise of smaller private bus operators. New infrastructure finance players are attempting to fill this gap. They have identified a niche in providing upfront capital for bus procurement and maintenance, depot reconfiguration, charging infrastructure and a long-term hedged price on electricity supply. Such groups would represent the interests of electricity retailers, bus manufacturers and infrastructure financiers, and bus operators would pay an ongoing 'availability' fee for the provision of a functioning ZEB system.

However, such arrangements could be problematic. Government would be exposed to two separate private-sector margins for risk – one for the financier, and one for the operator. Despite benefits of price certainty and technical risk management for existing private bus operators, the state is likely to pay a premium and have little flexibility in the way services are delivered. Such integrated offerings would also add a complex layer to Melbourne's current private bus contracting arrangements, which, as we discuss below, are already unsuitable for managing an effective ZEB transition.

MELBOURNE'S CONTRACTING ARRANGEMENTS: UNSUITABLE FOR THE ZEB TRANSITION

While BEB technology is rapidly maturing, Melbourne's current bus contracting arrangements are broadly incompatible with a smooth path to a ZEB future.

To explain why this is the case, we first describe the scope and form of existing bus contracts in Melbourne. We then identify inherent frictions between existing contracts and the demands of the shift to ZEBs. These include long-standing contract provisions relating to operations, maintenance, and new bus procurement, as well as misplaced or absent incentives for fleet, asset, and depot renewal. We further identify current asset ownership as a specific challenge in the Melbourne context. Finally, we identify opportunities for reform.

CONTRACT FORM

Melbourne's 355 route bus services are provided by 14 businesses under 28 separate contracts overseen by the Department of Transport (see Public Transport Victoria, 2021). The competitively tendered Melbourne Metro Bus Franchise (MMBF) contract, recently awarded to Kinetic (in place of Transdev), will run until 2031. The remaining 27 contracts with established small to medium-sized operators run for 7 years with the option of a 3-year extension, subject to operators meeting performance obligations (see UITPANZ and Allens Linklaters, 2021; Victorian Department of Transport, 2021b).

Contracts are predominantly route-based, mandating specific service parameters, such as timetabling and stopping patterns. The contracts also stipulate general vehicle and depot standards and include a performance monitoring regime to ensure these standards are met.

The acquisition of new buses is also governed by contract terms – although the process and procurement structures are not uniform.

Critically, contracts are structured around the operational requirements of diesel buses and, apart from the new MMBF[2], do not consider a transition to ZEBs. This introduces a range of complications.

Bus turnover schedules assume that retiring vehicles are replaced with new diesel buses. Contract payments are adjusted based on the age profile of each operator's fleet to allow for orderly replacement. This cost structure has been predictable and could be agreed at the outset of each contract. Pricing structures are negotiated with government on the confidence a new diesel bus will perform equally well (or better) in terms of reliability and performance than retiring diesel fleet. Further, pricing could be based on well-understood arrangements to hedge diesel fuel costs, foreseeable maintenance programs, and provisions for driver and maintenance staff training.

Cost structures for ZEBs are not yet predictable. ZEB purchase costs (at least for the foreseeable future)

[2] In September 2021, Kinetic was awarded the $2.3 billion Metropolitan Bus Franchise. Kinetic have agreed to introduce 36 fully electric buses to the network by mid-2025, including five by June 2022. 341 of the 537 buses will be replaced with hybrid or ZEBs over the 10 years.

remain higher than diesel buses, although this is offset by lower operating costs (see European Bank for Reconstruction and Development, 2021). Overall, the ongoing costs for maintenance, training, and power supply (through arrangements with electricity retailers and wholesalers) cannot be guaranteed with any certainty.

Bus operators will expect the government to bear any of the as-yet-undetermined risks of operating a ZEB fleet.

Current contracts may be able to deal with the purchase of new ZEB vehicles but do not have the capacity to allocate costs for installation of new charging infrastructure. There would also need to be new provisions to manage operational risk for power outages, charger malfunction, or failure of ZEBs to achieve advertised range performance: would these be the responsibility of the operator, the energy supply company, or the manufacturer? The new market for integrated finance/energy/bus supply packages, described earlier would undoubtedly appeal to smaller private operators, but would governments be willing to pay what is likely to be a steep price?

Current contract structures seem unsuitable for managing a smooth ZEB transition in Melbourne: our expert working group concluded that the ZEB transition will not just stretch existing contract assumptions, it will break them.

We anticipate the transition will only pick up pace only if the government waives some contract parameters and assumes a larger share of risk. This is especially the case given the Government's commitment to purchasing no new diesel buses after 2025. In Melbourne's fragmented bus market, many contracts expire in 2025 and new contracts could be in place to enforce the ZEB mandate, but not all do (see Table 1 below), and so the purchase of new ZEBs will presumably need to be done under existing contracts.

FRAGMENTED ASSET OWNERSHIP IN MELBOURNE

Compounding the contractual issues identified above is the fragmented asset ownership of depots and buses themselves. While most operators own their fleet and depots, this is not always the case. Many operators lease buses directly from private suppliers (where in many cases the ultimate owner of the bus is a bank or finance company). Some utilise only buses supplied by the state. Others operate a mixture of owned and state-leased buses. Likewise, although depots are predominantly held by each operator in freehold title (or long-term private lease), some depots remain in state ownership (see Table 1). Government also maintains an interest over some privately held depots through a mortgage to a state entity owned by PTV.

This patchwork asset structure ultimately reduces control and certainty for the state, complicating how government might choose to deploy ZEBs and how crucial changes, such as installation of charging infrastructure, might occur. It is thus logical to prioritise electrification of the publicly owned depots under Kinetic's MMBF to facilitate a substantial initial transition.

However, state investment to upgrade charging infrastructure at freehold depots may undermine any future attempts to conduct genuine competitive tendering for the routes operating from those sites. Similarly, expecting private operators to make significant investments in depot-based charging infrastructure when contract periods are vastly shorter than the operational life of such infrastructure would equally be unrealistic. The cost of any depot upgrade – and specifically the risk that assets might be stranded if subsequent contracts were not won – would be lumped into bid prices, inflating the cost of public bus operations. A resolution may involve government taking a long-term lease over the depot and having a 'right of first refusal' in any proposed sale as conditions of state investment in new charging infrastructure. Regardless of the exact approach adopted, novel methods of contractual 'work-around' may be required to ensure a ZEB transition on freehold depot sites can occur in the long-term public interest.

Further, the unique requirements of electricity supply to individual depots may distort the competitive positions of existing bus operators. The specific requirements of upgrading electricity supply will vary location to location. Some depots will be cheap to upgrade, others potentially prohibitively expensive. Investigation of local grid capacities at specific depots was beyond the capacity of this project, but government will need to understand this in some detail.

In the light of the issues raised here, we believe that state procurement of the ZEB fleet and non-depot charging infrastructure (should it be necessary) is likely to be the most cost-effective way to manage the transition. Failing that, the least requirement will be to provide operators with detailed standards and minimum specifications. However, the problem of procurement of charging infrastructure on privately owned depot sites remains fraught. One approach may be to significantly extend contract duration. this is not a complete solution, but it would allow more opportunity for amortisation of long-life fixed charging assets.

Without much greater government control of depot assets, we question the ability to conduct genuine competitive tendering for the non-MMBF contracts until ZEB technology has fully replaced existing diesel operations.

Operator	Number of routes	Depots	Depot Ownership	Estimated route-bus fleet	Contract end date
CDC Melbourne	55	Oakleigh South Sunshine Airport West Truganina	Private Private Private Private	90 61 37 170	30 June 2025
Cranbourne Transit	16	Cranbourne	Private	72	30 June 2028
Dysons	54	Bundoora Reservoir	Private Private	207 61	30 June 2025
Kastoria	14	Westmeadows	Private	84	30 June 2025
Martyrs	1	Warburton	Private	6	30 June 2025
Moonee Valley	2	Tullamarine	Private	9	30 June 2025
Moreland	2	Brunswick	Private	10	30 June 2025
McKenzies	4	Healesville	Private	9	30 June 2025
Panorama Coaches	5	Diamond Creek	Private	17	30 June 2025
Ryan Bros Bus Service	3	Tullamarine	Private	20	30 June 2025
Transit Systems	18	West Footscray	Private*	161	30 June 2028
Sunbury Bus Service	7	Sunbury	Private	19	30 June 2028
Kinetic	49	Sunshine West Thomastown Doncaster Heatherton Keysborough North Fitzroy	Public* Public* Public Public* Public* Public	85 50 164 44 55 136	31 Jan 2031
Ventura Bus Lines	125	West Heidelberg Rosebud Monbulk Dandenong Seaford Croydon Pakenham Moorabbin Hastings Knoxfield Lilydale Oakleigh	Private* Private Private Private* Private Private* Private Private Private Private* Private Private*	27 42 32 186 72 81 86 73 24 116 48 59	30 June 2028
TOTAL	355	34		2413	
	Table data sources: ptv.vic.gov.au, bus operator websites, tenders.vic.gov.au, landdata.vic.gov.au. Private*: Depot privately owned with mortgage to Public Transport Development Authority (PTV). Public*: Depot owned by the Franchise Asset Ownership Corporation, a state-owned entity.				

Table 1: Melbourne private bus operator, depot, route, and fleet structure

RE-SHAPING BUS CONTRACTS IN MELBOURNE

Our working group concluded that, for the transition to ZEBs to occur smoothly, a complete re-structuring of Melbourne's existing bus contracts will be required.

One option is to replace current competitive tendering with a more transparent 'cost-plus' model during the interim phase, and to resume franchising only once significant changes such as depot upgrades and charging infrastructure installation have occurred and the operating costs and risks of ZEBs are better understood.

Another option, with institutional precedent, is reducing contract operational performance risk (OPR) to zero until ZEB performance benchmarks are established, before re-instituting re-calculated OPRs.

Both these options will require DoT to build its expertise in all the relevant operational issues including the ways in which energy might be priced into ZEB operations.

Importantly, industry players were unanimous that the state will need to take on the risks of the ZEB transition, particularly as control would revert to the government should operators be unable to meet their contractual obligations. This points to a greater need for government to make the key decisions in the ZEB transition, contractual or otherwise, rather than wait for the market to deliver.

THE MAIN GAME: EMISSIONS REDUCTION

The intricate technical and contractual demands of the ZEB transition can easily divert attention from the main goal which is to decarbonise Victoria's transport system as fast as possible.

Australia's commitment the 2015 Paris Climate Agreement has been translated into various policy pledges by state and territory governments to reach net zero emissions by 2050 or earlier (ClimateWorks Australia, 2020). With transport contributing a third of national emissions, there is a climate imperative for Australia's transport sector to accelerate towards less carbon-intensive transport modes and travel patterns (ClimateWorks Australia, 2020). To do this, commitments to better integrated transport and land use planning will need to be strengthened to drastically reduce private car travel in our car-dependent cities. Technological shifts also have a role to play in reducing transport emissions. Beyond electrifying private vehicles, BEBs and possibly FCEBs will play an increasingly important role in emissions reduction, particularly as efforts to increase public transport's mode share intensify.

Rapid replacement of the diesel bus fleet is an essential part of reducing transport emissions, but it is not the whole story. Achieving the necessary rate of emission reduction will require many car-trips to be replaced by electrified public transport.

So, what changes will be needed to make to bus services to attract a significant mode shift? How many more buses will we need, and how will the subsequent increased demand for green power and depot space be met?

DoT's recently published Victorian Bus Plan has no explicit objective for patronage growth, although a target of 200 million annual riders by 2030 (up from 122 million in 2018/2019) was announced online in April 2021 (Victorian Department of Transport, 2021a) and almost immediately removed. It is not clear how this fleeting target was determined, nor if it still has any internal status.

It is outside the scope of this project to determine what degree of modal shift would represent a sufficient response to the climate emergency. Whatever the number, achieving patronage growth through the ZEB transition will require careful projections of the necessary bus fleet (and, therefore, the growth needed in capacity for depots, charging infrastructure, and green-power supply).

These calculations are not simple because the relationship between the size of a bus fleet and its ability to attract people out of their cars is not straightforward.

Even if we could double the bus fleet through the ZEB transition, we would not expect to double patronage if we used these extra vehicles only to increase frequencies on today's slow, circuitous, and poorly connected bus routes.

Fortunately, international and local experience shows that it is possible to dramatically increase patronage with only modest increases in the size of the bus fleet. The key to get maximum impact on patronage from any fleet is to deploy the available buses in a fast, frequent, and well-connected network that offers a competitive alternative to driving for as many different trip purposes as possible.

The creation of an efficient and effective bus network will require the work on the ZEB transition to be closely linked to specific actions under the Victorian Bus Plan. Two vital directions for these actions are described here.

The first is to accelerate the provision of on-road priority for buses. Focused on increasing bus speeds on congested arterial roads, bus-priority measures would enable faster, more reliable journeys which, in combination with deployment of quieter and smoother ZEBs, would attract new riders. We know that this works in Melbourne. The 2006 Smartbus initiatives included improved frequency, service hours, branding and on-road priority and led to a dramatic 44 million per annum gain in bus patronage

in the six years between 2006 and 2012 (Victorian Department of Transport, 2021c).

In the last decade, very few new bus priority initiatives have been implemented, but the improved travel time reliability fostered by such measures is critically important for management of the ZEB transition. Predictable travel times mean that operators can be certain of the number of buses required to meet their timetables, and additional buses are not needed to be kept in reserve to meet required schedules in congested periods. This simplifies calculations of the numbers of new ZEBs required.

The second important direction for actions in the Victorian Bus Plan is to reconfigure the bus network into simple, direct, and well-connected routes. Fast and direct alignments, combined with attention to efficient vehicle scheduling mean that improved frequencies can be provided with an equal (or even smaller) number of buses. So, a reconfigured network will minimise the costs of the ZEB transition. The academic and practice literature provides robust evidence for the benefits to passengers of fast, frequent, direct, and connected services (Dodson, Mees, Stone, & Burke, 2011; Mees, 2010; Stone, 2013; Walker, 2012). These improvements, and the network benefits they create, are the key to attracting drivers to public transport and increasing operational efficiency through greater ridership per bus-km. So, they are an essential requirement for significant CO2 emissions reductions from the transport sector.

Fortunately, the Victorian Bus Plan indicates the government's intention to provide buses with on road priority and reconfigure routes into faster, more direct alignments and run times (Victorian Department of Transport, 2021c, p. 13). However, detail is completely lacking. Substantial changes are not anticipated until later phases of the plan and, in any case, network reform will be difficult under current contracting structures. As we have seen, new contract arrangements will be essential for the ZEB transition. Significant value can be realised by pursuing network reforms and the electrification of vehicles concurrently in a single process of contract reform.

With many of the non-MMBF contracts up for renewal in mid-2025 (see table 1), this is a unique opportunity to overcome past obstacles to reform and to achieve significant, generational change in both the propulsion and network structure of Melbourne's bus services.

CONCLUSION

A ZEB transition for Melbourne is technically and economically achievable in the near term. However, this transition represents a fundamental change to existing bus operations. The demands of labour re-skilling, depot management, power supply, choice of charging infrastructure and contracting models all make it clear that the transition requires careful planning and government leadership.

Although complex, a detailed transition plan can successfully address the uncertainties and risks inherent in this transition. The complexities of balancing assets, operations, infrastructure, and energy will require government to provide leadership across multiple industries, to effectively coordinate and manage costs and risks. Additionally, with the climate emergency as the main policy impetus for this transition, the state will need to couple a ZEB transition with operational changes to encourage greater bus patronage. Network reform which results in simpler, direct route alignments and on-road bus priority is a proven way to get people out of their cars and onto the bus.

Underpinning these changes is the need for revised contracting structures. Below are some of the key issues and recommendations that we believe decision-makers should be considering:

- Victoria's current bus contracting model cannot accommodate the significant upheaval required to transition to ZEBs. effective contract arrangements will need to explicitly consider ZEB operational requirements, promote open information sharing, and enable government and contractors to collaboratively solve issues without resorting to conflict while the transition is occurring. Additionally, contract reform will need to facilitate ZEBs and bus network reform in tandem, with the transition of most of the non-MMBF contracts in July 2025 as a critical juncture.
- The publicly owned depots within the contemporary MMBF contract offer the easiest avenue to quick ZEB deployment. We recommend these locations are prioritised, ensuring a rapid increase in ZEB operations and technical know-how.
- Melbourne's fragmented asset ownership poses a significant barrier to the ZEB transition. Operators are, in effect, deliverers of services for which almost all capital and operating costs are covered by the state. So, they are not able to take on the risks of significant capital investments. But, current ownership arrangements complicate new infrastructure investment. A compromise might mean that the government procures and retains ownership of the ZEB fleet and any necessary non-depot charging infrastructure.
- Careful consideration is required to find ways to provide new charging infrastructure within existing privately-owned depots. Competitive tendering of routes operated from these depots is not likely to be viable without greater government control of depots even if only during the period of significant change to capital and operational risk. Other options might require longer contracts that include conditions for asset transfer as has been done in other jurisdictions. An alternative may be government taking a long-term lease and 'right of first refusal' over the depot site as a condition of funding the installation of charging apparatus.
- BEB, as opposed to FCEB technology is both technically mature and economically competitive with diesel buses for future deployment. Although transitional costs of establishing charging infrastructure and skills retraining are significant, lower operational and maintenance costs of BEBs are likely to rapidly outcompete diesel buses in the near term.
- Maturing BEB technology offers a significant opportunity to lower the carbon emissions of Australia's urban bus fleet. However, merely replacing the existing diesel fleet and route

structure with a BEB fleet misses a significant opportunity to re-imagine the role of buses in the transport mix. We strongly recommend that the ZEB transition be supported by a reforming the network of Melbourne's bus services. This involves explicitly aligning the ZEB transition with network reform to achieve fast, frequent, and direct services as described in the Victorian Bus Plan. This new network would better serve the 'anywhere to anywhere' distributed travel demand of Australia's suburbs. Higher bus occupancies reduce emissions and improve accessibility and opportunity for car-free lifestyle. In this way, bus operations better compete with private vehicle use and can play their part in reducing transport-sector carbon emissions. Such network reform, triggered by the ZEB transition, offers a rare opportunity to deliver multiple positive public policy outcomes.

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