Submission No 29

ELECTRIC BUSES IN REGIONAL AND METROPOLITAN PUBLIC TRANSPORT NETWORKS IN NSW

Organisation: Transdev Australasia

Date Received: 20 December 2019

20 December 2019

Legislative Assembly Committee on Transport and Infrastructure
Parliament of NSW
Parliament House
6 Macquarie Street
Sydney NSW 2000

Dear Committee

Subject: Electric buses in regional and metropolitan public transport networks in NSW

Thank you for the opportunity to make a submission to the Inquiry into electric buses in regional and metropolitan public transport networks in New South Wales. As a global leader in sustainable mobility, Transdev can share insights and expertise about reducing emissions and pollution from public transport and how we partner with governments to help achieve environmental goals.

Transdev Australasia has been delivering services to local communities on behalf of Transport for NSW for nearly 20 years. Our buses keep people moving in and around South Sydney, South West Sydney and Sydney's North Shore. As one of the largest bus operators in Sydney, we have a deep understanding of the local operating environment and a commitment to deliver innovative transport solutions to the community.

Our vision for future mobility is Personalised, Autonomous, Connected and Electric and Eco-Friendly (P.A.C.E.). To achieve this, we are investing in low and zero emission transport solutions and taking a proactive approach to deploying electric and hydrogen vehicles on our networks around the world.

In Australia, we are working with the Victorian Government on a pilot electric bus project in inner Melbourne. This project is not only aimed at reducing emissions and pollution from the local bus network, but has the potential to create new manufacturing jobs for skilled workers from the state's automotive industry.

This pilot is informed by our experience successfully operating electric bus fleets in cities such as Eindhoven and Amstelland-Meerlanden, in the Netherlands, and Eskilstuna, Sweden. In December 2020, Transdev will also launch the largest electric bus fleet in the Nordic region, with a total of 160 buses in Gothenburg, Sweden.

Members of our team of global experts would be delighted to discuss our submission, the results of our pilots and deployments locally and overseas and the

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specific opportunities and challenges present in NSW. If you would like to learn more, please contact Melanie Flanigan, Group Manager Stakeholder Engagement on mobile [redacted] or via email [redacted].

Yours sincerely,

Luke Agati
Chief Executive Officer

Ian Craig
Chief Officer Bus Operations

Parliament of NSW – Legislative Assembly Committee on Transport and Infrastructure

Electric buses in regional and metropolitan public transport networks in NSW

Transdev Australasia Submission

transdev
the mobility company

Executive Summary

Luke Agati
Chief Executive Officer

Ian Craig
Chief Officer Bus Operations

Transdev Australasia welcomes the opportunity to respond to the Legislative Assembly Committee on Transport and Infrastructure's Inquiry into electric buses in regional and metropolitan public transport networks in NSW.

As a global leader in public transportation and sustainable mobility, Transdev supports transport initiatives that reduce emissions and pollution and promote a better quality of life in the communities where we operate.

At Transdev, we believe innovative public transportation solutions can play an important role in achieving a cleaner environment through emissions abatement and that public transport can take the lead in the energy transition from fossil fuels. We know this because we deliver transport solutions that not only keep people moving around cities but make a significant contribution towards meeting local, national and international environmental policy goals.

Across the world, Transdev partners with governments and public transport authorities (PTAs) to deploy electric buses across a range of metropolitan and regional environments. Today, we operate over 800 zero emission buses in 27 communities in nine countries. Each year, we add new cities and new vehicles to our network.

To support the transition towards zero emission fleets, we also invest in projects to complement transport networks, partnering with vehicle manufacturers and fuel technologists to assess innovations like improving the efficiency and the use of new fuels such as hydrogen. Through our Electric Bus Living Lab, we test new technologies so we can advise PTAs on transitioning their fleets to low and zero emission solutions. Our investment in innovation means our city partners can reduce emissions and pollution while still delivering safe, reliable and affordable transport services.

As one of the largest bus operators in Sydney, we understand the local operating environment and have a longstanding commitment to continually improving our services to deliver innovative transport solutions in NSW. Transdev has been providing services to local communities on behalf of Transport for NSW for nearly 20 years. Our operating region covers three geographic areas – South Sydney, South West Sydney and Sydney's North Shore.

Our experience and expertise mean we can assure the Legislative Assembly Committee on Transport and Infrastructure (the Committee) that electric bus technology is sufficiently advanced to support mobility in NSW's regional and metropolitan areas and that transitioning the fleet to electric buses is a viable policy option. For NSW, we believe:

1. There are real environmental and liveability benefits gained from electric buses – reduced emissions, lower air and noise pollution. They are also easy to service (being substantially less complex than diesel equivalents) and are as reliable as existing buses.
2. Transitioning the fleet requires more than replacing existing stock with electric vehicles, as electric buses require specific infrastructure for recharging. This will, at minimum, require upgrades to existing depots and potentially on route infrastructure, additional training for employees and adjustments to scheduling. The capacity of the electricity distribution grid to support the additional load from recharging buses will also need to be considered.

Executive Summary

3. Electric buses are currently the most widely deployed zero emission public transport solution around the world. Advances in hydrogen production technology and fuel cells over the next decade are expected to make hydrogen powered buses more viable in the future.
4. Government and PTAs will play a critical role in the transition of the fleet, in terms of setting policy, facilitating supporting infrastructure and ensuring procurement requirements support the deployment of electric buses.
5. Government and industry can work together to support the manufacture and assembly of electric buses and related technology such as parts.

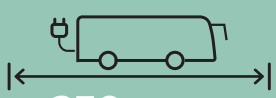
Transdev successfully operates electric bus pilots, projects and services in many cities around the world, including:

- **Amsterdam and Eindhoven, the Netherlands:** Transdev currently operates the largest fleet of electric buses in Europe in Amsterdam, which serves Amstelland-Meerlanden (AML). AML has gained a reputation as the European hub for electric buses. The system launched with 100 electric buses and the entire fleet of nearly 260 buses will be electric by 2021. In Eindhoven, the transit system featured 43 all-electric buses at start-up in December 2016. The goal is to complete the transition to a 100% electric fleet of about 220 buses by January 1, 2025.
- **Foothill, United States:** The Foothill Transit system needed to speed up its energy transition to keep up with the Californian authorities' decision to achieve 100% emission-free transportation by 2040. Efforts began in 2010 with a fleet of three electric buses, which has since grown to 33.
- **Melbourne, Australia:** We are partnering with the Victorian state government on a trial of an electric bus on an urban route through Melbourne. The body of the bus was built in Victoria with the support of the Government. The trial will continue until January 2021 and will be reviewed to determine the potential to roll out fully electric buses across Victoria.
- **Sud Region, France:** The Sud Region selected Transdev to operate two all-electric express routes on the Zou! System. From September 2019, 10 electric vehicles began to provide services between Avignon, Aix-en-Provence and Toulon travelling through three administrative departments: Bouches-du-Rhône, Var, and Vaucluse. The electric vehicles complete trips of a considerable distance at nearly 200km.

Overall, Transdev sees great potential in deploying an electric bus fleet in NSW and we would be delighted to meet with the Committee to discuss our experience and expertise with you in more detail.

Key figures for Amstelland-Meerlanden, the Netherlands

100 articulated electric buses



350 km/day traveled per vehicle

13 million km/year

Over **21,000** tonnes of CO_2 avoided

Key considerations for the Committee

1 **Transitioning the existing bus fleet to electric vehicles will reduce emissions from the transport sector.** There is a real opportunity to develop a staged and considered plan for this transition to ensure it occurs in an orderly, cost-effective way and maintains reliable, comfortable and affordable services for commuters.

2 **The transition to an electric fleet is not just about introducing new electric buses.** Easy, economical and reliable recharging infrastructure is also an essential requirement. Additional to this investment, there is also the issue of the capacity of the electricity distribution grid to support more electric public transport.

3 **While electric vehicles are currently the most advanced low emission transport technology,** innovation in hydrogen fuel cells and hydrogen production are expected to make hydrogen mass transit vehicles more viable in the medium to long term.

4 **Developing a local manufacturing and assembly industry will need support from the NSW government,** in the form of policy and procurement rules promoting the transition of the fleet to electricity.

5 **Partnerships with key traditional stakeholders** such as transport authorities, suppliers, local council and communities, as well as increased focus and alignment with non-traditional stakeholders in the energy industry including retailers, distributors, energy infrastructure contractors and regulators will be key for success.

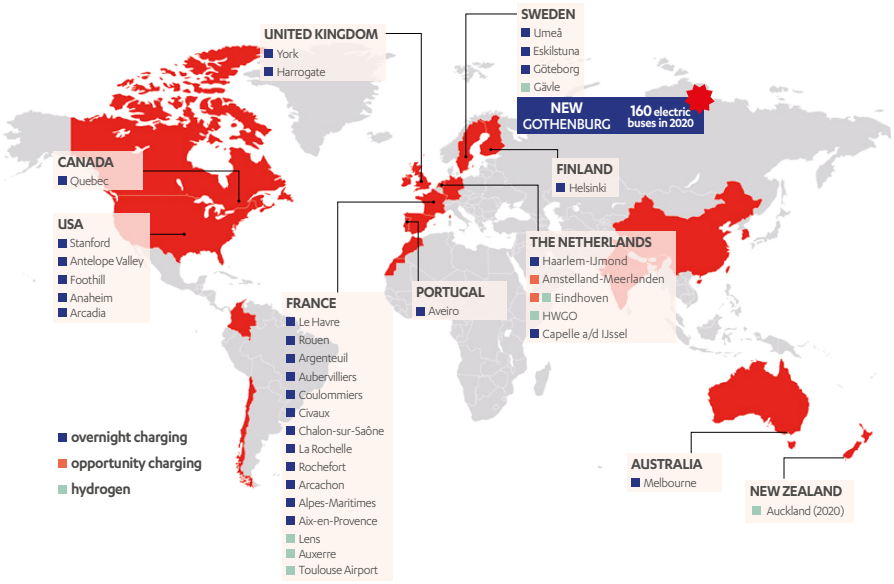
About Transdev

Around the world, Transdev partners with Government partners to deliver tailored zero emission mobility solutions that keep people moving in our cities.

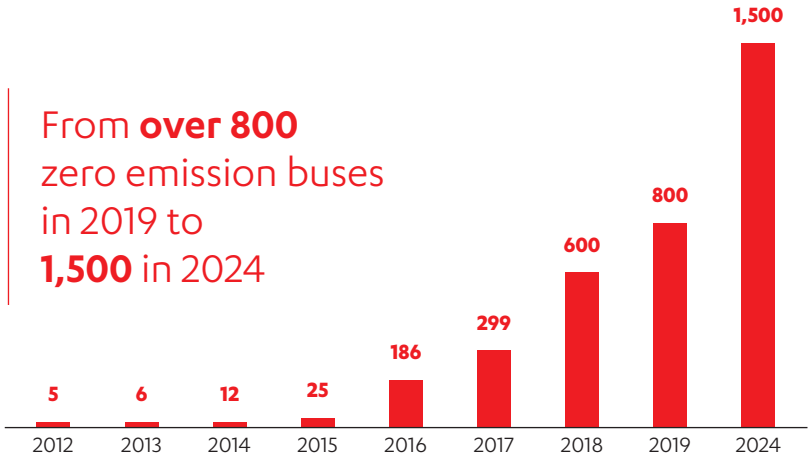
Our vision for the future of mobility is Personalised, Autonomous, Connected and Electric and Eco-Friendly (P.A.C.E.). We believe the future of transport is in more tailored and personalised services, more choice and a better customer experience, as well as reducing the environmental impact of our sector.

Building sustainable mobility means, first and foremost, positioning public transport as the desirable alternative and convincing as many people as possible to choose public transportation. To do this, our first mission is to offer a quality service, one that is both optimised and efficient in order to increase ridership.

Transdev is committed to the transition away from fossil fuels and to a less emission intensive industry. To this end, we are investing in low and zero emissions transport solutions and are a global leader in the deployment of electric and hydrogen vehicles on our networks.



From **over 800** zero emission buses in 2019 to **1,500** in 2024



P.A.C.E.

- Personalised
- Autonomous
- Connected
- Electric and Eco-Friendly

Response to terms of inquiry

The following sections will reference Transdev's response to the Committee's seven terms of reference.

Benefits of electric buses and factors that limit their wider uptake

The benefits of electric buses in terms of emission and pollution reduction are well-known. However, delivering a new fleet of electric buses will require more than replacing existing stock.

Electric buses provide a range of benefits, including:

- Reduced pollution and environmental impact from the bus network.
- Improved air quality for residents and workers in areas around bus routes.
- Reduced noise for passengers and drivers, improving the customer experience and creating a safer work environment for drivers.
- Electric buses are as reliable as existing diesel stock, with respect to breakdowns and time off the road.
- Electric buses require less maintenance than their diesel counterparts.

There are also some challenges to transitioning an existing bus fleet to electric vehicles:

- Recharging/refuelling infrastructure needs to be developed.
- Securing a reliable source of replacement vehicles to facilitate the transition of the fleet and ongoing servicing and support.
- Batteries need to be replaced during the buses' lifetime, however there are likely options to recycle old batteries for other purposes.
- Developing the bus workforce to operate and maintain the new vehicles, as well as plan and schedule services.
- Working with new stakeholders such as utility providers and civil works contractors on delivering supporting infrastructure.

Transdev appreciates that replacing a bus fleet can be costly, especially if the transition to a new fleet is done faster than the expected replacement/attrition rate. We also understand that many of the benefits are challenging to quantify financially against the obvious costs of replacing a fleet. Nonetheless, reducing the emission intensity of the NSW bus network will make a big difference environmentally.

Minimum energy and infrastructure requirements to power electric bus fleets

2

Transitioning to an electric bus fleet will require new infrastructure or upgrades to existing infrastructure, including charging stations and depots.

The figure below illustrates the range of slow charge and fast charge technologies available for electric buses, to suit the service environment charging strategy.

Transdev has developed a dynamic eBus toolbox in partnership with an independent Dutch research institute. The toolbox is designed to help local authorities and operators wanting to identify the electric solution that best suits their specific needs. Five parameters are taken into account including infrastructure requirements (more detail on this can be found in Terms of Reference 7).

Transdev does not recommend starting off with opportunity charging vehicles due to the additional complexity and costs associated with the charging infrastructure. This would also exclude a number of potential suppliers who cannot deliver a battery technology that allows fast charging.

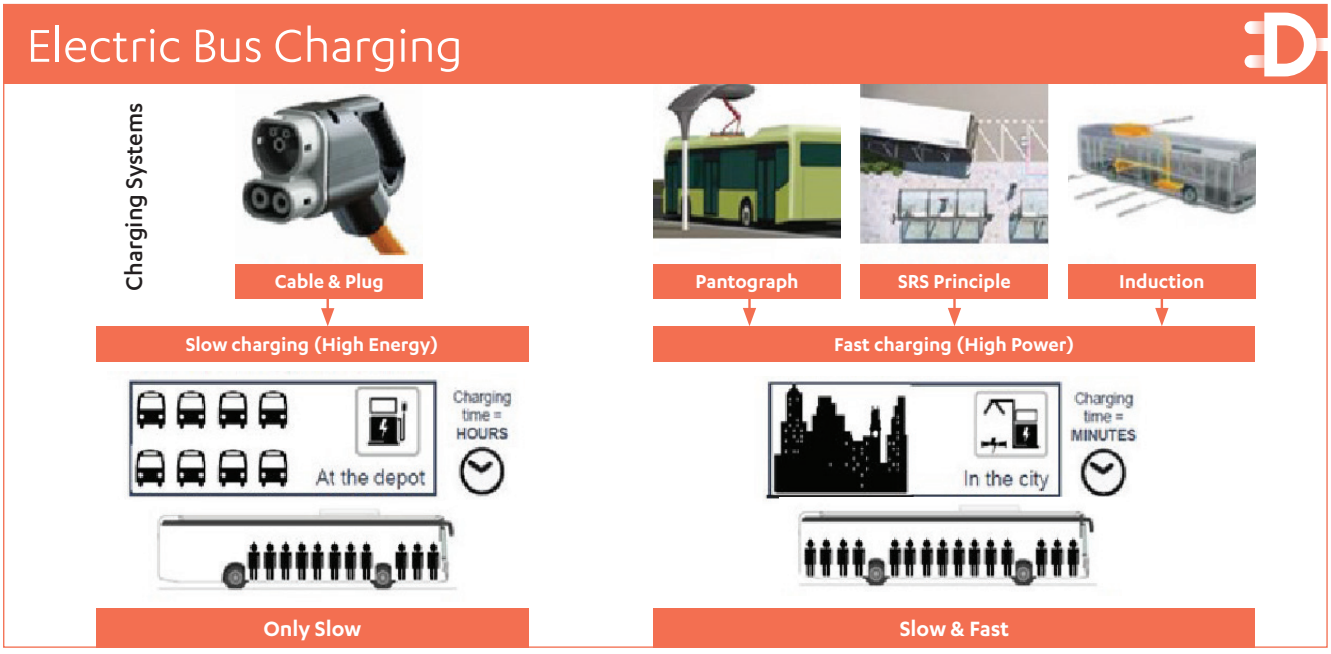
When charging overnight, a charger will need to be installed for each bus, so that all buses can be charged at the same time during the night. There are solutions that suggest that we still need individual charging cables but these can be linked to one charger.

Opportunity charging is the only technical solution today for intense operations:

- High mileage/day (more than 250km).
- Wide operational span (no time to charge during the night).
- Articulated vehicles (if they were to run 250km/day they would transport more batteries than passengers).

While opportunity charging does impact operations, these impacts can be integrated utilising driver breaks and shift changeovers to daily operations.

Opportunity charging is generally peak charging and would have to be carefully considered as part of the overall cost effective strategy. In saying this however, by scheduling the charging sequences it is possible to reduce energy costs.



Batteries

Charging time, range and operating temperatures are all dependent on the type of battery being used. The table below illustrates key aspects of the common battery chemistries currently available on the market.

	Lithium Titanate	Lithium Iron Phosphate	Lithium Nickel Manganese Cobalt Oxide
Normal voltage (V)	2.3V	3.3 / 3.4V	3.6 to 3.7V
Cathode material	Complex oxide including lithium, nickel, and the other elements	LFP (Lithium Iron Phosphate)	Lithium Nickel Manganese Cobalt Oxide
Anode material	LTO (Lithium Titanium Oxide) No Carbon / Graphite	Carbon / Graphite	Graphite
Thermal runaway risk	None	Possible	Possible
Life (Cycles)	15,000	4,000	4,000
Min Charge Time (start from 20% SOC)	50% in 10 min (suitable for fast charge) 5 min planned in the future	50% in 30 min (normally night charge)	50% in 40 min (normally night charge)
Capacity after 600 Cycles	100%	87% to 90%	N/A
State of Charge (SOC) Calculation	Easy	Hard	N/A
Possible temperature range	-30°C to 55°C Great at low and high temperatures	Limited at low temperatures	Limited at low temperatures
Specific energy	80 Wh/kg	120 Wh/kg	140 Wh/kg
Cooling	Liquid cooling needed	Liquid cooling possible Liquid cooling possible	Liquid cooling possible
Charging speed	Suitable for fast charging	Only suitable for slow charging, Not preferred for articulated buses	Suitable for slow charging
Balancing battery cells	Passive balancing (during discharging)	Active balancing after slow charging	Active balancing after slow charging

Depots

In NSW, Transdev does not own the infrastructure it uses to operate the bus network. It operates its transit services from a variety of different buildings and depots, some old, some new, some in residential areas and others in industrial areas, with some services or routes in environmentally sensitive areas.

To accommodate electric buses, existing depot infrastructure will need to be redeveloped and innovative new depots will need to be built to ensure vehicles can be charged and maintained efficiently and the services can continue to run smoothly throughout the transition of the fleet.

In depot design or redesign for the introduction of electric buses, consideration will need to be given to provide sufficient space for chargers, grid connection and cabling. Further measurements will be required to prevent buses and chargers from being damaged.

Grid Connection and Capacity

Existing depot grid connections will likely need to be upgraded, requiring work with electrical contractors, energy retailers and distributors. Consideration will need to be given to grid capacity and availability and cost of electricity at the optimal times for charging.

Infrastructure Requirements and Options

There are several Australian Standards related to electric vehicles that specify a number of safety and electric charging requirements (listed over). European standards are used as a cross reference and benchmark over and above current Australian standards. Confirmation will need to be sought from the bus provider that the electric buses and recharging stations will be compliant with relevant Australian and international standards. General Australian Design Rules (ADRs) and electric bus regulations are in their infancy but will become more relevant within all organisations as the technology evolves.

Some of the current standards are as follows:

- AS ISO 6469.1:2014 Electrically propelled road vehicles - Safety specifications - On-board rechargeable energy storage system (RESS)
- AS ISO 6469.2:2014 Electrically propelled road vehicles - Safety specifications - Vehicle operational safety means and protection against failures
- AS ISO 6469.3:2014 Electrically propelled road vehicles - Safety specifications - Protection of persons against electric shock
- AS ISO 8713-2012 Electric road vehicles - Terminology
- AS IEC 61851.23:2014 Electric vehicle conductive charging system - D.C. electric vehicle charging station
- AS IEC 61851.24:2014 Electric vehicle conductive charging system - Digital communication between a direct current (DC) electric vehicle charging station and an electric vehicle for control of DC charging
- AS IEC 62196.2:2014 Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Dimensional compatibility and interchangeability requirements for alternating current (AC).

Other Considerations

- Provision within the depot for storage, special equipment and any existing equipment to validate compliance (i.e. vehicle hoists).
- DC charging (no AC charging which can cause problems with the energy network).
- Charging monitoring.
- Telematics: having access to Controller Area Network (CAN bus) for vehicle operational data such as State of Charge (SOC), energy consumption, State of Health (SOH) data and similar.

Other renewable, emissions neutral energy sources

3

Around the world, Transdev fleets comprise a range of eco-friendly mobility options - alternative fuels, renewal of heat engines, hybrid and fully electric vehicles.

In our experience, one of the most promising fuel technologies for zero emission transportation is hydrogen. Transdev believes that, in the future, hydrogen may become the energy source of choice for transportation networks around the world.

Right now, electric vehicle technology is more advanced than hydrogen fuel cells. However, innovation in hydrogen production and vehicle infrastructure is expected to improve the cost and viability of hydrogen-powered transportation in the medium to long term. To this end, Transdev welcomes the Council of Australian Governments (COAG) Energy Council's National Hydrogen Strategy and looks forward to working closely with federal and state Governments, hydrogen technologists and other stakeholders on pilots and programs to accelerate the introduction of hydrogen into the transport system.

Some of the key advantages of hydrogen buses include:

- Long range - 300km+ before recharging is required.
- Refuelling is much quicker than conventional electric battery recharging. It is comparable to diesel fuelling in that it is completed in minutes.
- There is no loss of capacity because fuel cell and tanking equipment are very light.

Right now, there are some challenges with deploying a hydrogen fleet, such as:

- The cost to produce hydrogen as a fuel is currently very high.
- Energy and maintenance costs are higher than other vehicles as they are high pressure and have high voltages to be maintained.
- Fuel stations require additional levels of risk management.
- There are operational constraints introduced into the bus network from relying on hydrogen deliveries rather than producing it on site.

TRANSDEV'S HYDROGEN BUS PILOTS

We are currently working in partnership with several PTAs to introduce further hydrogen buses:

- **In the Netherlands,** Transdev has two projects: the Hoeksche Waard and Goeree-Overflakkee (HWGO Consortium) project outside of Rotterdam, with 4 VDL hydrogen buses in operation, and another project in Eindhoven with two hydrogen-powered buses planned.
- **In France,** Transdev has three hydrogen projects: the first in Lens on the TADAO network where we will soon unveil a complete Bus Rapid Transit (BRT) line using six hydrogen-powered buses. TADAO is France's first 100% hydrogen bus line operating a route length of 14km and over 380,000 kilometres per annum. The buses were supplied by Safra, a local French company, which handled all aspects of the design. The second hydrogen project will be in Auxerre and the third at Toulouse airport.
- **In Auckland,** Auckland Transport (AT) is undertaking a hydrogen trial that will include a hydrogen station in partnership with Ports of Auckland and bus operations. The six buses are being built locally in Christchurch and each bus will accommodate up to 78 passengers. The trial is expected to start from September 2020 and Transdev, through local operator Howick & Eastern, will trial a bus on a selected route.

Other Pros and Cons of Hydrogen

Pros

- ▲ Hydrogen is a good option when it is not only used for buses, e.g. storing renewable energy such as solar or wind power.
- ▲ Hydrogen vehicles do not impact operation in the same way as battery electric vehicles can.
- ▲ Hydrogen can be created from chemical by-product processes.

Cons

- ▼ Hydrogen vehicles are still prototypes.
- ▼ Hydrogen vehicles are also equipped with batteries.
- ▼ Fuelling stations need a high level of risk management.
- ▼ Hydrogen produced from compressed natural gas (CNG) is not environmentally friendly – 1 kg of hydrogen produced emits an amount equivalent to 9–12kg of carbon dioxide.

Key figures for Lens, France

Frequency
15/30 min.

Route lenght:
14 km
in a fairly dense urban area

Average service speed
21 km/h

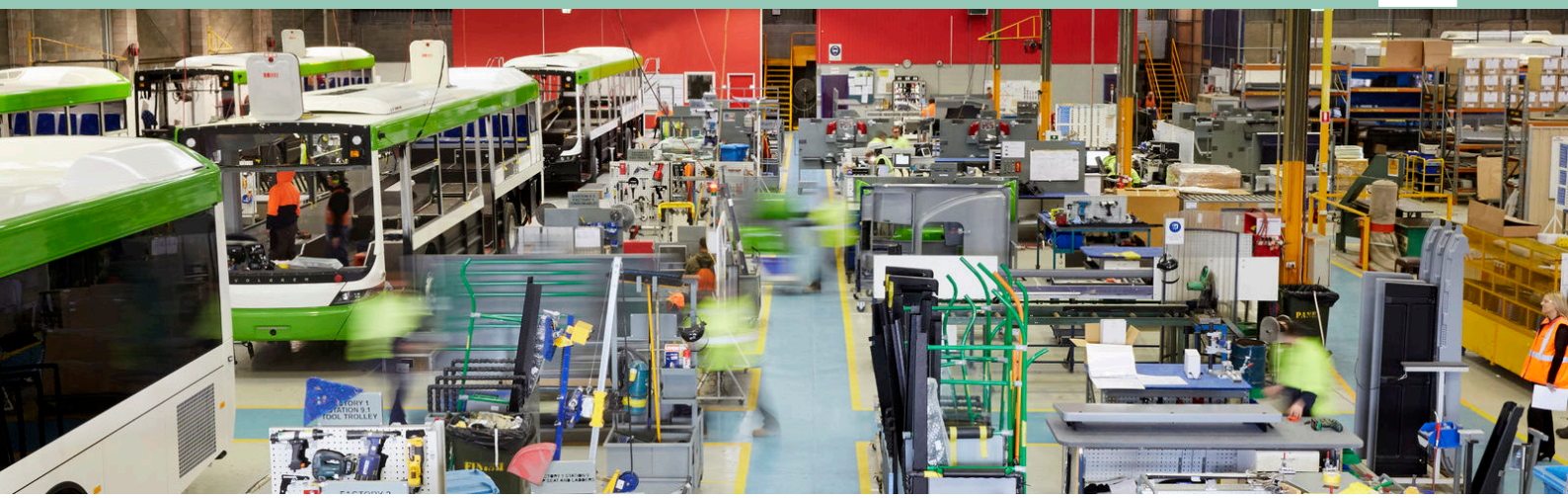
Recharging time for the 6 buses:
15 min.
for a range of
350 km

380,000 km/year

530 tonnes of CO_2
avoided each year

Route time:
40 min.

Ways to support manufacture and assembly of electric buses in NSW



Transdev supports the development of a local manufacturing and assembly sector for electric buses. By setting the policy and procurement rules towards a transition to electric buses, the NSW Government will lay the groundwork for establishing a local industry. Transdev can partner with the Government and its agencies to provide insights and support for this new sector, based on our experience overseas and in Australasia.

To illustrate how Government and transport operators can work together to achieve environmental policy goals, as well as create jobs, Transdev is working with the Victorian Government on piloting its first electric bus in the state. The body construction and fit out for the new bus was undertaken locally by Volgren, supporting Victorian jobs and backing local automotive industry workers to develop new capability and innovation (more detail about performance can be found in the next section).

While this pilot is in its early stages, we would be pleased to share our findings from the trial with the Committee at a future date.

Based on the learnings of local bus manufacturing internationally, attention will be focused on the charging infrastructures.

Gemilang is the first heavy vehicle manufacturing member of **Hydrogen Mobility Australia**, now known as the H2 Council

100% Australian owned and operated

Experience with introducing electric bus fleets in other jurisdictions

5

Transdev is a global leader in delivering zero emission transportation. Working with our Government partners, we are proud to operate the largest zero emission fleet in Europe. By the end of 2019, we will operate over 800 fully electric vehicles, with 1,500 fully electric buses expected globally by the end of 2024.

Melbourne, Australia

Working in partnership with the Victorian Government, Transdev recently introduced the first Volgren Electric bus into its Melbourne network. The new zero emission bus is fitted with 324kWH of Lithium Iron Phosphate batteries providing 220–300km of travel range. This is also a 'smart' bus, featuring a low floor, intelligent early detection collision avoidance systems and USB charging ports. The trial is being benchmarked against the current emissions standards in both Australia (Euro 5) and Europe (Euro 6) to determine whether electric buses are an economical transport solution.

The trial will continue until January 2021 and will be reviewed to determine the potential to roll out electric bus fleets across Victoria. While the trial is still in its early stages, we would be delighted to share our preliminary findings with the Committee once these have been assessed.

Amstelland-Meerlanden, the Netherlands

Transdev has commissioned more than 100 all-electric buses in the greater Amsterdam region and Schiphol Airport. This deployment will continue to grow over the years to come – from 2021, the entire fleet will be electric. Our fleet will cover around 30 million kilometres each year.

This is the biggest fleet with high capacity buses in Europe (and most likely worldwide). There are two types of electric vehicles: Schipholnet has 51 buses similar to those in Eindhoven (BRT look); and R-Net, a regional network with 49 buses that appear as a standard articulated bus, but with the same electric drive line and batteries as the Schipholnet buses.

By the end of January 2019 (after 10 months of operation) our fleet of electric buses travelled 8,193,782km or approximately 82,000 km/bus.

The 24/7 airport bus services require vehicles to be on the road as much as possible. Transdev's solution allows them to completely charge in approximately 30 minutes at the fast charging stations, and with a complete charge done overnight (4-5 hours) at the depot. The additional challenge compared with the Eindhoven operation is that there is no time to do a collective slow charge during the night as the service is continuously operating 24/7, therefore another battery technology has been chosen that allows passive battery cell balancing.

The buses carry a 170kWh battery providing a range of around 72km between charges, with an average daily mileage of over 300km. The pantograph charging system optimises the space available inside vehicles and at depots while reducing overall weight. The 500 drivers joined a zero emission training course that included a session on safe battery charging.

Eindhoven, the Netherlands

Transdev operates a fleet of 43 articulated electric buses in the city of Eindhoven. This was the first fleet with high capacity buses (136 passengers) in Europe. By the end of January 2019, after 25 months of operation, the electric buses travelled 6,415,279km – around 150,000 km/bus. The reliability of the buses appears to be slightly higher than the previous operation using diesel buses.

In Eindhoven, Transdev developed an innovative charging strategy that enables the buses to run more than 300km a day on highly patronised routes. This involved implementation of a regime which combined ultra-fast charging technology and a sophisticated rotation system.

The return on investment has been calculated to take into account the longer depreciation costs, the higher yearly mileage, the high commercial speed (17–27km/h depending on the route) lower energy cost and a strategy to increase route ridership.

Eskilstuna, Sweden

In Eskilstuna, currently, 12 of our 65 buses are electric. Silent and non-polluting, our electric vehicles improve the residents' quality of life on a daily basis. They have an impressive autonomous operating range of 300 kilometres, are recharged overnight and cover all of the 23 lines comprising the city's network.

Eskilstuna aims to completely phase out the use of fossil fuels for its transport in 2050. The electric buses are expected to reduce particle emissions by 30% in 2020.

Overall in Sweden, Transdev currently operates 55 electric buses in Umeå, Eskilstuna, Gothenburg and Stockholm. In December 2020, Transdev will also launch the largest electric bus fleet in the Nordic region with a total of 157 buses in Gothenburg.

As always, Transdev would be pleased to present the findings from our global electric bus operations to the Committee in more detail.

Electric Bus Solutions

HYBRID BUSES

Serial hybrid
Electric propulsion only

Plug in hybrid
Extending the range of electric propulsion

ZERO EMISSION TAIL PIPE SOLUTIONS

Trolley bus
Conventional trolley and hybrid trolley or IMC

Opportunity charging electric bus
Smaller battery pack sizes

Overnight charging electric bus
Large battery pack

Hydrogen electric bus

Other Electric Bus Solutions

Transdev is also piloting fully electric mobility solutions that support a more diverse bus fleet. These solutions are designed to improve mobility in densely populated cities and in environments that are not suited to large passenger vehicles.

City centre micro-shuttles

The shuttle solution has been thoroughly tried and tested, the technical performances being ideally suited to high traffic urban environments. Transdev is currently the leading operator in France of this type of vehicle with over 40 micro, mini and midi buses, making up 42% of the French fleet.

Autonomous battery buses

The fully electric bus solution is quickly developing as issues of battery weight and capacity are being successfully addressed. Under the Finnish national program 'EVE' (Electric Vehicle Systems) 2011–2015, Transdev Finland tested T.ebus, fully electric urban buses in commercial operation conditions and a challenging climatic environment (-25°C in snowy conditions to +30°C), on some routes in Espoo, in the greater Helsinki area.

In 2016, Transdev purchased 43 electric articulated buses to be implemented in the Bravo network in North Brabant, Netherlands. Standard capacity buses will be added in two additional phases reaching the goal of a fully electric fleet by 2025.

Opportunity charging buses with fast charge on route

This solution facilitates 'refuelling' all along the routes at different stops. The WATT solution does not require any dedicated infrastructure other than charged 'posts' that both store and transfer the energy. Placed next to the bus stop or integrated into them, they are supplied by the low voltage electricity system which charges the super-capacitors they are fitted with.

By October 2017, Transdev had 13 conductive opportunity charged standard buses in operation out of the Arcadia facility in the eastern part of Los Angeles, USA. This solution has also been rolled in Umeå, northern Sweden across nine rapid charging buses.

Opportunities and challenges of transitioning the entire metropolitan bus fleet to electric

6

Switching from diesel to electricity is not merely a matter of replacing vehicles. To tailor mobility solutions that work for different communities and environments for the long term, Transdev and its government partners need to work together to ensure: the technical and infrastructure requirements of an electric fleet can be met; that vehicles and fuel technologies are appropriate for different routes; that there is a reliable supply of new vehicles and batteries; that the fleet workforce has the right skills and capabilities; and finally, that people are encouraged to use buses.

Converting fleets from diesel to electric involves fundamental changes to the existing transit system. Governments, in partnership with operators, need to ask:

- What technology suits the local environment (climate, terrain, ridership and similar)?
- What specifications are needed to issue a realistic call for tenders to manufacturers or pursue an upgrade project?
- What involvement is needed from stakeholders?
- What new skills do the operations teams need to acquire (planning, supervision, maintenance, etc.)?

The main challenges in the transition to an electric fleet include:

- The availability and expense of charging infrastructure.
- Positioning marks on buses for charging.
- Battery technology.
- Scheduling to account for limited ranges and time taken to recharge.
- The capacity of existing electricity distribution infrastructure to handle battery recharging.
- Monitoring system and chargers are very important for reliable operation.
- How best to move from a diesel bus to eBus system – a phased eBus implementation is advised.
- Training for the ZEB workforce to ensure there are drivers and mechanics with the skills to operate and maintain a new fleet.

Additionally, transitional challenges that need to be taken into account include:

- Development approval for infrastructure upgrades – obtaining permits to allow grid connection, and equipment installation if in public domain.
- Depot location relative to suitable available electricity and other source infrastructure.
- Industrial relations considerations to integrate the zero emission buses into regular scheduled routes.
- Vehicle acceptance tests.
- Securing a reliable supply of appropriate vehicles to ensure an orderly transition away from diesel.

Any other related matters

7

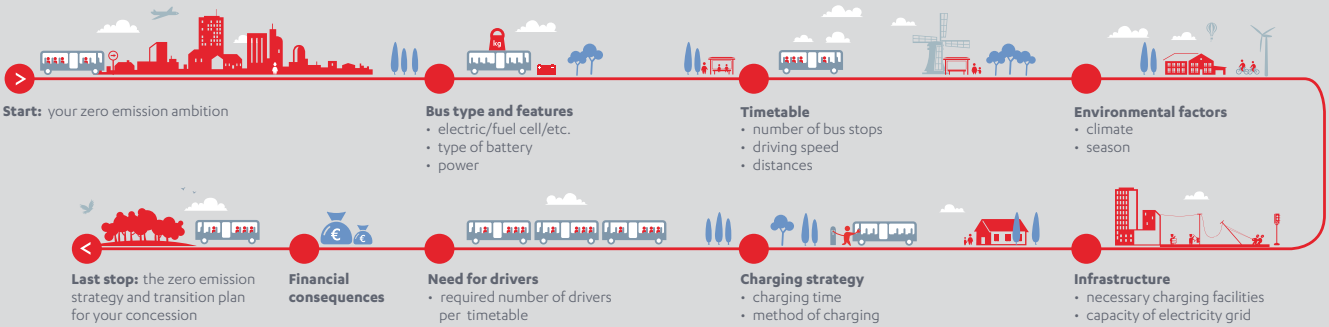
Living Lab

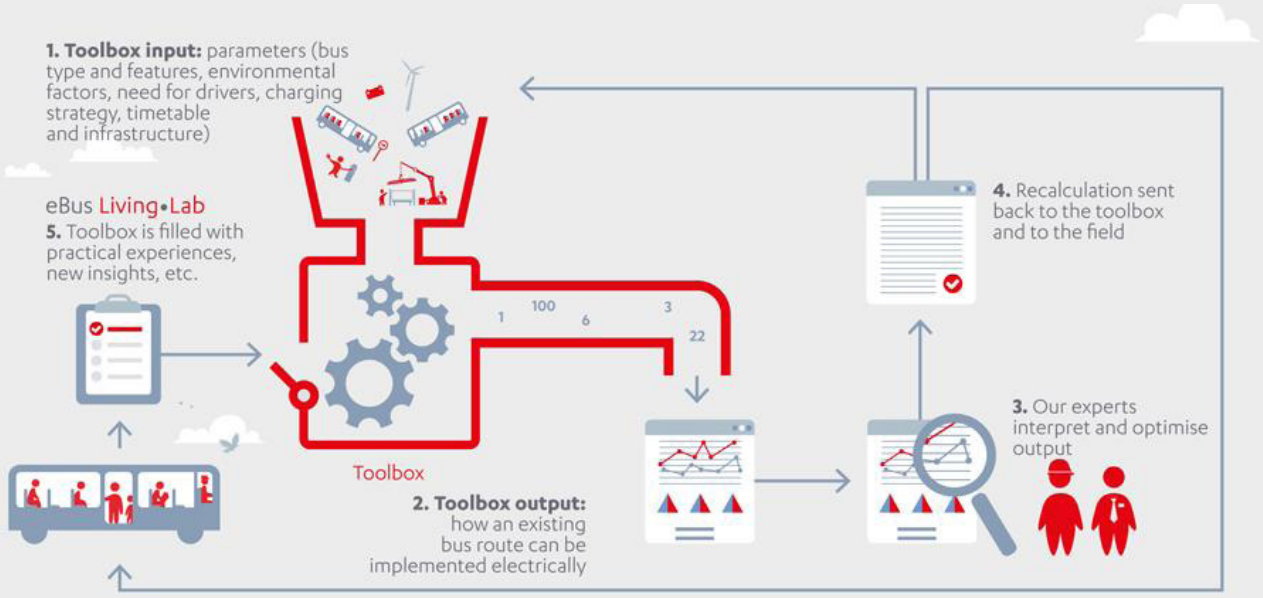
If the NSW Government approves the transition to electric buses, Transdev would make available our Electric Bus Living Lab, a transportation and research community that analyses and capitalises on learnings from the various electric mobility trials led by Transdev worldwide.

The Living Lab is a tool used to advise transit agencies on their best choice in terms of environmental performance, safety, operations and economic impact. The parameters of the Living Lab are illustrated in the figure below.

At Transdev we believe in sharing international best practice and each year stage a Living Lab conference. The concept of the Living Lab was born from meetings held in 2015 between Transdev and industry leaders from all over the world, who felt they needed a forum to discuss meaningful and real-life examples of innovative and sustainable public transport solutions. This year, Transdev staged the fourth Living Lab and over 110 participants (including transportation authorities, ministers, government agencies and research centres) from 14 countries came together to gain new insights for shifting to cleaner forms of energy in transit systems. Reliability, safety, industrialisation, maintainability, battery life and costs are among the themes debated by the community of electromobility experts who collaborate to enhance existing solutions and shape the future of mobility.

Parameters of the eBus Living Lab





eBus toolbox

Transdev has developed a dynamic eBus toolbox in partnership with an independent Dutch research institute. The toolbox is designed to help local authorities and operators wanting to identify the electric solution that best suits their specific needs. Five parameters are taken into account:

1. Vehicle characteristics;
2. Operational impacts;
3. External factors;
4. Charging infrastructure; and
5. Financial elements.

We would be delighted to make our eBus toolbox available to the Committee to help their deliberations.

Transdev's Zero Emission Global Expertise

Our global team of zero emissions experts would be delighted to provide further insights to the Committee into the transition of the NSW bus fleet:

Tanguy Bouton

Corporate Fleet Director, Transdev Group

Tanguy has over 10 years of experience in the transportation industry, specifically concerning energy transition. He has been working for Transdev for over 4 years, most recently appointed as the Corporate Fleet Director.

Tanguy initially worked in the manufacturing industry for Power Vehicle Innovation (PVI), a French truck and bus manufacturer that specialises in the production of zero emission vehicles.

His role included overseeing the first trial of a 12 metre electric bus in France – WATT System technology at Nice Cote d'Azur Airport. He then joined RATP Group, a French public transport operator and maintainer, and worked as a Network Planner in Riyadh, Saudi Arabia, before joining Transdev Group Headquarters as the Energy Transformation Business Manager.

Tanguy holds two Masters degrees including a Masters in International Business Consulting from La Sorbonne University, as well as a Master specialising in urbanism and urban transportation from Paris Est University.

Joshua Carmichael

Advisor – Battery & Hydrogen Zero Emission, Transdev Netherlands

Joshua joined Transdev Netherlands in 2018, in a role that focuses on the technical, commercial, chemical and strategic impact of battery and hydrogen technologies and energy grid considerations of bus operations in the Netherlands.

Joshua started his career in 2008, working for DENSO in business development, strategy and innovation across a variety of industries. In 2016 he briefly moved to South Australia where he was appointed as the Director of the Low Carbon Unit – advising the Cabinet of South Australia on renewable technology policy, programs and investment. He developed the state's Low Emission Vehicle Policy, Green Hydrogen Roadmap, advised on the tender for six to eight fuel cell buses, directed the project for the world's largest lithium ion battery, and helped managed the $150m Renewable Technology Fund.

Joshua holds a Bachelor of Business in International Business from the University of South Australia, as well as a Master in Business Studies from the University of Amsterdam. Notably, Joshua completed an Executive Leadership Program focusing on Competitive Strategy from INSEAD and a Strategic Negotiations Program from Harvard Business School.

Bart Kraaijvanger

Zero Emission Program Manager, Transdev Netherlands

Bart is a public transport electric bus fleet management specialist with more than 25 years' experience in transportation and fleet management. He is responsible for managing Transdev's Zero Emission Program in the Netherlands, as well as Transdev Netherland's Zero Emission Competence Centre since 2016.

During this time, he has successfully managed the implementation of the two largest zero emission bus fleets in Europe; 43 articulated electric buses in Eindhoven in 2016, and 100 articulated electric buses in Amstelland-Meerlanden in 2018, including Schiphol Airport. In Amstelland-Meerlanden, the success of the innovative project is partly owed to the partnership between key stakeholders and their clear articulation of a shared vision. The electric buses collectively cover up to 30,000km per day, and are fitted with the latest generation of fast-charging batteries. These batteries are charged in approximately 30 minutes at charging points along the route, allowing 24-hour service.

Bart completed his studies at HAN University of Applied Sciences in the Netherlands.

Marc Cleave

Head of Engineering, Transdev Australasia

Marc has more than 20 years of experience in worldwide bus automotive manufacturing, body/chassis design engineering and electric vehicle development. He has been recognised in the Global Bus manufacturing industry for his ability to strategically identify key market opportunities and has a proven track record in driving forward the improvements necessary to align organisations with operational excellence.

At the age of 25, Marc became the youngest Senior Design Engineer in the history of the UK's largest bus manufacturer, Alexander Dennis. He led the Single Deck Engineering Team and was involved in the introduction of the first ever ADL integrated Enviro Product into the UK and overseas markets. In his move to Australia, he spent 13 years at Bustech leading Australia's only advanced bus OEM, with chassis designed, engineered and made locally. His time with Bustech as General Manager/Chief Engineer was at the forefront of bus design and development including producing the iconic urban double decker (CDi model) and Australia's first electric bus (ZDi model).

Marc holds a Bachelor in Engineering (Manufacturing Systems Engineering) (Honours) from Glasgow Caledonian University. His extensive knowledge and experience contributes greatly to the success of Transdev Australasia.

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