Submission
No 4

ELECTRIC BUSES IN REGIONAL AND METROPOLITAN PUBLIC TRANSPORT NETWORKS IN NSW

Organisation: Volvo Bus Australia

Date Received: 5 December 2019

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VOLVO BUSES

Response to Inquiry into Electric Buses in Regional and Metropolitan Public Transport Networks in NSW

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1.0 Introduction

In 2009, the Volvo Group trialled multiple new fuel types for review by governments around the world. This line-up of products included bio-gas, dimethyl ether, synthetic diesel, bio-diesel, hydrogen fuel cell, LNG and electric drivelines. Based on the research conducted since that time, it is clear that the most effective and efficient use of energy in city bus applications is an electric driveline. For example, electrification decreases energy use by as much as 80% compared to equivalent diesel buses, and even more when compared to gas. In considering the entire energy chain, an electric bus has a lower total energy requirement for the specific operation. As a result of this extensive research Volvo's plans for the future are based around fully electric vehicles, and Volvo has invested heavily in this technology since that time.

Volvo launched the Volvo diesel hybrid back in 2008, the Volvo Electric (plug-in) Hybrid in 2014 for complete bus markets, and in 2016 released our full electric bus for complete bus markets in Europe. We are currently developing an electric chassis product suitable for the Australian climate and local bodybuild.

While we have extensive experience in this area, we still believe the full commercialisation of full battery electric buses remain some years away for contract operations in Australia, where the planning for infrastructure, connection to the grid and power supply security are still in progress, and the demand for vehicle uptime and service reliability is high. It is Volvo's view there are also a number of key areas and considerations still to be investigated and further understood here in Australia in regards to the business model required for electric buses - for example, the increased capital and infrastructure investments required.

We acknowledge that running smaller trials is possible sooner, and many companies will take the current opportunities to do this. Volvo draws attention however to the fact that to truly test the technology and its operational viability for regional and metropolitan NSW a full route of 4 to 8 buses should be trialled – and this also takes time. Volvo would like to be involved in this process, and in particular in any sounding board and think tank activities. Volvo has a strong focus on ensuring the long term sustainable use of electric buses in Australian cities, and how they can operate in commercially viable operations.

When developing and taking to market our electromobility products, Volvo has been extremely aware that while delivering environmental, brand image, and transport attractiveness benefits, today's operating demands such as uptime, reliability, body life, parts support, training and safety, all continue to remain critical for operators and service delivery. Volvo's philosophy for electric buses is that the bus we offer must achieve the same levels of reliability, longevity and service delivery as the diesel bus we replace. In the electromobility segment, the same principles apply as diesel in relation to reliability of the driveline, body life, parts support, dealer support and technical expertise, and this is critical to the successful implementation of electric vehicles for long term commercial operation.

Based on our experience, the purpose of this document is to provide the Committee with an overview of key considerations and success factors for the implementation of full electric vehicles as outlined in the Terms of Reference.

2.0 Key Considerations for Electromobility

There are a number of key considerations for a city when assessing the use and implementation of electromobility products. Based on Volvo's experience, the main considerations include the following -

2.1 Comparing to Diesel?

It is currently common practice to compare an electric vehicle to a diesel bus. However given the benefits, infrastructure requirement, business model and capital cost an electric vehicle it can be said an electric vehicle is actually more closely aligned to a light rail installation or a train and should be compared to those modes and projects accordingly.

Comparing the cost of an electric bus, costing the benefits and understanding the city wider impact must become part of the discussion if we are to truly value the different elements of a purely electric bus system. Operators and government comparing this solution to diesel are unlikely to have accounted for the wide-ranging benefits of the solution, nor have they captured the need for a change in business model to deliver an electric bus project.

2.2 Business Model

The use of electric vehicles will require a new business model. The business model may look very different to traditional ownership and operation one we see today. The number of stakeholders typically increases and traditional bus sales change significantly. Where electric buses are working well, we see the city, State or Federal Government (Environment, Transport, Infrastructure and Energy), local council, road owners, operators, electricity providers, charging system providers and suppliers collaborating on the system and the solution.

2.3 Cost Benefit Analysis

To truly value the contribution of electric vehicles we need to move beyond discussions of emissions. Progressive cities are now evaluating the economic impact and quantifiable benefits of noise reduction and health impacts in addition to the reduction in emissions. In these cases, the value of using a vehicle includes the assessment of financial benefits of reducing noise, emissions and health impacts and placing an economic value on each element. This economic analysis of contracts and the contribution of the vehicle are significantly different to traditional models of contract costing used in most jurisdictions and require forward thinking in relation to the value of societal impacts. Examples of how to calculate such can be seen today in most city bus tenders across the EU.

2.4 Weight vs. Range vs. Capacity

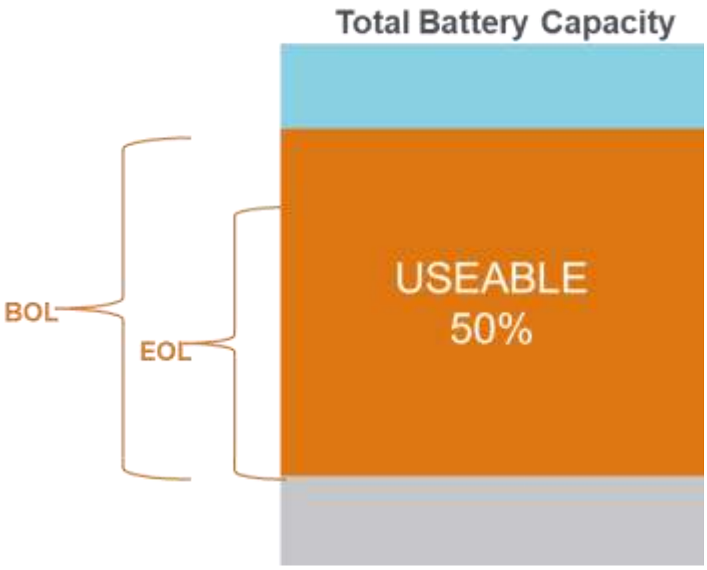
To achieve the greatest range, more batteries are required. More batteries mean more vehicle weight and therefore fewer passengers. You can reduce the number of batteries but you need to increase the frequency of charge. The balance of these elements is one of the key drivers related to vehicles size and weight. If standards remain constant then government will need to balance the need for less high capacity vehicles as opposed to an increase in vehicle population based on smaller carrying capacity and increased weight. It has also been seen that an electric vehicle's maximum range can vary significantly in reality due to a number of operating parameters. Range and distance must be assessed on real world, and worst case scenarios to ensure the vehicles always have enough charge to complete their route.

2.5 Battery Capacity, Useable Energy and Vehicle Range

When considering and comparing vehicle ranges, it is also important to compares apples with apples and consider the capacity or 'useable energy' of the batteries on the buses, rather than measurements in kms.

The useable energy is not 100% of the batteries' capacity, but as an example some batteries' usable energy may only be between 50-80% of the total battery capacity depending on the charging solution being used.

When doing energy and range calculations it is also important to consider the differences in useable capacity / energy at the battery's Beginning of Life (BOL) and End of Life (EOL). As shown in the example below, the battery's useable energy is only 50% of its total capacity when it is new (BOL), and even less when has been used for a period of time (EOL). Simulations and range calculations should always consider the worst case scenario at battery EOL.



EXAMPLE ONLY

2.6 Infrastructure

There is no doubt that when a fleet of buses running a commercial route bus operation are converted to electric drive there is a need for new infrastructure. This will be true regardless if you choose to charge the vehicles in the bus depot or on the route. Either solution will require a change to the depot or routes both to provide sufficient availability of charge points and/or opportunity charging stations on route. Imagine charging 100-200 buses in a depot overnight, think about the electricity required to slow charge that many buses, the number of power outlets, the way the depot will need to be modified and most importantly the need for a sub-station nearby to deliver the required amount of power.

2.7 Energy requirements for consumption

When calculating the number of buses for a particular route, the kW/hr charge rate of each individual bus and how they are charged needs to be considered when calculating overall power a depot will require. This can vary between 25kw/Hr to up to over 150kw/hr pending the battery type. As an example, a depot with 20 electric buses where the recommended charge rate is 50kw/hr for 4hrs overnight will require 1 Megawatt/hr of usage overnight when the buses are standing.

Power demands need to be relayed back to local power authorities to ensure street existing front power available is sufficient, or whether increased power supplies from sub-stations needs to be laid.

2.8 Climate and Air-Conditioning

The management of climate and need for robust and reliable air-conditioning systems pose one of the greatest technical challenges to providers of electric vehicle technologies. The Australian climate requires a large percentage of the energy available on an electric bus to be used for climate control rather than propulsion of the bus. This requirement is one of the hardest challenges for manufacturers to solve as the balance between the range of the vehicle and the ability to properly cool the vehicle is a challenge. Volvo has developed extensive experience and is now running diesel hybrid buses in Singapore, Perth, Melbourne, Regional Victoria, Adelaide, Wollongong and Brisbane, and clearly understands what's required in these varying, and often hot climates.

2.9 Contract Model

Currently operator contracts include the cost of maintenance, fuel, AdBlue and capital costs related to a vehicle. When we move to electric vehicles, some of these items will be traded for battery leases, electricity purchases and/or leased vehicle operating models. Volvo would be happy to work with Governments and operators to assist them in understanding the economic modeling required to properly reflect the cost of operation.

2.10 Transport Security

With demand for electricity at an all-time high in Australia, Volvo believes that bus fleets should have a mix of energy options at their disposal. If there is a disruption to electricity supply in a city how will the movement of people be affected? A hybrid or diesel vehicle can still move people, whereas the electric fleet may be grounded after a period of interruption.

2.11 Electricity Source

When assessing the environmental impact of electric vehicles, cities need to assess the total impact, not just that of the bus. Powering vehicles using non-renewable energy does not deliver a zero emission outcome when the full energy use calculations are completed. Volvo can provide additional information on this should it be required based on extensive research undertaken in this area.

2.12 Government Policy

Are there zones in which transport must be silent? Is noise valued by the community or Government? Volvo has the ability to manage speed and the length of electric operation remotely by using GPS signals and geo-fencing technology to ensure that vehicles behave in a particular way. For example, Volvo can program an electric hybrid bus to use the diesel engine in some areas but limit the bus to pure electric operation at other times (assuming enough energy can be created prior to entering this mode).

2.13 Vehicle Regulations

In most countries around the world, the regulation of electric buses is not keeping pace with the implementation. Volvo is working to the highest standards already developed in Europe but with no local standards and regulations for the safety, integrity or operation of electric buses, governments are exposed to a variety of short term solutions. Volvo wishes to assist where possible in the development of safe, commercial standard for electric vehicles.

2.14 Training, skills and facilities

The move to full electric also sees a large shift in the skills required. No longer are diesel technicians and heavy duty mechanics required but newly trained auto electricians with a very new skill set compared to what we see in bus workshops today. Similarly, with the batteries and a number of key components on the roof the design of workshops will be very different, and working at heights equipment and training required.

3.0 The Volvo electromobility range

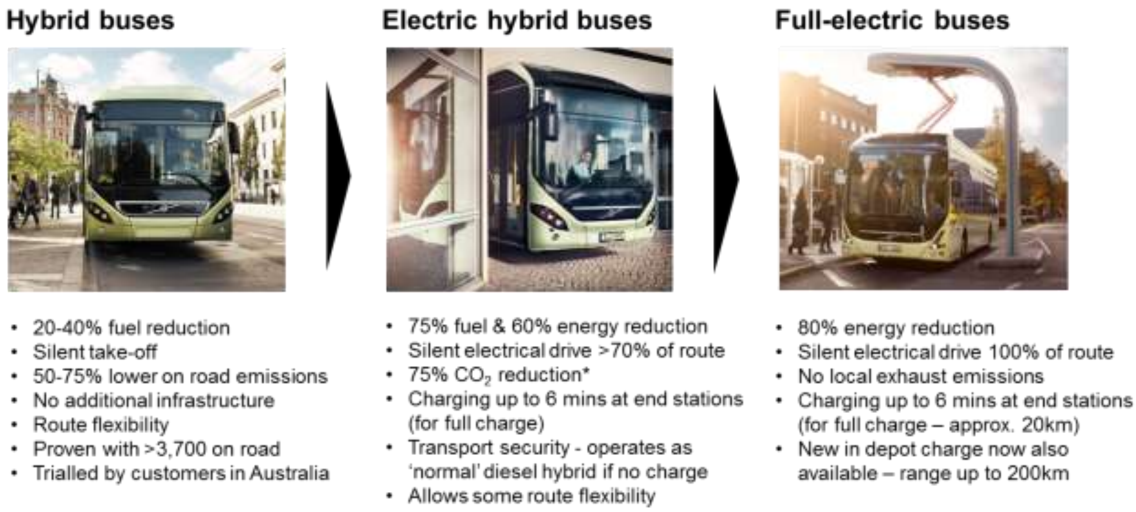
Electrification of the city bus traffic is emerging rapidly all over the world and there is a general trend toward allowing fewer cars into city centres. This means a growing demand for transport capacity without increasing the environmental stress. The need for safety zones, silent zones, zero-emission areas and even indoor terminals has become a reality. Volvo's product range and offering covers all these concerns and considerations.

At Volvo Buses we have a complete range of electromobility products. Our standard hybrid has been in commercial operation since 2008, and today there are more than 4,500 in operation around the world, including in Australia. This technology, which delivers up to 40% savings in fuel and C02 emissions, requires no additional infrastructure and can be integrated into an existing operation with ease.

Our next step that some cities are opting for is to continue to utilise a diesel engine but also fast charge our buses to extend the range that can be achieved on the battery. Our electric hybrid, or "plug in" hybrid, requires a fast charge (3-6mins) from a pantograph on the bus route that allows operation in electric mode for up to 80% of the operation.

After a number of successful trials running since 2016, Volvo released into series production in 2018 its full electric bus which can operate either using the fast charge system with use of pantographs (opportunity charging) either on-route or at the end stations, or with the slower Combined Charging System (CCS) back at the depot which delivers an extended range.

These vehicle types are shown below, along with the benefits demonstrated in operation to date. Please note, the electric hybrid and full electric are not yet available in Australia.



4.0 Volvo new technology roadmap and timeframes

Based on our global experience, Volvo recommends cities and operators take a planned and stepped approach to their electromobility journey, as seen in European cities such as London and in our region in the city of Singapore. This approach starts with the proven diesel hybrid solution, followed by trials of full electric buses, and then a planned and gradual progression towards a fully electrified public transport system, together with the energy supply companies and other stakeholders.

It is important to highlight however that even well into the future Volvo sees a mix of vehicle technologies running in the cities of tomorrow. This allows cities and operators to find the best option for each route and take a customised approach to efficiently running different parts of a city. Not all routes for example lend themselves to the benefits of full electric bus technology in the same way. Zero Emission (electric) zones in the city centre, low emissions zones in the rest of the city (hybrid) and integration with traditional diesel services in other areas are the most likely balance that is sustainable and efficient for the city of tomorrow.

Already today, Volvo's diesel hybrid bus can directly replace an older fleet without the need for investment in additional infrastructure, and achieve both emission and fuel reductions. In operation the Volvo diesel hybrid has in Australia proven to reduce nitrogen oxides and particulate emissions by up to 50%, as well as fuel and carbon dioxide emissions by up to 40%, depending on the specific operation and climatic conditions.

4.1 Volvo Hybrid Product Overview

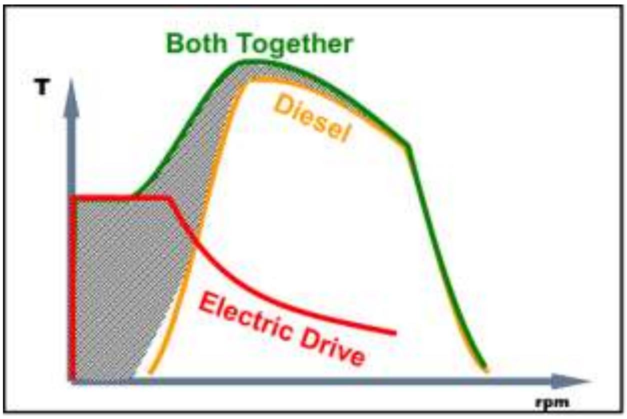
The Volvo Hybrid features Volvo's unique parallel hybrid driveline, taking energy efficiency and emission reduction to a higher level, and far beyond legislation. It is the most fuel-efficient and reliable hybrid bus on the market. It does not need to connect to an external electric energy grid as is the case with full electric vehicles as all energy is generated on-board the bus. In essence, it is 'grid and infrastructure free'.

Volvo's hybrid bus is a parallel hybrid – with results of this system extremely positive and now proven in commercial operation for many years. In a parallel hybrid system the electric motor and the diesel motor are directly connected to the gearbox/wheels. The electric motor can drive the gearbox by itself (electric only mode). At this time, the bus is silent and also emits zero emissions. Similarly, the diesel motor can also drive the gearbox wheels by itself (diesel mode). The third mode is where both the diesel engine and electric motor powers sources work together as a team to drive the gearbox – they work in parallel mode, hence the name.

As described above, both the diesel engine and electric motor powers sources can operate independently of one another as well as work together in parallel. In normal circumstances the electric motor is used when moving off from standstill and for accelerating to speeds of up to about 28 km/h, which promotes considerable fuel savings. At higher speeds, the diesel engine takes over propulsion of the bus and at the same time charges the electric motor's batteries.

The Volvo hybrid is ideal for urban operations. The electric motor serves both as a propulsion motor and as a generator. When the brakes are applied, their retardation effect is harnessed to recharge the batteries – energy that would otherwise simply be wasted in the form of surplus heat in the braking system. Repeated braking is thus an operational benefit. Hybrid technology is therefore ideal in operations characterised by repeated stops and starts, with frequent acceleration and braking, such as in congested urban traffic.

Owing to its considerable torque, the compact electric motor offers good performance in the low-speed sector and supplements the diesel engine's superior properties at higher speeds. The electric motor produces maximum torque right from start, which results in excellent starting characteristics and driveability. Electric power is also used when the vehicle is at a standstill. When the vehicle pauses at a bus stop or traffic light, the diesel engine switches off automatically. As a result, the bus produces no exhaust gases and is very quiet in operation. The graph below shows the benefits of combining electric and diesel power from the start up to operating phase of vehicle operation.



4.2 Benefits of a Hybrid Bus

Environmental benefits

The environmental benefits of hybrid technology are well documented and when utilised in the optimal operating environment the vehicle can provide significant savings in fuel consumption coupled with reductions in harmful CO_2, NO_x and particulate matter (PM). Volvo hybrid buses in operation today have proven to save up to 40% in fuel and CO_2, and to cut harmful NO_x emissions and particulates by as much as half. This not only has environmental benefits, but similarly health benefits for those inhaling the city air.

In more practical terms, operating one Volvo hybrid for a year could improve an operator's carbon dioxide footprint by 27 tonnes. Typically this means 12g less CO_2 per passenger mile, and the hybrid also offers a 50% reduction in particulates and NO_x.

Proven in commercial operation

Volvo Bus Corporation has extensive experience in the development and operation of hybrid vehicles. In October 2008 Volvo Bus was the first company to release a fully integrated commercially available hybrid when it launched the single deck platform in Hannover, Germany during the IAA Exhibition. This was quickly followed by the launch of the Volvo double-deck hybrid bus in United Kingdom as part of the city of London's focus for the 2012 Olympic Games. Today, Volvo has sold more than 4,000 hybrid buses (both single and double deck) in more than 20 countries. This includes more than 1,500 hybrid buses operating in the city London.

Locally, more than forty (40) Volvo hybrid buses have been delivered into Victoria for operation in Melbourne and the Latrobe Valley, as well as into NSW for operation on privately run rail and university bus route operations with outstanding success.

No infrastructure and full route flexibility

Volvo hybrids can replace standard diesel buses immediately today across the state without the need for any additional infrastructure, as mentioned earlier they are 'grid-free'. This means that the same complete route flexibility is maintained and there are no limitations as to where and for how long hybrid bus can run for during the day – and all while saving up to 40% in fuel and C02, and cutting NOx and particulates by half.

Full low floor for accessibility

The latest Volvo hybrid has been designed with the passenger in mind, featuring a full low floor for the entire length of the bus for enhanced accessibility for passengers as well as offering passenger flow, boarding and off-boarding benefits.

Fully Integrated Solution

Unlike many other hybrids in the marketplace, the Volvo Hybrid is a fully integrated solution – utilising "in house" technology. In other words, the Volvo Hybrid driveline is comprised of all Volvo technology, not a collection of related technologies from different manufacturers. All elements of the driveline are uniquely designed to work together. As such the Volvo solution also provides operators with a single point of support, as with regular diesel vehicles already in operation.

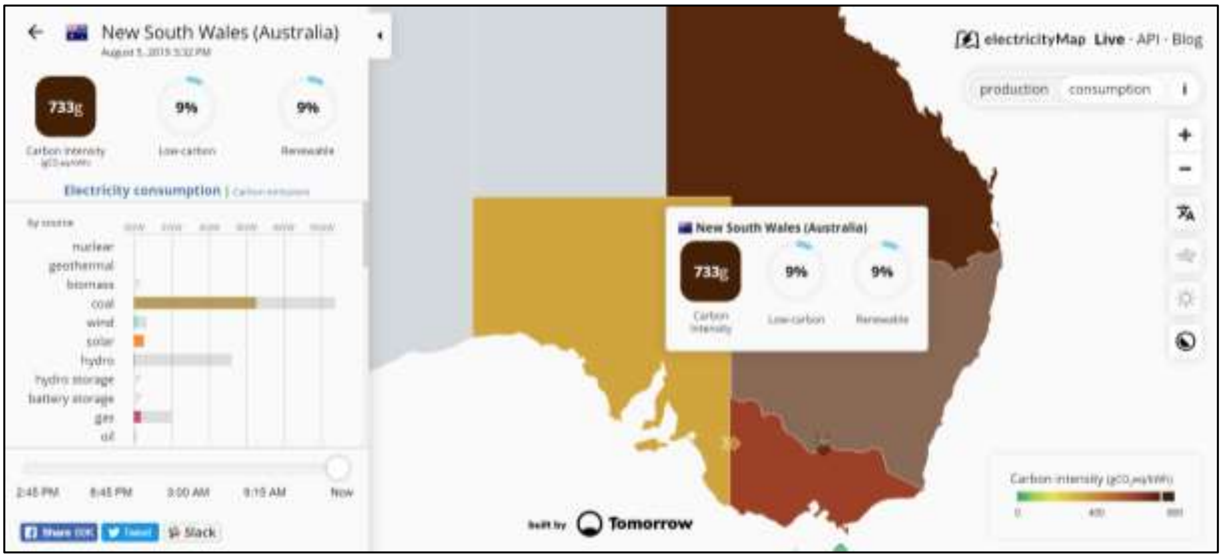
Volvo hybrid safety

As mentioned earlier, safety is one of Volvo's Core values and therefore plays a vital part in the success of our Hybrid vehicles. The Volvo Hybrid is installed with numerous safety features to ensure that the vehicle is both safe to build, operate and maintain despite its 600v electrical system. Volvo also ensures through a comprehensive training program, people working on the bus (building or servicing) are suitably trained. Details of specific safety features are available on request.

4.3 Carbon footprint - Volvo Hybrid vs. Electric Buses

Currently today the vast majority of NSW's electricity comes from non-renewable sources, with the largest source being from coal. As can be seen on the electricitymap.org website, NSW is considered in the highest band/rating (dark brown) for Carbon Intensity when it comes to both electricity production and consumption.

Screenshot from electricitymap.org website showing NSW carbon intensity



On average, over a full 24hr period NSW's carbon intensity is around 755g (gCO2eq/kWh) since carbon intensity changes depending on the time of day. If this is taken into account when comparing the carbon footprint of hybrid buses versus electric buses operating in NSW today, a Volvo hybrid bus has a lower overall carbon footprint than an electric bus.

A detailed environmental comparison between Euro VI diesel, hybrid and full electric buses based on today's Carbon Intensity in NSW is available on request. It is also based on these comparisons that Volvo request the hybrid bus be included on the new TfNSW Procurement Panel.

4.1 Volvo Electric chassis

A project at Volvo Bus Corporation is already well underway to package the chassis only components of complete Volvo 7900E electric bus operating in Europe today, which can then be fitted with a locally manufactured fully ADR compliant 2.5m wide body - as is done today for the standard diesel models. Additional details on the Volvo electric bus chassis can be provided on request.

4.2 Local body manufacturing

When Volvo's electric chassis product is available we will have the capability through our partnership with local bodybuilders to assemble electric bus bodies in Australia – including in NSW.

Whilst full electric vehicles provide some differences in the manufacturing process, the chassis and body relationship and interface is similar to that employed in the hybrid model already built on today in Australia. As such the transition from existing diesel to hybrid to full electric requires only minor adjustment of our processes, and presents opportunities for standardised body assembly on a variety of different drivelines including diesel, hybrid and full electric buses.

5.0 Benefits of the Volvo Electric bus

The Volvo Electric bus runs in silent and 100% emission free mode and will not only deliver environmental benefits but also most certainly increase the attractiveness of public transport. The bus delivers 100% fuel savings and 80% in total energy savings, contributing to a low life-cycle cost for the operator.

5.1 Noise

Reducing noise pollution is becoming increasingly important to make cities attractive and sustainable. The Volvo Electric bus reduces both the indoor and outdoor noise generated by the vehicle. Reducing the outdoor low frequency noise is especially important as it easily travels through buildings and walls.

A number of studies exist regarding the impact of noise on society, with some going as far as to quantify that impact. For example –

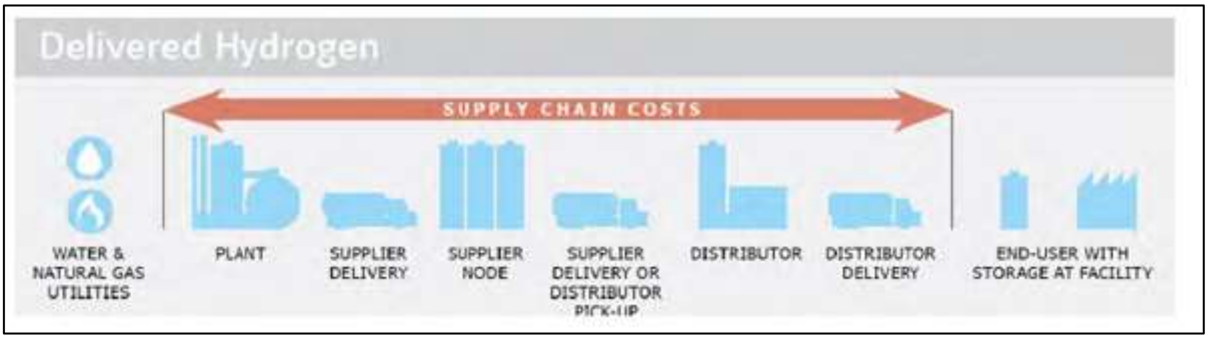
- A Swedish study by Koucky & Partners AB shows a cost for the Swedish society of 16 BSEK annually due to high noise levels.
- A shift from diesel to electric saves 4 SEK per km according to the same study.

Another key study into the impact of noise on society is "Quieter Cities of the Future", by the International Council of Academies of Engineering and Technological Sciences (CAETS) Noise Control Technology Committee and the International Institute of Noise Control Engineering which states "the adverse health effects of traffic noise are comparable to the health effects of road traffic accidents". This report in downloadable from the CATES database at the following link - http://www.caets.org/File.aspx?id=11745

In the EU the cost of noise and emission is included in Life Cycle Cost (LCC) calculations. Example total cost calculations are available on request.

5.2 Electric vs. Fuel cell

As referred to in the introduction, in 2009 the Volvo Group trialled multiple new fuel types for review by Governments around the world. This line-up of products included hydrogen fuel cell vehicles. Even though hydrogen fuel cell vehicles (HFCV) today offer a longer non-stop range than battery electric vehicles (BEV), Volvo's research found, and continues to find, that hydrogen technology cannot currently compete with BEV from an energy efficiency or energy cost standpoint.

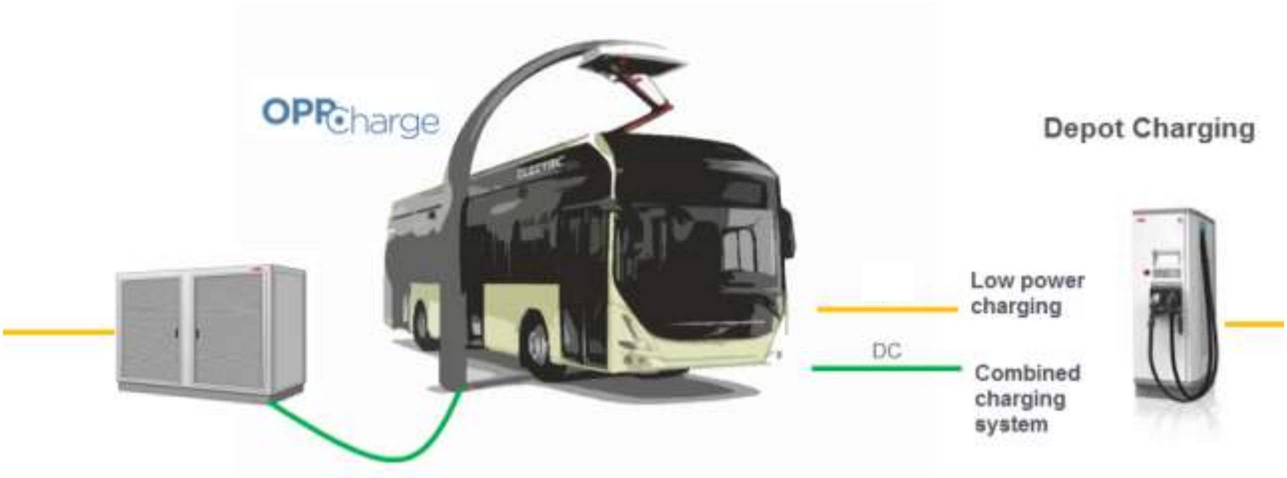


6.0 Charging and infrastructure

Volvo's electric buses (both complete Volvo vehicles and the Volvo electric chassis with locally manufactured body) can be charged on-route or in the depot. There is also a version with depot charge only.

Volvo supports OppCharge (overhead opportunity charging on the route), Combo 2/CSS depot charging, and any blend of the two. With charging on the route the range is unlimited, and for many routes, depending on local operating conditions, 3-6 minutes of charging is enough.

Volvo Buses have signed global agreements with ABB and Siemens for the development and delivery of charging infrastructure. We also work with Heliox as a charging supplier. The offer includes CCS charging (up to 150 kW) and opportunity charging (up to 300kW) via pantograph.



Charging flexibility

6.1 OppCharge (Opportunity Charging)

OppCharge is an open interface between the charging station and vehicle, which means the charging station can be used by other electrified bus makers too. Pantographs fitted to the overhead pylon make it possible to use a cost-effective solution with low weight on the bus roof. The conductive charging uses current collectors, with communication between the buses and charging station via Wi-Fi.

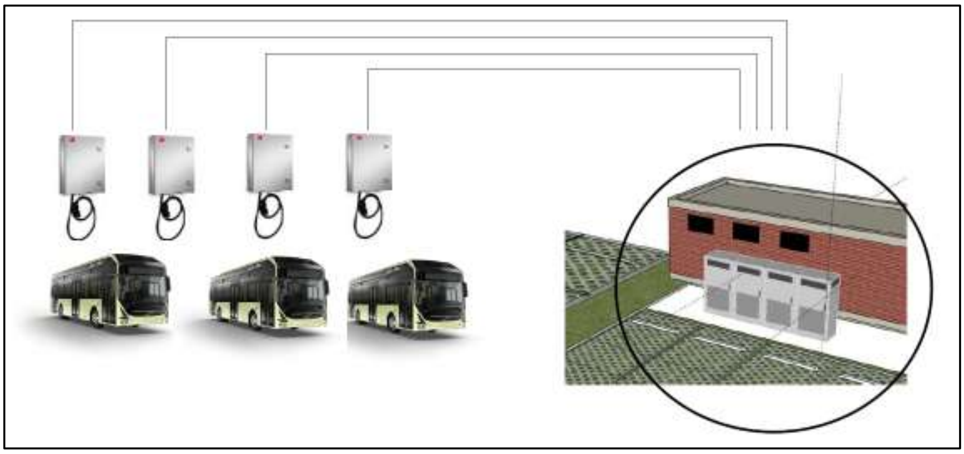
An opportunity charging system allows the bus operator to use a limited amount of batteries in order to maximize passenger capacity and still have enough batteries to bridge disturbances and abnormal traffic situations. Some of the advantages of this type of system include –

- Increased daily vehicle operation
- Increased passenger capacity
- Even distribution of power consumption throughout the day
- Efficient charging in terms of energy losses
- Flexibility to move vehicle operating base
- Common agreed open interface

More information about OppCharge can be found at: https://www.oppcharge.org/

6.2 Combined Charging System (CCS)

Charging is done easily by plugging in the connector manually to the vehicle when it is parked, for example, at the depot. CCS uses the European Standard Connector. Three outlets connected to one 150kW charger can charge three buses overnight using smart charging. An example of such installation at a depot below can be seen in the images below.



150 kW overnight charging system with three depot charge boxes

More information about both opportunity charging, and the CCS in depot charging can be viewed in the Volvo Bus video available online at the below link. This explains the different scenarios suitable for each charging solution, and presents example vehicle ranges, route lengths and charging times.

Link to Street smart charging by Volvo - https://www.youtube.com/watch?v=foDzAPfFxro

7.0 Project Implementation

Like the bus routes, there is also no one size fits all approach to the implementation of electrified bus routes and projects. Around the world there have been successful examples of different approaches and project management models. For example:-

- The operator covers all infrastructure, capital and operating costs in their operating bid – proposed as a turnkey solution towards the Transport Authority.
- The Transport Authority covers the investment in infrastructure, which is then utilised by multiple contracted operators.
- The energy provider pays for the infrastructure, with the view it is an investment to secure future revenue from electricity supply.

In Volvo's experience, in-depth planning and preparation for such a project is a critical success factor for any electric bus implementation. The construction and commissioning of infrastructure for example can take more than 12 months in some instances depending on the grid, power availability and cooperation with city planning and council for example. It is for this reason Volvo recommended starting immediately with the delivery of hybrid buses, while planning for a proper introduction of the full electric.

7.1 Tendering Complexities

Given the complexity of responding to a tender for full electric buses when compared with diesel or hybrid and in particular if it requests a full turn-key solution, Volvo would recommend allowing a minimum of twenty (20) weeks for tender submissions for future procurements. This would enable each route to be fully assessed for suitability and for accurate and detailed project plans to be provided. It would also enable full engagement with local manufacturers to ensure an Australian built body capable of meeting the latest TfNSW panel specifications and commercial terms as well as form partnerships with local TfNSW operator.

The TfNSW Panel #3 specification is for the procurement of buses only and does not take into consideration the complexities as detailed above. Currently the Panel #3 is the platform for procurement of buses only. Capital works, infrastructure, and other project elements would need to be considered outside of the panel.

8.0 Trial considerations

While single unit trials of electric vehicle technologies allow for cities and operators to enhance their understanding of this technology, the large scale application of electric vehicles requires far wider consideration of what will really be required. Applying this technology in non-route bus operations where the charging strategy can be modified does not represent well the challenges with high volume, large fleet, route bus operation.

To fully understand the impact of running electric buses has on the grid, timetable, and general operations Volvo recommends trialing a full electric route, as opposed to just one or two buses on a route, where possible. This will give far greater insight into the technology, performance and operational viability.

When planning a trial Volvo also recommends significant amount of time, in some cases we have seen up to a year, be factored in for the construction and set-up of infrastructure. This is very site by site based, and dependent on proximity to the required amounts of power. Some depots for example may require significant infrastructure, including a new power substation in some cases.

9.0 Experience with introducing electric bus fleets in other jurisdictions

9.1 Real world example - Volvo's Line 55, Gothenburg

Since June of 2015, Volvo Bus has been operating a commercial bus route in Gothenburg, Line 55. This operation requires a total of 10 buses which is served by a mixture of all three of Volvo's technologies – hybrid, electric hybrid, and full electric, with with proven environmental savings, uptime, performance, reliability and public appeal. In this particular operation:

- Buses are charged at overhead charging points (3-6 minute charge for 10-20 km range).
- Buses carry same number of passengers or more than the diesel equivalent.
- Electricity for this system is provided by renewable sources (wind and aquatic).
- All buses are geo-fenced ensuring electric operation only at specific points on route.
- Indoor bus stops are utilised (shown below).

- 14 key stakeholders involved in the project including Volvo as the vehicle manufacture, the transport authority, bus operator, energy company, infrastructure provider, department of city planning, university and more.

More details about this project can be viewed online at: http://www.goteborgelectricity.se/en/node/11380.

More information about Volvo's electric offering can also be viewed online at http://www.volvobuses.com/en-en/our-offering/electromobility.html.

Volvo has successfully implemented electric bus projects in more than 20 cities around the world.

10.0 Route selection and example simulations

As highlighted in a number of areas above, not all routes lend themselves to the benefits of electric buses in the same way or to the same degree. Key factors when considering bur routes for electrification include –

- *Route length and total daily distance travelled* – need to ensure it does not extend beyond vehicle range and/or that there is adequate charge time
- *Depot location, and distance to first and last stops* – must be factored into total daily running time.
- *Timetable, and times available for charging* – needed to ensure there is suitable times for charging either in the off peak at the depot, or on-route at end stations.
- *Maximum passenger load* – must be used in range calculations as weight impacts vehicle range.
- *Total ancillary draw* – for example from air conditioning, which again impacts range
- *Topography* –electric buses at this stage are not ideal for very hilly terrain

- *<u>Average speed and idle times</u>* – influences range and opportunity for battery charging via braking

In addition to the operational factors listed above, close proximity to people and residential areas should also be taken into consideration as this is where the benefits of zero emissions and noise are experienced and therefore maximized.

Before commencing and trial or commercial operation, based on our experience and technical expertise Volvo always simulates the operation and performance of electric buses operating on a specific route to ensure suitability. Example route simulations can be provided on request.