Submission No 22

ELECTRIC BUSES IN REGIONAL AND METROPOLITAN PUBLIC TRANSPORT NETWORKS IN NSW

Organisation: Siemens

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New South Wales Committee on Transport and Infrastructure

Inquiry into eBuses in regional and metropolitan public transport networks in NSW

Respondent: **Siemens Ltd.**

This submission addresses the following Terms of Reference:

1. Benefits of eBuses and factors that limit their wider uptake.
2. Minimum energy and infrastructure requirements to power eBus fleets.
3. Other renewable, emissions neutral energy sources.
5. Experience with introducing eBus fleets in other jurisdictions.
6. Opportunities and challenges of transitioning the entire metropolitan bus fleet to electric.
7. Any other related matters.
8. About Siemens

Siemens applauds the NSW State Government for initiating this inquiry by the NSW Committee on Transport and Infrastructure into electric buses (eBuses) in regional and metropolitan public transport networks. Siemens believe the transition from diesel and compressed natural gas (CNG) buses to electric will provide significant economic, environmental and health benefits for bus operators and the public.

As a leading global provider of Electric Vehicle (EV) charging infrastructure, system management software and consulting services, as well as the required grid stabilisation / augmentation technologies, we welcome this opportunity to contribute to this inquiry, and share some of our global experience when it comes to identifying the opportunities and challenges of electrifying a city's bus network.

You can learn more about our capabilities in the eBus charging infrastructure market in the "About Us" section at the end of this submission.

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1. Benefits of eBuses and factors that limit their wider uptake.

Many of the key benefits of electrifying a bus fleet are well understood. These include

Environmental and Health Benefits

EBuses have no tail-pipe emissions, reducing exposure to nitrous oxides and diesel particulate matter pollution and hence improving air quality in cities. EBuses also have greater fuel efficiency, reducing green house gas emissions.

EBuses are much quieter than diesel engine driven buses. They can therefore deliver a much quieter journey / better ride for passengers than fossil powered buses, with corresponding lower local environmental noise pollution.

Lower Total Cost of Ownership vs Diesel Bus Fleet

EBuses usually involve higher capital purchase costs, mostly associated with the battery charging unit, and this can be a barrier to adoption. However, the higher 'fuel' efficiency combined with simpler maintenance requirements / smaller spare parts inventory (because of fewer and more reliable drive-train components compared to diesel engines), results in lower running costs per kilometre and an overall lower total cost of ownership.

There is also the opportunity for self-charging the bus fleet from rooftop solar installations where sufficient and attractive roof space is available, for example at major depots. Significant solar installations combined with sizeable battery capacities can turn an eBus fleet into a sizeable "prosumer" (producer and consumer of electricity), which could create the opportunity to play a useful, and profitable, role in the grids' peak load management function. All this could further reduce the total cost of ownership. This is covered in more detail in Section 6 of this submission.

In addition to the above, the electrification of Australia's major bus fleets / networks would:

- Contribute to Australia meeting its international greenhouse gas emission targets: although bus related emissions make a relatively small contribution to transport related emission (about 3%), transport is responsible for approximately 18% of Australia's total emissions, and the latest Dept. of the Environment and Energy's projections are for transport emissions to increase to 2030
- From a national interest perspective, reduce Australia's dependence on imported crude oil and diesel, enhancing the country's energy security profile.

As with the introduction of most major changes, there are still some uncertainties for bus fleet operators regarding the adoption of eBuses at scale. These usually revolve around eBus battery charging strategies, selection of the most appropriate charging hardware, potential exposure to grid augmentation costs and the usual challenges associated with the introduction of a major change in business process.

To overcome these challenges, and maximise the potential operational and financial benefits of converting to an eBus fleet, Siemens wish to stress the importance of meticulous planning, preparation and effective change management.

A holistic view of a transition is needed. Whilst it may appear tempting to adopt a pilot approach, and build slowly on small and disparate trials within an existing network, we believe this can actually increase the complexity of adoption (as a new technology is being inappropriately shoe-horned into an existing operation), and potentially hinder adoption.

Charging Strategies and Route Planning

Since eBuses typically have a shorter driving range than diesel buses, a critical question that municipalities, transport operators, and manufacturers face is where and when to charge them.

The typical charging strategies are: overnight charging only (depot charging), recharging throughout the day (opportunity charging), or a combination of both. Each strategy will have associated benefits and trade-offs, and a mix of charging technologies is often required.

This can also affect bus routes network planning, which will now need to take into account both bus driving ranges, battery management and charging strategies. Whilst this may initially make the route planning task seem more complex, it can also create opportunities for route optimisation. There are specialist planning software tools which can make this exercise less onerous.

Finally, depot management changes may be required, covering items such as depot design and modification, parking requirements depending on charging station layouts, which play a role in either enabling or constraining eBus adoption.

Charging Hardware Selection and Potential Grid Impacts

Due to the energy capacity of the batteries involved, it is clear that high capacity / fast charging will be required. This in turn means that high power charging infrastructure will be needed to make an eBus fleet properly operational and efficient, including both charging equipment as well as any required grid connection upgrades for the 'point load' power needs at charging stations.

Effective charging and energy management now become key success factors in converting to an all eBus fleet, considering time to charge, ease of charging, installation needs and connection requirements. These capabilities are not normally found within bus network operators and can initially seem quite an obstacle to adoption.

The transition to all-electric fleets is a global phenomenon, and there are many reference cases of cities doing this very successfully. The industry is developing sophisticated planning tools and products which will make this task much easier, and we expect this planning function to become quite a normal part of a fleet operators' business. We include some examples in Section 5 of our submission.

2. Minimum energy infrastructure requirements to power eBus fleets.

EBus fleets introduce significant electrical loads in a highly localised area. As a significant load on the electricity network, grid operators may require certain obligations or services to be provided by bus depot operators. For example providing reactive power limits, becoming a standby interruptible load for major grid events, or guarantee power fluctuations limitations within a certain bandwidth during certain time of day. These grid requirements need to be clearly understood and articulated as part of planning.

It is possible that standby generators are required to improve power supply redundancy. However, alternative solutions could be adopted by taking an holistic approach to cluster multiple depots within a certain km radius to spread the risk of power failure across the group, rather than equip all depots with individual redundancy.

Introducing a significant load poses the need for grid upgrades in the form of upgraded transformers to new substations to meet localised electricity demands. These upgrades can be prohibitively expensive, however CAPEX expenditure can be significantly mitigated by employing dynamic load management capability to proactively control bus charging. For complete depot transition to eBuses, load management is absolutely critical.

Charging management software brings digitalisation capability to bus depot operations, enabling operators to monitor charging infrastructure and bus telemetrics, and manage electricity usage through load management. It can also interface to microgrid management software, energy markets and grid operator platforms. Integration with other public transport systems such as customer information systems is also possible. A holistic approach to charging management software could also be adopted, enabling multiple depots to be centrally managed at a bus operator or public transport authority level.

Charging Management Software

Significant CAPEX and OPEX savings can be achieved through the adoption of charging management software. Software with sophisticated load management capability enables the integration of bus operations with energy management, by importing the bus schedules and matching charging time and speed (kW rating) to operational need. This ensures that each eBus is charged to the required level to meet the distance of their planned route, while charging at the most cost effective kW rating (load balancing) and time (load shifting) to reduce electricity costs (OPEX) and grid infrastructure costs (CAPEX).

Load balancing, or peak shaving, ensures that a maximum charging power threshold is never exceeded or follows a maximum power target load curve. The software can derate the maximum available power provided by each charger to each bus. The target load curve can be:

- set for individual chargers, or for a group of chargers.
- static (constant)
- dynamic in response to various factors including time of the day, type of day (working, non-working, holiday), season, or in response to real time information from energy market signals regarding available grid capacity or variable tariffs.

Load shifting, or Time of Use (TOU) optimisation, ensures that all buses can be plugged into charging infrastructure at the end of their shift, however charging may not commence until a time when tariffs or demand is lower.

The following example demonstrates how load management software can reduce power requirements for a large eBus depot. This example is based on 150 eBuses with 240kWh batteries, 150x 80kW DC chargers, and buses arriving and departing at scheduled times.

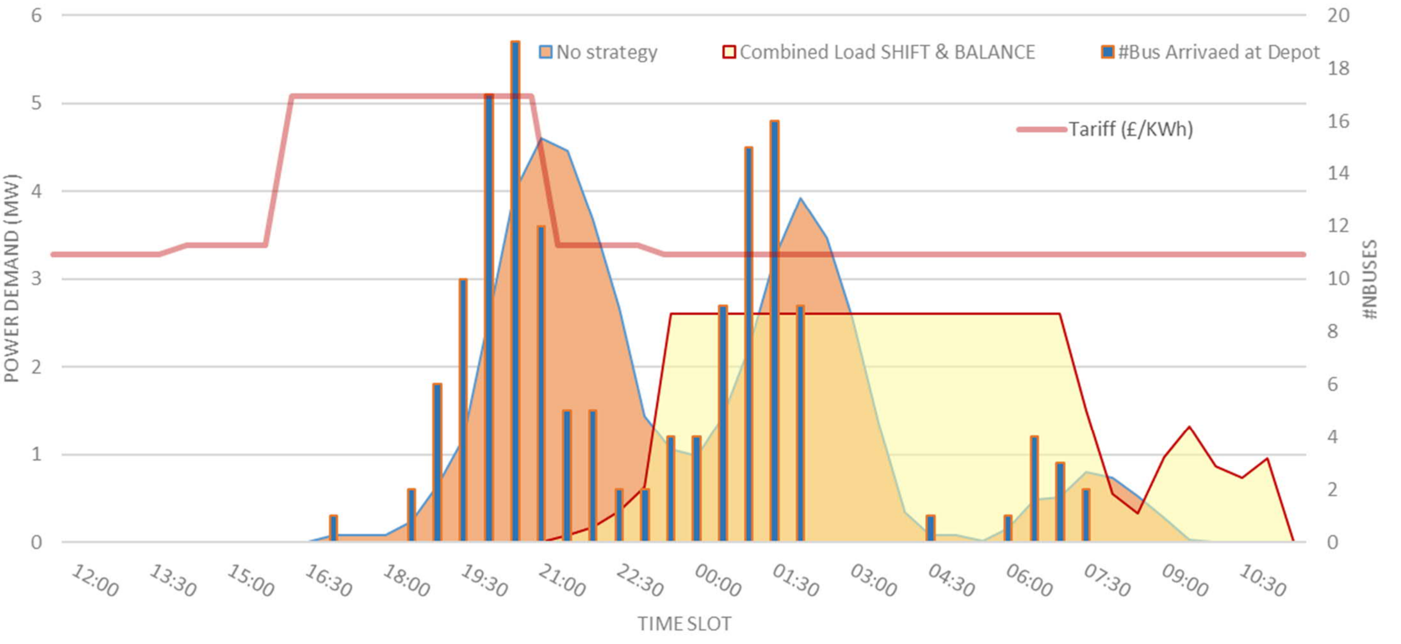

Figure 1: Load Management Example at Large Bus Depot

The graph shows how the following problems are addressed to reduce grid infrastructure upgrades and peak electricity demand:

Problem 1: Buses arrive together creating large power demand

Solution: Load balancing reduces the power connection requirements from 4.6MW to 1.7MW, significantly reducing CAPEX expenditure in grid infrastructure upgrades.

Problem 2: Large power demand at time when energy tariff is expensive

Solution: Load shifting delays the commencement of charging until a time when energy costs are cheaper, significantly reducing OPEX expenditure on energy.

As an example, Siemens provides the EVC3 Charging Management Software specifically for eBus depots, enabling bus operators to not only manage their charging infrastructure assets but access new sources of revenue through energy market participation. EVC3 enables bus operators to:

- Report and monitor: visualise and manage depot charging operations, including real time status of charging infrastructure and energy utilisation
- Load management: optimise and control depot charging in order to reduce OPEX and CAPEX, integrated with vehicle schedules and grid information
- Energy management: integrate and manage distributed energy resources such as solar and battery storage, to optimise renewable self-consumption.
- Energy system integration: integrate and manage depot as part of a wider system as an energy market participant, offering demand and frequency response services to the grid operator, easing network constraints and opening new sources of revenue for bus operators.

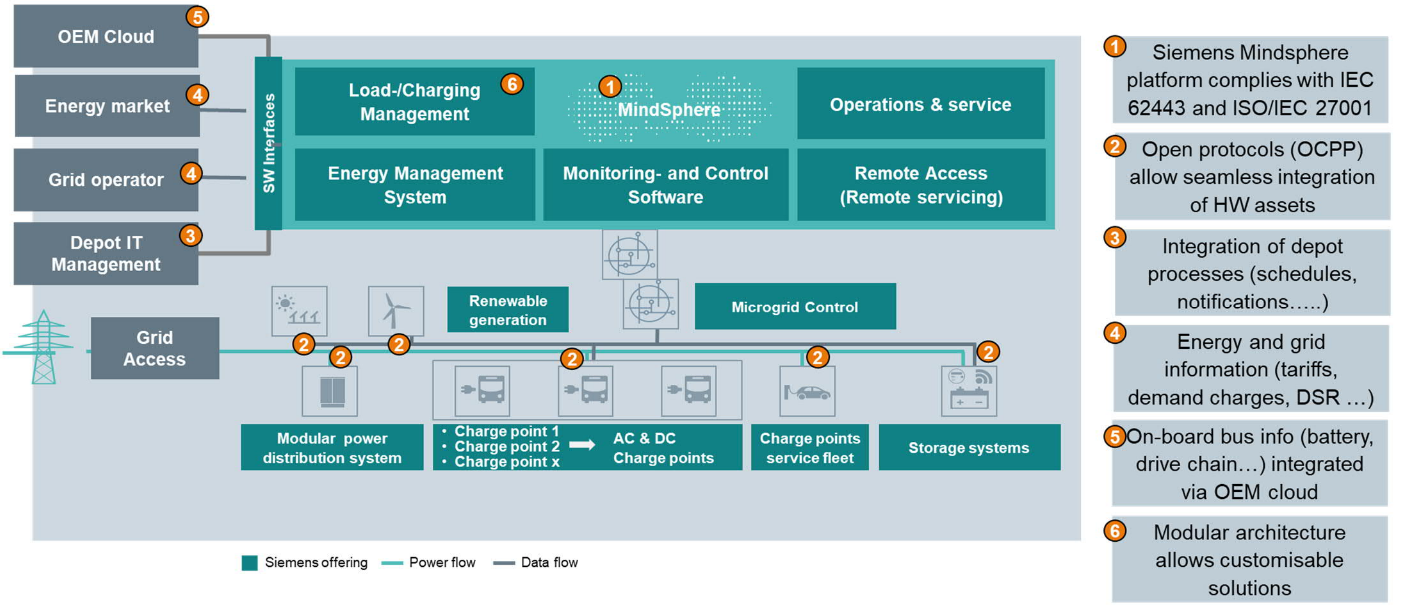

Figure 2: Siemens EVC3 Charging Management Software for Heavy Vehicles

3. Other renewable, emissions neutral energy sources.

In June 2019, the City of Sydney became the second Australian capital city to declare a Climate Emergency. The electrification of transport is one of many strategies to decarbonise the economy, but only if renewable resources are included as an integral part of the transition. This is particularly true in NSW where over 75% of electricity generation is from coal.

The geographical size and electrical demand of an eBus depot create opportunities for commercial scale solar arrays, battery storage and other innovative renewable solutions.

Solar Power

Many bus depots have large empty roof spaces, as well as uncovered parking areas, that could be covered in commercial scale solar arrays. Solar power, either used to cover business electricity needs, exported to the grid or captured in battery storage, will lower OPEX through reduced electricity expenditure. Solar also creates opportunities for greater energy resiliency in the case of brown/black outs.

Ryde Depot: Solar Case Study

Ryde Depot, operated by State Transit, is one of the largest in Sydney with approximately 300 buses. The following assumptions are made regarding solar generation potential at this site.

- Available roof area: ~4000m2 (based on Google maps)
- System size: 3840kW
- Solar generation: 5,196,941 kWh/Year (PVWatts Solar Calculator)
- Solar value: **$1,818,929** (based on offsetting electricity rate of $0.35/kWh)

Battery Storage

Large scale battery storage enables bus depots to take advantage of solar generation, stored for when it is most needed overnight to recharge eBus batteries. Integrating battery storage into a bus depot offers the following benefits:

- Provide access to renewable power overnight and during low solar times.
- Provide peak shaving to reduce peak demand for grid power
- Improve power quality by smoothing reactive and active power variations
- Lower grid reinforcement infrastructure costs

Microgrids

Microgrids allow the integration of distributed energy resources (renewable generation, battery storage) to optimise energy usage (self consumption and export). Microgrids also provide energy resiliency in the case of grid failure which would enable the depot to provide electricity to power operations but at a lower capacity.

5. Experience with introducing eBus fleets in other jurisdictions.

Siemens have supported over 25 bus operators with the installation of over 200 plug-in and opportunity charging units across Europe, Asia and North America over the last six (6) years. Siemens entered the EV charging infrastructure market in Australia in 2019 to help support and build the transition to eBuses started by visionary early adopter states.

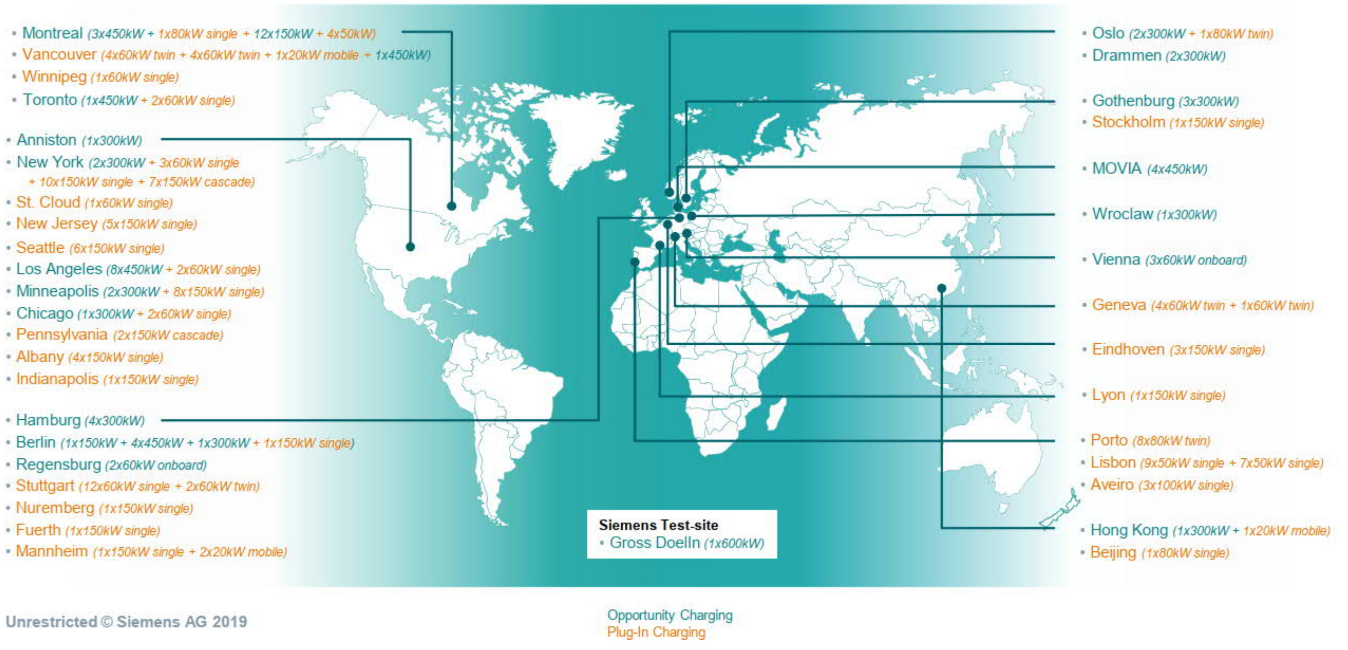

Figure 3: Siemens eBus Reference Projects

Siemens Sicharge UC product range includes both plug-in depot charging and overhead opportunity charging. The system is designed for maximum flexibility, through:

- Supporting power ratings from 50kW to 800kW
- Supporting battery voltages from 10V to 1000V, removing any limitation to charge emerging buses with higher battery voltages.
- A modular design enables additional Front Ends to be added to a maximum of five (5)
- A single Charging Centre can connect to up to five (5) Front Ends plus an opportunity charger
- A single Charging Centre supports mix of CCS and GBT protocols across connected Front Ends

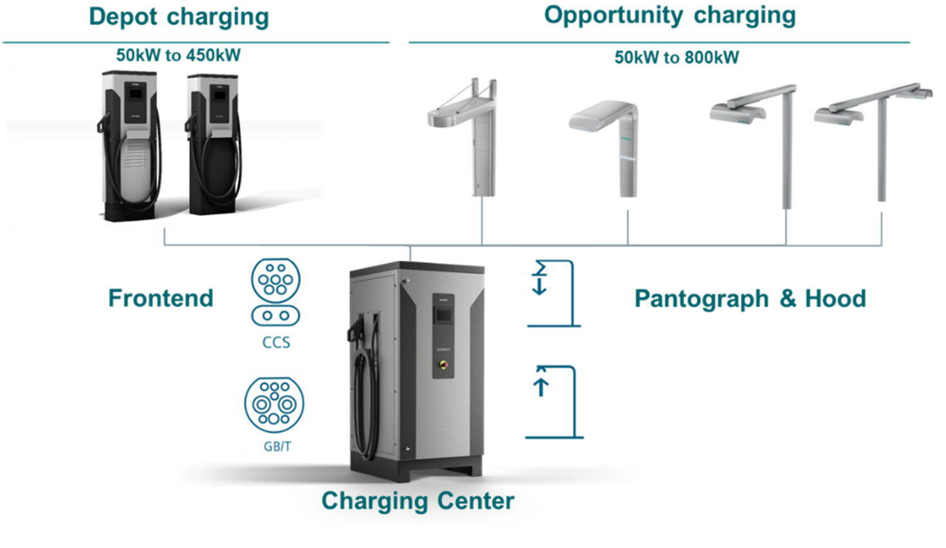

Figure 4: Siemens Sicharge UC eBus Charging Hardware Portfolio

The eBus charging infrastructure industry has adopted two dominant solutions for bus charging infrastructure; plug-in depot charging and opportunity charging. Both solutions are equally viable and selection of the optimal solution is dependent on the nature of the bus operations.

Plug-in depot charging is suitable for depots where buses are parked for extended periods overnight. Buses can either be charged at the same time, or sequential charging strategies can be adopted to lower peak demand for electricity while ensuring buses are charged sufficiently to meet their operational needs for their next trip. Siemens provides plug-in depot charging from 50kW to 450kW.

Opportunity charging is achieved either via a top-down pantograph that lowers to connect to contacts on the bus roof, or bottom-up pantograph that raises from the bus to connect to a charging hood. The charging hardware enables very high-power charging to be achieved, able to charge a 200kWh battery within minutes, and is typically used where very fast charging of batteries is required due to time constraints.

Opportunity charging is suitable for:

- installation anywhere on a route, whether in the depot, bus stop or interchange
- assists with the transition of existing bus routes from Internal Combustion Engine (ICE) to eBuses, where the existing route distance cannot be met by the limitations of the bus battery. Therefore, the existing bus route does not need to be augmented to meet the eBus capability, as high-speed top-up charging can occur along the route
- locating opportunity charging at interchanges enables multiple buses from various routes to access fast charging as part of the scheduled trip, optimising the use of charging infrastructure
- operations where buses operate close to 24 hours a day, for example airport shuttle buses.

T80 Liverpool to Parramatta: Charging Infrastructure Case Study

The T80 rapid bus transit route from Liverpool to Parramatta is one of the major metropolitan bus routes in Sydney, operating mainly along dedicated bus-only roads. The route is approximately 28km, with an hour-long journey time, and operates from 5am to 1am.

The T80 route is an example where a mix of plug-in depot and opportunity charging may be required to meet existing operations, assuming eBuses replace ICE buses but the existing bus schedule is unchanged. Based on the following assumptions, a fully charged battery charged overnight in the depot will also need top-up charging throughout the journey.

- 4hrs available per bus for overnight charge
- 14 trips per bus per day
- Each bus required to operate the full operating hours
- 392km covered per bus per day
- 300kWh eBus battery capacity
- 200km available distance per fully charged bus

In the above scenario, the eBus could be fast charged by an opportunity charger during the layover periods of between 12.5min to 30min, enabling it to cover the existing route.

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

Transitioning entire metropolitan bus fleets to fully electric poses a challenge in electricity demand. However, in the future, the battery capacity of the combined bus fleet also represents opportunities for bus operators to expand their business and become an active energy market participant, providing revenue for the bus operator and grid services to the grid operator.

Vehicle to X (V2X)

V2X is bidirectional energy transfer from the grid to the vehicle and the vehicle to X, where X can be a building, microgrid or the national grid itself.

V2X enables vehicles to become mobile grid storage devices that can trade electricity and provide ancillary grid services. EBuses can store or dispatch power to help stabilise the grid through frequency response, participate in arbitrage by storing when demand and tariffs are low and exporting when demand and tariffs are high, and can provide a green alternative to expensive, inefficient and environmentally unfriendly peaker plants. When multiple eBuses are available, aggregators can group batteries together into a virtual power plant to truly harness the potential of these grid services.

V2X capability is already being piloted globally in light vehicles, with a small number of commercial applications offering demand and frequency response services operating in Denmark and Japan. Currently V2X is only capable with the Chademo plug type, which is not used in eBuses as it is currently not suitable for high power charging. Trials are being conducted with buses using the CCS plug type. CCS supports high power charging. For example Siemens and VDL are currently trialling V2X functions in The Netherlands.

Sello - Example of Energy Market Participation

The following example demonstrates a real world application of V2X capability.

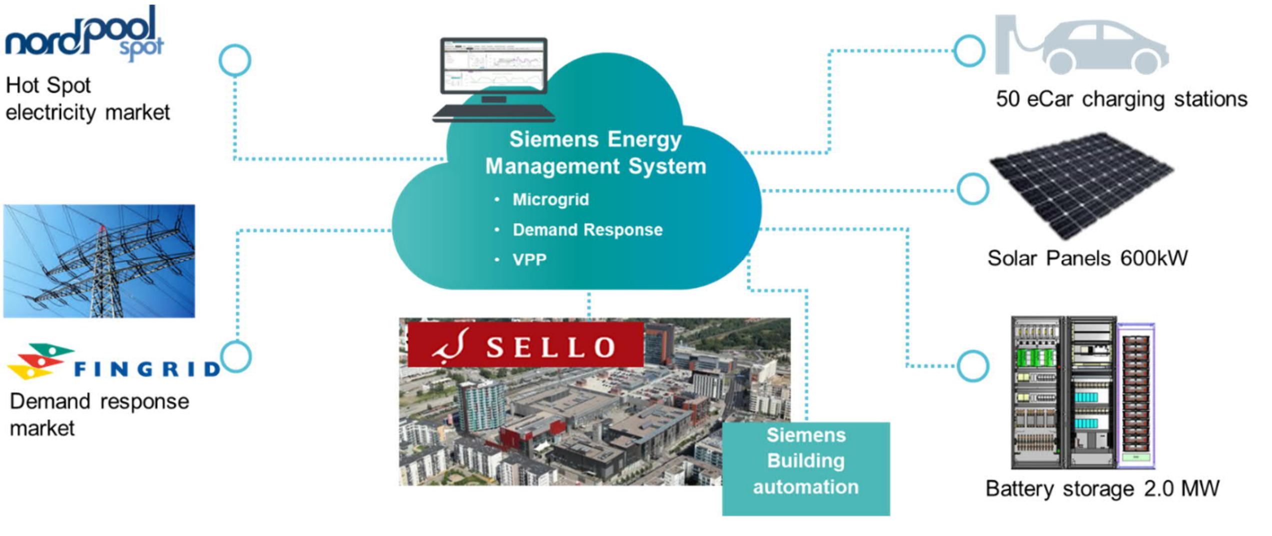

Figure 5: Sello Shopping Centre Example

Sello is the second largest shopping mall in Finland with 170 shops and 23million visitors a year. Sello implemented a distributed energy system including 600kW of solar PV and 2MW of battery storage. Sello have an electricity reserve market contract with the national grid operator Fingrid to export energy to the grid and provide flexibility services including demand and frequency response. Sello earn EUR$500,000 in revenue from energy market participation and save 281 tons of CO_2 a year.

Sello also have 50 electric vehicle charging stations which are currently load managed. Sello plan to integrate electric vehicles that are plugged in and charging into the total available storage and grid service capability. If we assume that 50 Nissan Leafs with 40kWh batteries are all plugged in at once, that represents another 2MW battery available.

7. Any other related matters.

Access to eBus Telemetrics

Telemetric data about the long-term performance of an eBus battery, including degradation and overall battery health, are not usually provided by eBus OEMs as the information is considered proprietary. When drafting contracts, bus operators or public transport authorities should stipulate a requirement for access to bus telemetrics to ensure the performance of the eBus overtime is transparent.

Standardisation of plug type

While European and Chinese eBuses typically use the CCS charging plug in markets outside of Asia, some Chinese OEMs have sold eBuses with GB/T charging plugs in the Oceania region. In New Zealand there is already a mix of CCS and GB/T buses, requiring bus operators to duplicate charging infrastructure to accommodate both protocols. Early standardisation of the plug type to CCS in Australia would avoid this problem.

Considerations for combining or splitting tenders for buses and charging hardware.

Tenders for eBuses and charging technology are often combined, partly to ensure compatibility in the absence of plug standardisation. However there are benefits in splitting these tenders. These include:

- Charging hardware has a longer lifetime than buses. Keeping tenders separate can avoid being locked into a particular bus technology, and provide greater flexibility
- Increased opportunities to install various charging technologies to meet a fleet operator's needs (some combined bus / charging options provide limited charging technology options)
- Increased charging competition leading to lower pricing
- Easier compatibility with various power management software products
- Clearer responsibilities between charging station operations and bus operations.

Derating in high temperatures

In a warming climate, outdoor equipment will get increasingly closer to the limits of their designed operating temperatures. This will be especially true over an Australian summer in NSW. Charging infrastructure should be specified to be able to meet higher operating temperatures, either through design or via airconditioned housing. For example plug-in depot charging could be installed in an airconditioned eHouse with Front Ends installed externally. Opportunity charging could be installed in a covered bus stop with a hardware mounted directly to the ceiling (as per photo from a Siemens project in Gotheborg, Sweden below).

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Figure 6: Siemens opportunity charging mounted directly to ceiling (Gotheborg, Sweden)

<u>Multiskilled technical service teams</u>

The transition to eBuses will present a short term challenge of ensuring maintenance teams are multiskilled across Internal Combustion Engine (ICE), hybrid and battery electric vehicles.

<u>AC vs DC charging</u>

Charging infrastructure is either AC or DC. DC charging is capable of much higher power and hence faster battery charging. To ensure that all buses are capable of charging using common charging infrastructure, Siemens recommends specifying that eBuses are capable of DC charging.

Note that V2X is not possible through AC charging infrastructure.

8. About Siemens

Siemens is one of the world's leading technology providers for the electrification, automation and digitalisation of the globe's major industrial sectors. The backbone of our business is the provision of power distribution infrastructure (high, medium and low voltage). A key enabler of the energy transition underway is the digitalisation of this infrastructure, or the development of 'Smart Grids' which, when coupled with what we refer to as 'Smart Buildings', results in 'Smart Infrastructure' – the name of the division that houses our e-Mobility (including eBus) business. We therefore support our customers through the provision of grid planning, infrastructure and digitalisation capability. Siemens are able to provide bundled, end-to-endsolutions for eBus charging infrastructure projects including:

- plug-in depot and opportunity charging hardware
- charging management software
- depot transition consulting services
- grid scale battery storage (BESS)
- string inverters for photo-voltaic
- low and medium voltage switchgear, transformers and ring-main units
- grid upgrade planning services

More information about our capabilities can be found at
https://new.siemens.com/global/en/company/about/businesses/smart-infrastructure.html

For information about Siemens eBus charging portfolio:
https://press.siemens.com/global/en/pressrelease/sicharge-uc-system-sets-new-standards-flexible-ebus-charging

For details of some completed eBus projects please refer to:
https://new.siemens.com/global/en/products/mobility/road-solutions/electromobility/ebus-charging.html