Actew AGL Distribution
22-Oct-2013

ACT Light Rail

Electrical Demand and Infrastructure Assessment

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Client: Actew AGL Distribution

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Prepared by

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Prepared by Ben Gill

Reviewed by Toby Roxburgh

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	9-Aug-2013	Draft	Simon Evans Associate Director	
2	22-Oct-2013	Final	Simon Evans Associate Director	

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Executive Summary

The ACT government is seeking to implement light rail from the City to Gungahlin. This presents a risk to ActewAGL during the next regulatory period for additional electrical infrastructure. This report assesses the energy demand, additional infrastructure and the associated cost impact if the light rail project proceeds during the next regulatory period.

Our approach looked at:

- energy consumption for light rail systems around the world
- the proposed light rail delivery system, including
  - underground / power delivery system
  - replacement of Red Rapid bus route
  - express service stopping in 3 locations
- energy consumption for the proposed light rail system
- peak demand
- infrastructure delivery
- indicative costs.

The estimated network maximum demand increase is estimated to be between 2 MVA and 13 MVA depending on the battery storage and usage requirements of the system.

An additional 1.2 GWh per annum may be required to operate the system.

The assessment has indicated that there are three potential infrastructure requirements outlined below, of which only one will be required:

- provide one 5MVA 11kV feeder to serve transformers along the route, the supply depot and associated substation
- provide two 5MVA 11kV feeders to serve transformers along the route, the supply depot and associated substation
- provide connections from the existing network to major train stations using existing feeders and provide an additional substation for the supply depot.

Given the uncertainty in the system delivery timeline it is recommended that network augmentation costs up to $19.5 million are allowed for, with consideration given to using train battery systems to reduce peak demand impacts and allowing existing infrastructure to run at a higher load during the short station charging times.

1.0 Introduction

To achieve a more efficient transport network for Canberra over the next 20 years the ACT government is seeking to implement a light rail transit (LRT) system from the City to Gungahlin, along Northbourne Avenue and Flemington Road. The proposed system is expected to replace the existing Red Rapid bus route and aims to achieve a 10 minute frequency by 2021 and 8 minute frequency by 2031.

As LRT systems are electrically operated, the potential increased energy demand poses a risk to existing electrical infrastructure during the next regulatory period.

The purpose of this report is to assess the energy demand, additional infrastructure and the associated cost impact if the light rail project proceeds during the next regulatory period. In addition, the report will provide a high level cost budget for infrastructure works in addition to current expansion plans in the Northbourne Avenue corridor.

1.1 Sources of information

The following sources of information have been reviewed:

- City to Gungahlin Transit Corridor Infrastructure Australia Project Submission, April 2012, ESDD
- City to Gungahlin Transit Corridor Concept Design Report, April 2012, URS
- Red Rapid Route, ACTION (Refer to Appendix E)
- Proving Safe Inductive Power Transfer for LRVs, Augsburg, Germany, Bombardier (Refer to Appendix D)
- Communications with Bombardier Australia (Refer to Appendix B)

1.2 Limitations

As the delivery system has yet to be finalised, this document is based on a number of assumptions. The final infrastructure delivery requirements and costs will need to be calculated once the ACT government have selected a delivery method and preferred supplier.

2.0 Light Rail Configuration

2.1 Vehicle number and utilisation

Based on the concept design report (April 2012) completed by URS Australia Pty Ltd, the predicted capacity of the light rail vehicle is 220 passengers. To achieve the target 8 minute frequency by 2030 outlined in the report it is estimated that a minimum of 12 LRVs will be required based on a predicted 41minute travel time by 2031[1].

For the purposes of this exercise the Bombardier FLEXITY 2 LRV will be used for the energy consumption estimation as it has an estimated maximum capacity of 222 passengers. Refer to Appendix C for product specification, outlining a FLEXITY 2 LRT system installed in Blackpool, UK.

2.2 Separation of stations

It is assumed for the Canberra light rail project that underground inductive charging stations will be utilised. This is in part due to the national importance of image portrayed by Northbourne Avenue which would be negatively impacted by the installation of overhead wires.

The proposed light rail delivery system aims to replace the existing Red Rapid bus route. In addition, it is expected that a 100 X 200m area will be required for an LRV depot to support stabling, light and heavy maintenance of the LRT fleet as well as on-site offices and staff facilities. The LRV depot will ideally be located near the middle of the route to minimise dead running i.e. empty services are run to the start or from the finish of the route.

[1] Minister Simon Corbell – ISCA event 28/8/13

Figure 1 below illustrates a possible route, with major stations (red), minor stations (yellow) and proposed LRT depot (blue) identified.

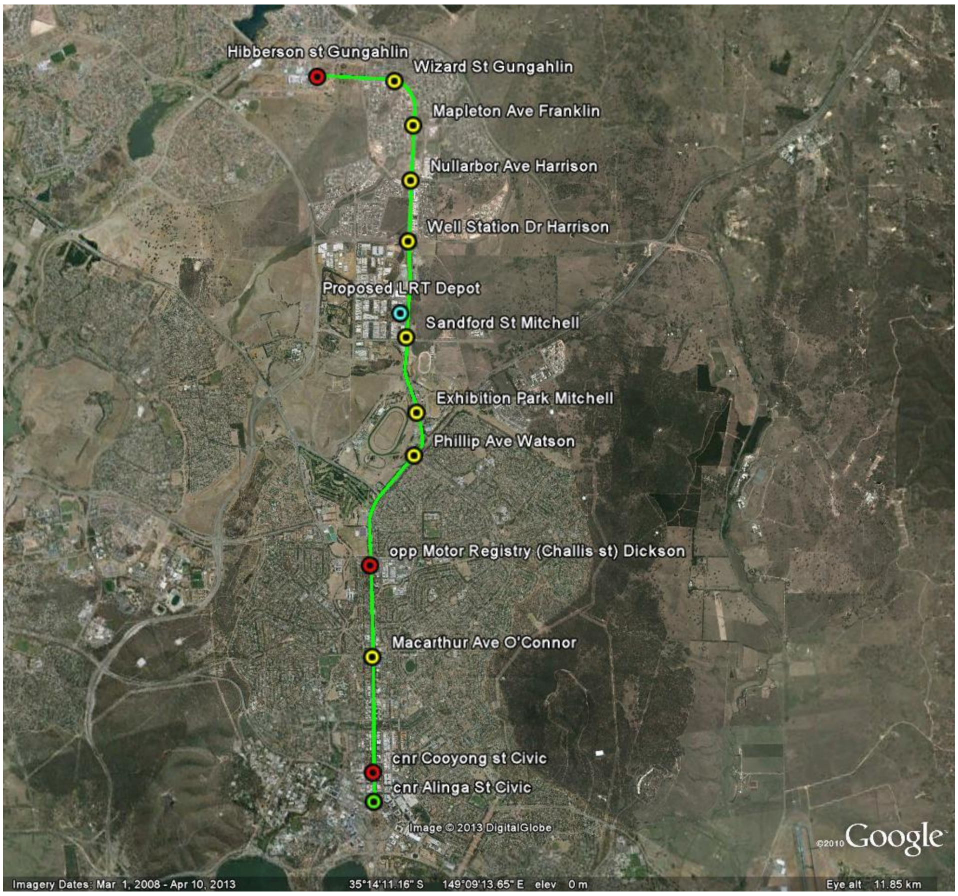


Figure 1 Proposed Canberra LRT route. Minor stations are shown in red, major stations in yellow. A proposed depot location is shown in blue.

The separation of stations determines the battery capacity required. In addition, the required battery capacity influences the overall mass of the vehicle, which in turn will influence the energy consumption. Two options are considered in this assessment:

- Charging at the major stations: Northbourne (near bus station), Dickson (between motor registry and Challis St) and Gungahlin (Hiberson St) with a stopping time of 60 seconds at each major station.
- Charging at the major stations as above with the addition of minor charging stations at Sandford St and Macarthur Avenue (Refer to Appendix E) with stopping times of 60 seconds at major stations and 30 seconds at minor stations.

2.3 Total fleet power requirement and maximum demand

2.3.1 Maximum demand

The charging stations are sized for a maximum demand of 1MVA per train, using a power factor of 0.9.

This demand is estimated based on communications with Bombardier (Appendix B), where it was stated that for a catenary-free charging station a maximum power transmission in motion of 900kW could be expected.

In the event that two trains charge simultaneously at the same station the maximum demand would be 2 MVA.

The maximum demand for the LRT depot was estimated using 80 VA/m^2 assuming the capacity to charge 3 LRVs at 1 MVA each. The overall maximum demand is estimated as 4.6 MVA. The depot is expected to be supplied by its own substation.

Table 1 below summarises the maximum demand at the charging stations for the two options.

Table 1 Station maximum demand per option

Station	Option 1 Main station charging only Maximum demand (MVA)	Option 2 Additional station charging Maximum demand (MVA)
Hibberson St Gungahlin	2.0	2.0
Wizard St Gungahlin	-	-
Mapleton Ave Franklin	-	-
Nullarbor Ave Harrison	-	-
Well Station Dr Harrison	-	-
Proposed LRT Depot	4.6	4.6
Sandford St Mitchell	-	1.0
Exhibition Park Mitchell	-	-
Philip Ave Watson	-	-
opp Motor Registry Dickson	2.0	2.0
Macarthur Ave O'Connor	-	1.0
cnr Cooyong St Civic	2.0	2.0
cnr Alinga St Civic	-	-
Total	**10.6**	**12.6**

As it is expected that LRVs will remain at a given stop for 30–60 seconds, an actual power transmission of 450 kW rather than 900kW is assumed as more appropriate.

By using the reduced peak charging requirement, the maximum demand is reduced to 1 MVA per charging station, allowing for two trains to charge simultaneously.

This configuration may prevent the need for a secondary feeder as a 5 MVA maximum usage per feeder is unlikely to be reached as it would require 10 out of 12 trains to be charging at any one time. Note further detailed design is required to verify this assumption.

In addition, further infrastructure requirements could be reduced by temporary overloading of transformers within heat tolerance limits or switching off charging during peak demand hours in summer. This could reduce the infrastructure upgrade to an estimated 4.6 MVA at the depot. During peak demand events with trains operational on the track the depot requirements could be under 2 MVA.

2.3.2 Energy consumption

The energy consumption of the LRVs is estimated with reference to the Melbourne LRT network.

In a year, the Melbourne LRVs travel a combined total of 24.8 million kilometres. The estimated annual energy consumption for the network is 75,150 MWh per year. Therefore, the energy consumed per kilometre travelled can be estimated as approximately 3 kWh/km [2].

The proposed track for the Canberra light rail is 12 km long. A system similar to the Melbourne LRT would require 36 kWh per trip. Assuming operation between 7am and 7pm would result in 90 trips per day based on 8 minute

[2] Taken from 2010 Perth Light Rail Network Report: http://greenswa.net.au/sites/default/files/perth-light-rail-report-2010.pdf

frequency. This would result in a daily consumption of 3,240 kWh and an annual consumption of 1.18 GWh/year (assuming 7 days per week operation).

Through communication with Bombardier (Appendix B) the proposed route for the Canberra light rail system is considered flat as it does not experience a gradient greater than 1% i.e. 10m elevation per kilometre travelled (Appendix A). As the Melbourne LRT network experiences gradients in excess of 1% it is assumed that the estimated energy consumption is a worst case scenario.

2.4 Vehicle demand and storage characteristics

2.4.1 Battery

The required battery capacity for the LRV depends on the spacing between charging stations. Note this assessment assumes a discharge of 60% for lithium ion batteries.

For the two options outlined in section 2.2, the required capacities were estimated as described below.

For option 1, charging at each end with an intermediate station at Dickson requires a minimum battery capacity of approximately 45 kWh. This enables the train to travel from Gungahlin to Dickson (8.9 km using 26.5 kWh) without the use of overhead wires.

Assuming the train stops at the Dickson station for approximately 60 seconds, 7.1 kWh of energy is transferred to the batteries. This requires the station to be equipped to deal with a maximum demand of 1 MVA (two trains charging at same time). For the Gungahlin and Civic stations, the train has approximately 7 minutes to turn around and charge for the next trip. This time is sufficient to completely charge the batteries and results in a lower power requirement for the Gungahlin and Civic stations.

For option 2, with the addition of minor stations at Sandford St and Macarthur Avenue, the minimum battery capacity is approximately 25kWh. This allows the train to complete the longest length of the trip; Gungahlin to Sandford St (5km using 14.8kWh) without the use of overhead wires. The same applies for the Civic and Gungahlin stations as with option 1, though the power requirement would be less due to the increased number of charging stations.

2.5 Additional future building demand along light rail corridor

The increased density of development along LRT corridor will likely require the addition of a substation and feeders for these buildings. The light rail requirements should be considered with the increased density of development on the light rail corridor.

3.0 Implications

3.1 Existing electrical plan

At the time of writing this report the existing electrical plan has only 4.5MVA spare feeder capacity for the light rail route along Northbourne avenue. This is expected to be used quickly with redevelopment and so new infrastructure will be required for the light rail.

3.2 Impact of LRT on grid

The required 10MVA to 13MVA of expected load is likely to require additional feeders and substations for the light rail corridor. With limited feeders currently available and additional density in the areas, it is likely that additional infrastructure will be required. This is shown in section 2.3.1.

Load shifting will need to be considered to reduce peak demand along the route.

4.0 Budget estimate

Given the assumptions and requirements detailed in previous sections, a high-level cost budget for infrastructure works in addition to current expansion plans in the Northbourne Avenue corridor has been provided below for both options. This does not include a contingency and could be impacted by demand management or other plans in the corridor.

Table 2 Cost estimate for option 1 (major stop charging)

Item description	Cost ($ AUD)	Notes
Electrical Feeders: 14km x $300/m x 2	**$8,400,000**	Cost estimate to be confirmed. Capacity at Zone substation also to be confirmed
Recharging station point x 6	substation $200,000 switchgear $100,000 cables $100,000 in-ground loops $50,000 other $50,000 **Sub-total $450,000**	Costs included for a standard station, assumed 3 stations
Lighting	**$0**	Assumed to be already allocated to corridor
Supply Depot	$500,000 **Sub-total $500,000**	Infrastructure provided by ACT government Expected demand 3MVA maximum (chamber substation provision, upgraded from existing usage)
Low voltage & SCADA (10%)	**$605,000**	Station and other associated works
TOTAL	**$10,855,000**	

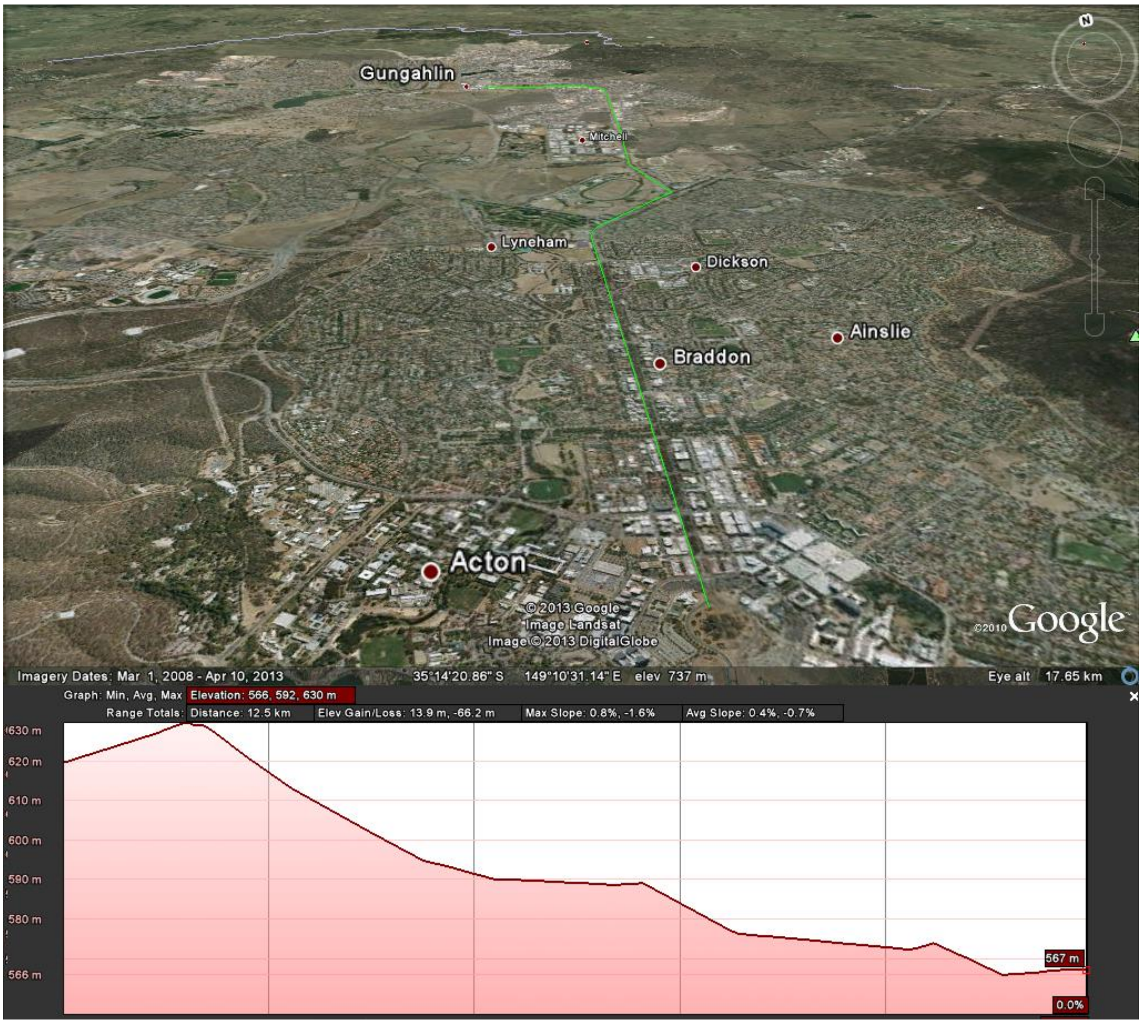
Table 3 Cost estimate for option 2 (all stop charging)

Item description	Cost ($ AUD)	Notes
Electrical Feeder: 14km x $300/m x 3	**$12,600,000**	Cost estimate to be confirmed. Capacity at Zone substation also to be confirmed
Recharging station point x 12	substation $200,000 switchgear $100,000 cables $100,000 in-ground loops $50,000 other $50,000 **Total $450,000**	Costs included for all stops
Lighting	**$0**	Assumed to be already allocated to corridor
Supply Depot	**Total $500,000**	Infrastructure provided by ACT government Expected demand 3MVA maximum (chamber substation provision, upgraded from existing usage)
Low voltage & SCADA (10%)	$1,010,000	Station and other associated works
TOTAL	**$19,510,000**	

Appendix A

Gradient profile

Appendix B Gradient profile



Appendix B

Bombardier Communications

Appendix B Bombardier Communications

From: john.ince@au.transport.bombardier.com [mailto:john.ince@au.transport.bombardier.com]
Sent: Tuesday, 13 August 2013 2:12PM
To: Gill, Benjamin
Cc: Evans, Simon; Roxburgh, Toby
Subject: Re: FW: Canberra Light Rail
Benjamin

A gradient of less than 1% is what we technically refer to in the industry as "flat".

Sorry, couldn't resist that. Yes this would be pretty marginal, although having said that there are a couple of stretches around the grasslands in Mitchell where there is a short steep section? At this stage I would be inclined to treat it as flat though.

With all the ussual caveats around being subject to a detailed engineering analysis, I can't see the energy requirements being substatially different.

Regards

John Ince
Business Development Manager

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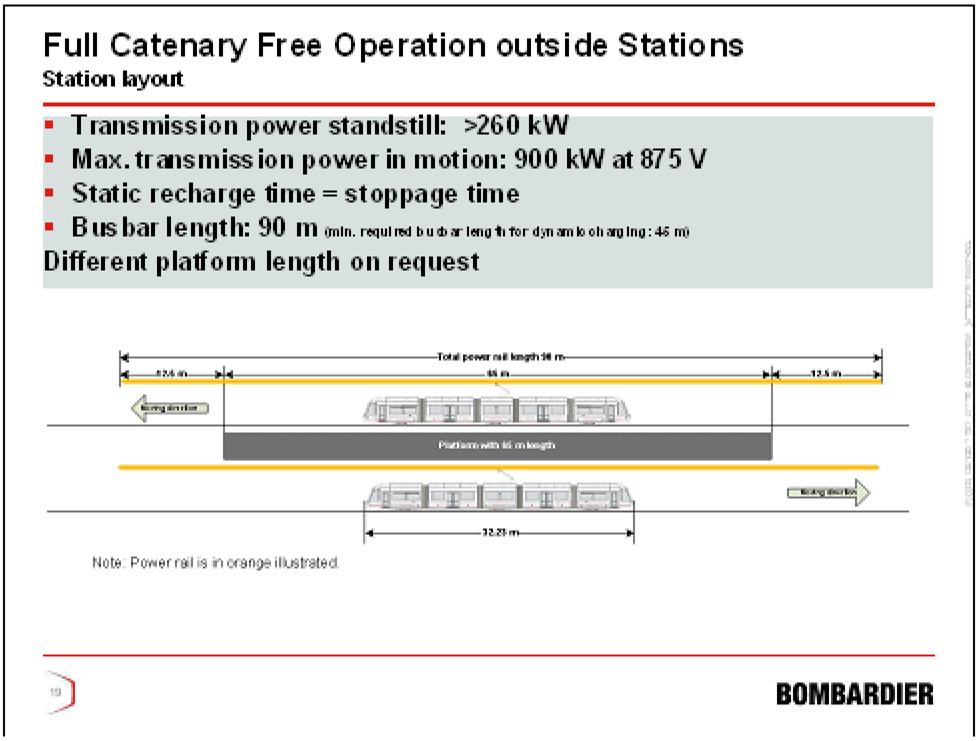
From: john.ince@au.transport.bombardier.com [mailto:john.ince@au.transport.bombardier.com]
Sent: Monday, 5 August 2013 1:43 PM
To: Gill, Benjamin
Cc: Evans, Simon; Roxburgh, Toby
Subject: Re: FW: Canberra Light Rail

Gents,

Further to my note last week, I have attached some generic information below. This aligns with what I stated last week - the added point is looking at transmission power in excess of 260 kW.
Below is a high level summary of a theoretical installation which uses a 260kW charging rate as an indicative value.



As noted previously, the things that will be needed to model this accurately are timetable and vehicle headways, vehicle size and weight, overall track length (both catenary and catenary free sections), distance between stations, dwell time, track curvature and most importantly gradient.

Regards

John Ince
Business Development Manager

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From: john.ince@au.transport.bombardier.com [mailto:john.ince@au.transport.bombardier.com]
Sent: Wednesday, 24 July 2013 3:12PM
To: Gill, Benjamin
Cc: Evans, Simon; Roxburgh, Toby
Subject: Re: FW: Canberra Light Rail

Ben,

Apologies, I was awaiting the feedback on capacity.

In order to progress this, generically the response is as follows.

Broadly speaking, the solution is generally to have recharging in the stations with a section either side (say about 15-20 metres or so either side) that allows charging to begin before the vehicle is stationary and to assist with accelaration out of the station. Again broadly, the vehicle begins the day or run with a full charge and then "tops up" at each stop, with recharge times in the order of 20 to 30 seconds per station - our battery technology is designed to handle this cycling pattern. As battery technology is developing continually, the only data we would be releasing at this time is that we use a lithium ion technology. In the case of using an overhead power supply at the stops, where the vehicle has a pantograph style pickup, we would base this on roughly 90 metres of powered overhead in total per recharging location. This allows about 65-70 metres of platform (allowing for coupling two trams together for peaks or special events) and the balance as a powered section either side of the platform. From a visual point of view this would not necessarily be a traditional "catenary wire" but can be achieved with some kind of contact strip or busbar that can be incorporated into the architecture of the stations.

We can handle charging either via an inductive loop in ground (so no overhead) or an overhead and pantograph (whether in stations only or on sections of the route) or a mixture of the two. If there is a requirement that it be a ground based solution for power supply rather than an overhead, our recommendation is that the inductive solution be used rather than some form of third rail or physical connection. The inductive pick up is not effected by ground conditions (rain, mud, snow, autumn leaves) and the general public can't access it if it is in the platform edge as some third rail sections could be.

The key considerations are distance between recharge stations, gradient and service frequency. As this is all still up in the air it is pretty difficult to give you a real estimate as to recharge time, system requirements etc. Broadly, our rule of thumb is that power draw for a catenary vs a catenary free ystem is that they would be about the same. Don't forget also that the batteries would be capturing braking energy as well as recharging at the stops.

For this type of project a 5 module, 35 metre tram would be a good bet for the type of vehicle to be used - it has a capacity of around 200-230 people depending on the loading and interior configuration. Depending on the distance and conditions that it will be operating in under catenary free operations, we would either have a small battery for shorter distances and a small overall portion of the system (eg. half a dozen stops at the Civic end of Northbourne) or a bigger battery capacity if you were looking at the whole or significant portions of the overall route.

So, responding to your initial question - 20-30 seconds for top up charghing in the stations - whether that is a couple of stations only or if it is every station on the route. The vehicle and battery system are designed to perform all day everyday under these conditions and will be fine tuned to the specific environment of the project.

Give me a yell when you have read and digested the above - simple question, difficult answer dependent on many things that are not decided yet!

John Ince

Business Development Manager

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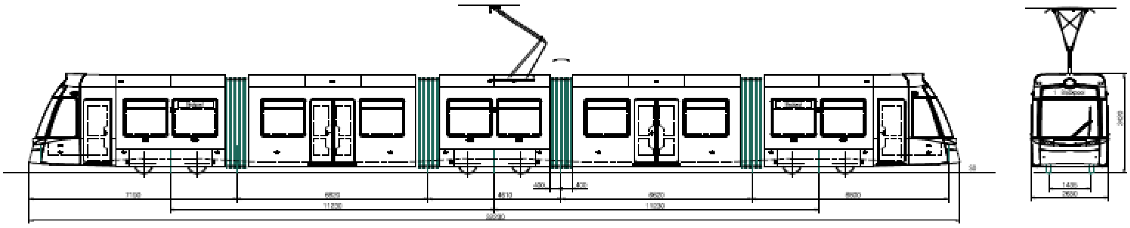
Appendix C

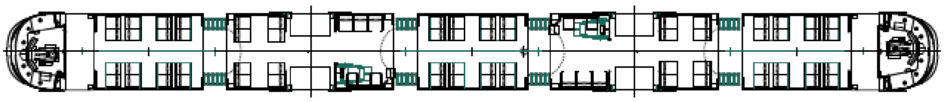
Flexity 2 LRV, Blackpool UK

Appendix C Flexity 2 LRV, Blackpool UK

FLEXITY 2 tram

Blackpool, United Kingdom





General Data

Contract award	July 2009
Type of vehicle	*BOMBARDIER FLEXITY 2*
Model	Bi-directional
Owner	Blackpool Council
Quantity	16
Train consist	5 modules

Dimensions and Weight

Length of vehicle	32.2 m
Height	3.42 m
Width	2.65 m
Entrance height above TOR	
- vehicle empty, new wheels	320 mm
Percentage of low-floor area	100 %
Doors	8
• Electric double-sliding doors	2 per side
- door clearance height	2,030 mm
- door clearance width	1,300 mm
• Electric single-sliding doors	2 per side
- door clearance height	2,030 mm
- door clearance width	800 mm
Wheel diameter (new / worn)	600 mm/540 mm
Gauge	1435 mm
Minimum horizontal curve radius (track/depot)	25 m/20 m
Minimum vertical curve radius, (hog/sag)	275 m/400 m
Car weight (empty)	40.9 t
Car weight (loaded) (4 pass./m²)	56.7 t
Maximum axle load (4 pass./m²)	9.6 t
Buffer load	400 kN

Technical Characteristics

Nominal current supply: 600 VDC
Energy recuperation
Low voltage: 24 VDC
Four 3-phase asynchronous motors
Motor power 120 kW
Liquid-cooled motor
2 powered bogies - 1 trailer bogie
Rubber-metal springs primary suspension
Elastomer secondary suspension
Slip and skid protection
Rescue coupling for emergency
Generatoric service brake
Electrohydraulic disk brake system
Magnetic brake: 6 x 81 kN
Air conditioned interior cab
Passenger information system

Performance and Capacity

Maximum speed	70 km/h
Medium acceleration (2/3 load) from 0 ... 70 km/h	0.5 m/s²
Deceleration (2/3 load)	
• service brake	1.2 m/s²
• emergency brake	2.73 m/s²
Maximum gradient	60 ‰
Seated passengers (incl. tip up seats)	74
Standing passengers (4 pass./m²)	148
Multipurpose areas	2

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BOMBARDIER

Appendix D

Proving Safe Inductive Power Transfer for LRVs, Augsburg, Germany

Appendix D Proving Safe Inductive Power Transfer for LRVs, Augsburg, Germany

Insert..\..\4. Tech work area\4.3 ESD\BOMBARDIER_PRIMOVE_Augsburg_Datasheet_EN.pdf

Facts and figures

Project timeline:
Start of civil works: June 2010
Start of operations: September 2010
Authorisation to carry visitors: September 2011

Vehicle type:
1 bidirectional low-floor tram

Length of test track:
800 metres

Charging power:
200 kW

Power supply network:
750 Vdc

Percentage of power transfer efficiency:
95%

Maximum speed:
50 km/h

Recuperation of braking energy:
Up to 90%

Appendix E

Red Rapid Route

Appendix E Red Rapid Route