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Business Case for the deployment of battery electric vehicles on the UCT Shuttle service

PURCO/University of Cape Town

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Abbreviations

Abbreviation	Meaning
A	Ampere
B-BBEE	Broad-Based Black Economic Empowerment
BEV	Battery Electric Vehicle
BESS	Battery Energy Storage System
CCS	Combined Charging System
CO	Carbon Monoxide
CO_2	Carbon dioxide
CSD	Contract Strategy Document
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GABS	Golden Arrow Bus Service
GHG	Green House Gases
GVM	Gross Vehicle Mass
ICE	Internal Combustion Engine
kV	kilovolt
LIB	Lithium-Ion Battery
LV	Low Voltage
MV	Medium Voltage
NOx	Nitrous Oxide gases
OEM	Original Equipment Manufacturer
PFMA	Public Finance Management Act
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PPS	Properties and Services division
PURCO	Purchasing Consortium Southern Africa
RFI	Request for Information
RFQ	Request for Quotation
RFP	Request for Proposal
SMME	Small, Micro and Medium Enterprise
TBRT	Table Bay Rapid Transit
UCT	University of Cape Town
VALA	Volume Assembly Localisation Allowance
VFM	Value-for-Money

Executive Summary

Introduction

Zutari, in partnership with PURCO SA, has been tasked with establishing the feasibility, viability and desirability of the University of Cape Town (UCT) switching from their current Internal Combustion Engine (ICE) shuttle fleet to a Battery Electric Vehicle (BEV) bus fleet. The study is undertaken in the context of the broader UCT vision and strategy for a long-term sustainable future and extends beyond the strictly financial aspects of making such a change. The key factors in the study are reflected diagrammatically in Figure 1.

Assignment aims

The University of Cape Town is considering replacing their current bus fleet of 27 buses (leased from Bidvest) with electric powered buses when the lease expires in December 2025. The intent at this stage is that the project will be implemented in two phases. This would entail an initial proof of concept stage (entailing one or two buses being run as a pilot study) before the roll out of the new fleet. The University hopes to go to market for both the fleet and the infrastructure, although the exact structuring of this transaction still needs to be determined. This might entail a consolidated lease for both elements and stages, or a staged procurement process. The University now requires assistance in assessing the viability (and possible risks) of this change, and they require support to enable the procurement of the service and assets. This document represents Zutari's report on the required assessment.

Evaluation framework

The study examines the potential for transitioning from diesel engine to battery electric vehicles in terms of an evaluation framework comprising:

- **Feasibility** – this is primarily related to technical feasibility and relates to:
  - The availability of electric buses with the power, range, and passenger capacity to provide the necessary services in the University of Cape Town environment without significant changes to the fleet size or operations
  - The availability of sites able to accommodate the bus fleet for overnight and for other charging opportunities
  - The availability of electricity supply for the charging sites from the existing electricity grid
  - The local availability of the skills and capacity to maintain and operate electric buses

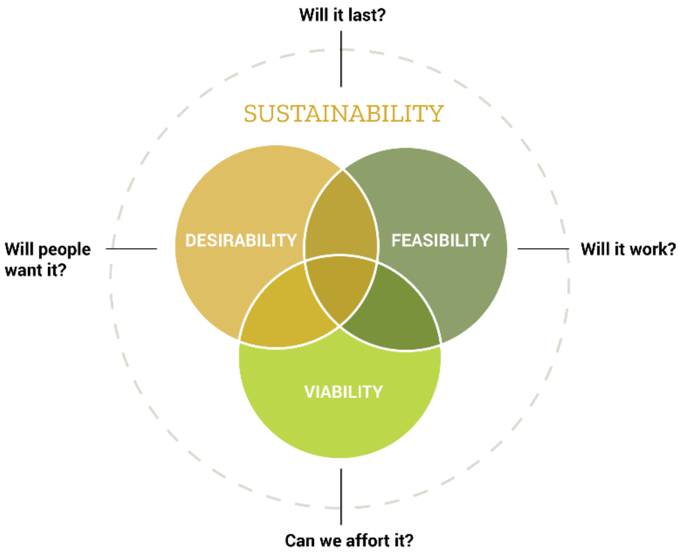

Figure 1-1: Evaluation Framework

- **Viability** – this is primarily related to the financial soundness of making the change, but also considers the energy environment and its impact on available options:
  - Affordability for UCT and the cost of acquiring and operating an appropriate bus fleet
- **Sustainability** – this is primarily in the context of environmental and technological sustainability and consideration of such factors as:
  - Increased independence from fossil fuel and resilience built on renewable energy.

- Reduction in Greenhouse Gasses (GHG) emissions
- An estimate of the Rand value of "Going Green", which may influence the financial viability
- Vehicle lifespan, both in conventional life expectation terms and in terms of technological change. This will include aspects such as battery lifespan and disposal

- **Desirability** – in the context of the foregoing measures of feasibility, viability and sustainability, is it desirable to make a shift in fleet motive[1] power? Will the implementation of a shift to the alternative energy model examined in this study:
  - Positively influence UCT's standing as a leading academic institution on the African Continent?
  - Offer possible research advantages?

Although technological advances are being made in sustainable mass transport with other power plant as well, battery electric vehicles are the focus of this study with the analysis being based on a 10-year technological life cycle but also influenced by current leasing terms.

Buses

Taking the current UCT Shuttle service operations and fleet into account and using information relating to that fleet as well as some additional calculations, the basic requirements for standard (nominal 12 m) buses in terms of peak power (±200kW) and power storage capacity (±200kWh[2]) have been established. This information has been used to explore the electric bus market and found to be representative of the capabilities of the equivalent standard buses available internationally. Most buses can exceed these requirements to some extent and achieve a greater gradeability than required for UCT. The same bus market exploration has highlighted that the international availability of midi-buses (nominal 9m) (±140kW and ±140kWh) is very limited, although there are midi-buses meeting the required specifications available from the European market.

What has also been established is that there is essentially no local availability of suitable buses, with the local market being in its infancy and the major manufacturers only just starting to examine the South African market opportunities. The implication is that buses need to be imported and this has a significant financial impact as discussed later.

Charging equipment

Ignoring the immediate local availability of buses, the issues of charging equipment that will facilitate charging of the buses matched to the operational requirements of the UCT Shuttle Service system have been examined. There are two main options available, DC fast charging and AC regular charging, each with advantages and disadvantages. Both types were considered as warranted for the UCT environment to provide a balance between cost, grid power requirements and the ability to keep all buses active during peak operating hours. The technology that is required, however, is based on the specific vehicle selected and the specific Original Equipment Manufacturer (OEM). In comparison to the cost of the buses, this forms a relatively small part of the overall cost, and the systems are fairly-readily available although there is understood to be a market shortage just at present (October 2022).

Grid supply capacity

With respect to the grid supply capacity, the charging strategy that was developed as part of this study shows that all charging of vehicles will take place during the night-time, with some opportunistic charging available as highlighted in the charging strategy. This has the advantages of lower cost of electricity and reducing the impact of peak power demands.

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[1] The term "motive power" refers here to the means of power production, such as diesel, hydrogen, battery electricity, etc. although it can also refer to simply the power required to move a vehicle.
[2] That the two numbers are both 200 is purely coincidental to the UCT operating environment.

UCT is supplied from the City of Cape Town's electricity grid. Presently there is no self-generation at a large scale that is present at or available to the campus. There is, though, an installed base of diesel generators that provides backup power for campus activities. Adjustments to the existing electrical network on campus have been proposed for the supply to the proposed charging infrastructure, including some additional back-up power.

Parking, holding and recharging areas

In respect of bus parking infrastructure, the holding areas currently being planned by UCT have been evaluated and found to be adequate for the deployment of electric buses. Provision is made in the design of these facilities for the placement of the required charging equipment and power reticulation. This is done by University of Cape Town's current infrastructure upgrades that include cable ducts for the future reticulation cable installation.

Financial analysis

A detailed financial analysis, comparing the use of ICE to BEVs has been undertaken to evaluate the comparative life cycle costs. Whilst this analysis clearly indicates that the deployment of BEVs has a significant positive impact on operating costs, the lack of BEVs on the local market results in the life cycle cost of BEVs being in approximately 42% more expensive based on current cost structures. The relative net present value (NPV) of the battery electric versus diesel bus options is shown in Figure .

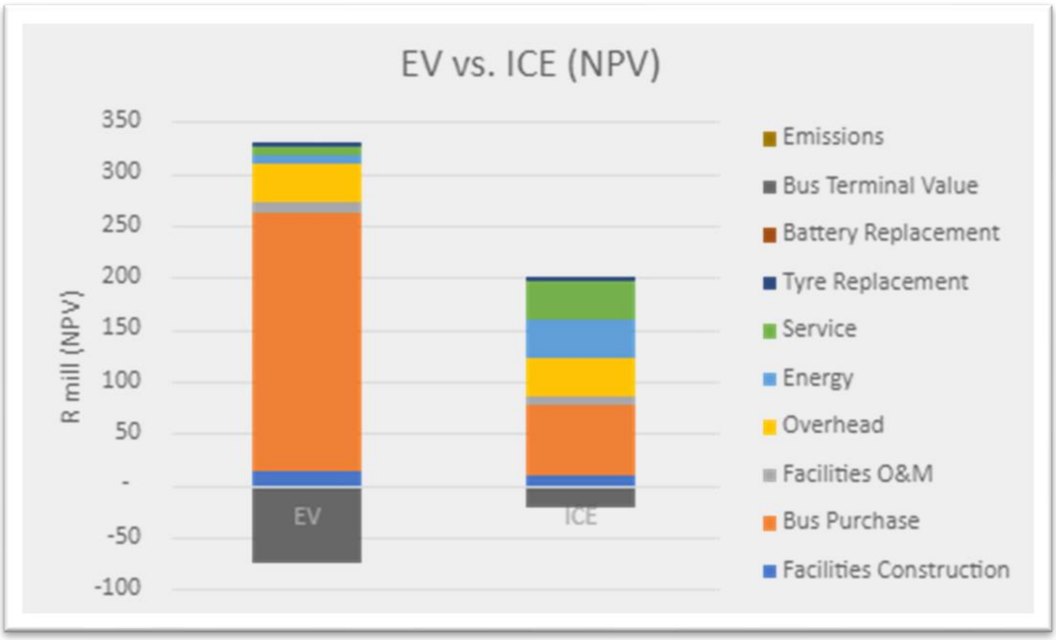


Figure 1-2: Net present value of battery electric versus diesel buses.

Figure 1-2: Net present value of battery electric versus diesel buses. indicates how the initial facility investment is higher for electric buses but, that the operational difference between Internal Combustion Engine buses and the Electric Vehicle buses differ annually. This graph is further explained in detail in Section 7.5, page 46

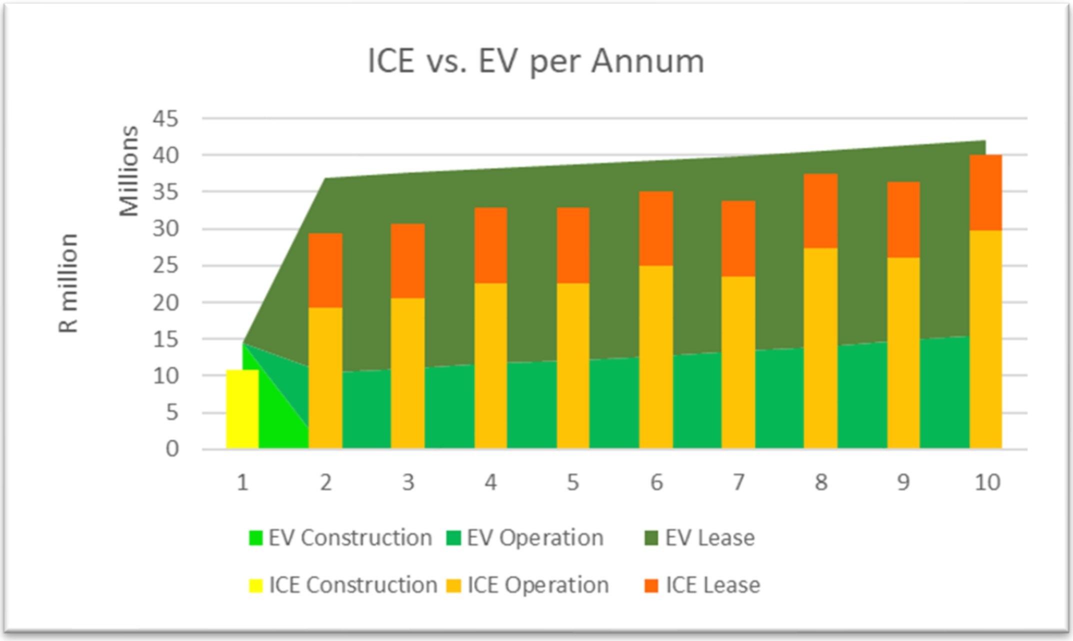


Figure 1-3: EV and ICE Annual Operational Cost Profile, Lease Basis (R mill).

Environmental analysis

Whilst it is quite clear that local greenhouse gas emissions are eliminated through the deployment of Battery Electric Vehicles, their deployment relocates some of the emissions actually generated by power generation and raises some new environmental concerns in respect of the materials used in the batteries and their eventual disposal. Concurrently, Internal Combustion Engines buses with engines with a EURO VI environmental rating have substantially reduced Green House Gases (GHG) and other emissions[3] since the EURO I inception as a standard in 1992. These buses have very low local greenhouse gas emissions but are, of course, still reliant on fossil fuels. In short however, the overall environmental benefits of Battery Electric Vehicles over Internal Combustion Engines vehicles benefits are not yet quite as definitive as might be believed, especially in South Africa where fossil fuel, mostly coal, is the primary input for electricity generation and produces GHG far above the current global emissions average. This has a substantial impact on the current Emissions (CO_2) Per Km (EPK) calculated if the bus fleet is charged from the Eskom grid. Perhaps surprisingly, grid tied electrical charging generates more GHG than modern diesel bus operations. The emissions are as followed broken down in EPK:

- **Diesel EPK 1048 g/km CO_2**
- **Electrical EPK 1738.8 g/km CO_2**
- **Solar EPK 80 g/km* CO_2**

Solar/renewable energy charging, however, would be less GHG intensive. This has no financial viability impact on the project as CO_2 is not quantified in capital on a day-to-day operational cost.

[3] Diesel engine vehicles also produce Nitrous Oxides (NOx) and Particular Matter that are both extremely harmful to health. The increasing EURO standards have significantly reduced permissible levels of these emissions, amongst others, as well: (ICCT_Euro6-VI_briefing_jun2016)

Local and international considerations

Notwithstanding the foregoing concerns, it is recognised that both internationally and locally, there is a very strong drive towards the deployment of BEVs. In South Africa, there is a Green Paper promoting the use of “new energy” vehicles, but this has not yet been taken up in any formal form and the reality is that South Africa is still lagging somewhat in comparison with the international arena in this space. In this context, UCT needs to assess its appetite for being a leader in the field, with the incumbent risks, or a preference for waiting for a more mature market environment.

Local coach builders such as Busmark (who were involved with the coach building for the BYD buses that are in the Golden Arrow Bus Services fleet) and others that have been involved in bus building for many years are prepared for the technology implementation. As investments in the EV sector increases the transition from ICE to EV or FCEV vehicles is expected to be much smoother.

Alternative considerations and opportunities for UCT

There is an overall “value of going green” effect that cannot be quantified for adopting a strategy of transitioning to an Electric Bus fleet. By not being able to financially measure these intangibles, such as being the trend leaders in South Africa, building grounds for academic studies and signalling intent of “going green”, these cannot form part of a financial analysis but should be considered as strategic intent indicators and drivers for UCT going forward. The value of the deployment of BEVs as an option under consideration at the University as part of a broader sustainability drive should not be based on tangible cost alone but consider these intangibles as an offset to financial considerations. This means that the value of the BEVs within the opportunities available for other sustainability projects must be carefully considered.

Conclusions

The study undertaken and reported here indicates that whilst there are certainly benefits to the deployment of BEVs, the South African market is still in its infancy with no local manufacturer or even established supplier present. This results in high initial costs and limited supporting infrastructure being available. The financial impact is estimated to result in a significantly higher life-cycle cost to deploy BEVs rather than ICE buses, without there being a clear-cut case for the environmental benefits of BEVs given current electricity generation practices in the country. Based on the values used in this study, a premium of approximately 42% could be expected for the deployment of battery electric buses instead of diesels over the 9-year analysis period. It is recognised that many factors could influence the relative values and so it is emphasised that these numbers are based on currently available information

Recommendations

The study team recommends that UCT delay the deployment of a BEV fleet and rather seeks to prolong the use of the existing ICE alternative, whilst awaiting the development of the local market. If the existing fleet is to be replaced with new vehicles, EURO VI environmentally rated vehicles should be given preference in any lease renewal, EURO V being the minimum acceptable rating.

In respect of the local electric bus market, it is noted that there is some movement amongst the Metro Municipalities operating integrated rapid public transport networks to investigate, pilot and ultimately transition to BEVs. These cities have significantly higher fleet requirements than UCT and will thus provide more impetus for local market development.

It is proposed that UCT allow for the market to mature prior to committing to what, at present, is neither the most financially viable for the University nor environmentally beneficial option for the country given the high level of CO_2 production of current electricity generation mix in South Africa.

With electrical grid and generation infrastructure spends tending to be directed towards the cleaner technologies, it is envisaged that there will be improvements regarding the use of EVs and their environmental impact, even if they are charged from the grid. Figure 1-4: Schematic representation of Business Case recommendationis a representation of the business case suggestions as discussed in section 9 Final recommendations. This visually represents a suggested timeline as per the aforementioned reference that allows for increasing the current lease, allowing for EV market maturity and then gradually switching to EV buses.

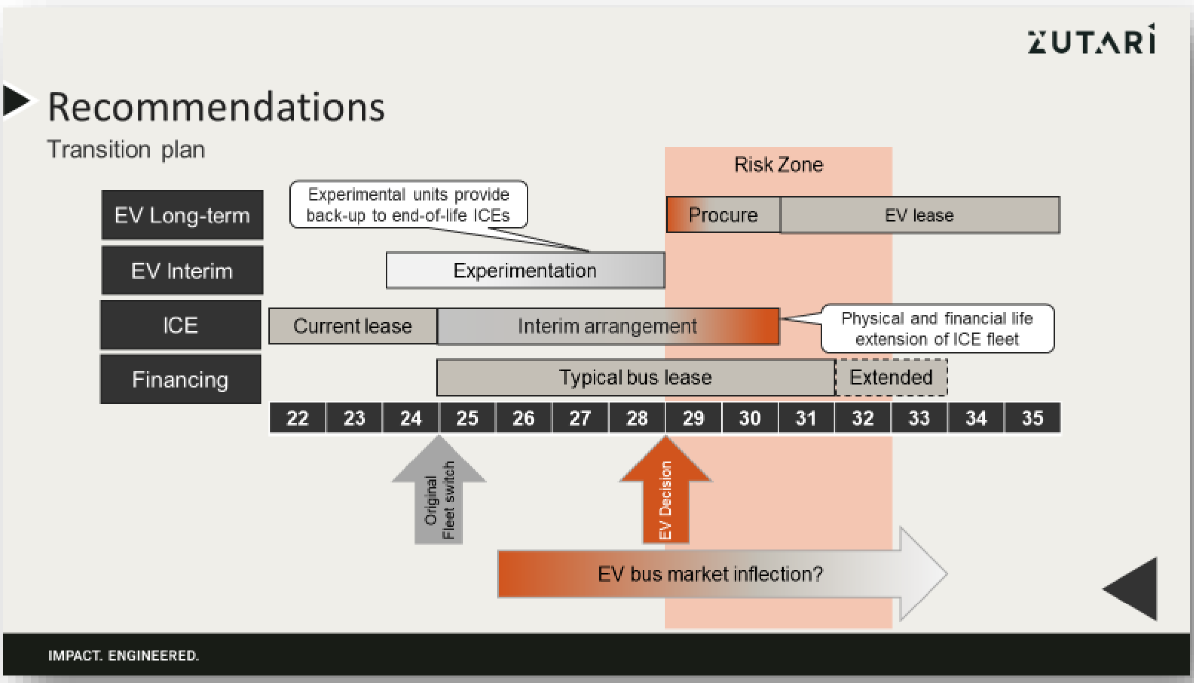


Figure 1-4: Schematic representation of Business Case recommendation

1 Introduction and Background

The UCT Shuttle service is a Student and Staff Transport system that is a well-entrenched part of UCT offering and is one of the most utilized[4] bus systems in South Africa. Aside from being an attractive feature of the University for parents and students, this system assists in alleviating multiple, local transport related problems, such as parking, traffic flow, residence needs and diverse campus spatial locations.

The current provision of the UCT Shuttle service is through an in-house operating team using leased diesel engine buses. The lease on the buses is due for renewal at the end of 2025 and, in planning for that renewal, UCT is considering the opportunities for alternative bus technology in support of its broader sustainability initiatives. In this regard, the UCT shuttle fleet services over 100km of route, 7 days a week, culminating in a total distance of almost 20,000 km per week and using around 50,000 litres of diesel per quarter. This level of fossil fuel usage warrants a careful look at alternative and more sustainable, options to reduce the environmental footprint of the fleet whilst still accommodating the transport needs of the users.

This study examines the implications of shifting from the use of diesel to battery electric buses in terms of a variety of factors, including electric bus availability, capability, and life cycle costs along with the infrastructure requirements necessary to support electric bus operations.

1.1 Strategic Intent

As a leading academic institution, UCT has a role to play in promoting environmental sustainability and technological development. The University thus has a programme in place that constantly seeks to reduce the environmental impact of the University, improve sustainability in general and self-sustainability where appropriate. In the process this provides the backdrop for research and development that leads to ongoing improvements on the environmental and sustainability fronts.

One of the elements in the energy footprint of the University is the UCT Shuttle service and, whilst this is not seen as a primary element of the sustainability drive, it is nevertheless a significant and very obvious element of that footprint. The strategic goal of relying, as far as is possible, on renewable energy sources, low to zero atmospheric pollutant technologies and a general minimisation of negative environmental impact means examining all components of the UCT environment, including the UCT Shuttle service, for goal supporting opportunities.

[4] Considered in terms of the daily movement patterns and levels of bus utilisation, not in terms of overall passenger numbers or system size.

2 Status Quo Assessment

In order to evaluate the benefits of shifting from the current diesel bus operations to an alternative such as electric buses, it is necessary to understand the operational requirements as well as the impacts of the current system.

2.1 Current Fleet, Routes, Stops and Holding areas

2.1.1 Fleet

The fleet consist of 30 vehicles, including an adapted vehicle for disabled passengers. Three different vehicle types are being used, as reflected in Table 2-1 and examples of which are shown in Figures 2-1 and 2-2:

Table 2-1: Current UCT Shuttle bus fleet.

Vehicle Type	Number of vehicles in fleet	Capacity (Passengers + Driver)
Scania standard bus in various configurations - Figure 2-1 (EURO V environmental rating.)	2	41 (seated) 45 (standing)
	3	61 (seated) 15 (standing)
	13	37 (seated) 45 (standing)
Volare midi-bus - Figure 2-2 (EURO III environmental rating)	9	32 (seated) 23 (standing)
Quantum	3	14

Each bus is fitted with a monitoring system that allows its location to be constantly checked. The buses cater for sight- and hearing-impaired users.

Figure 2-1: Scania Bus

Figure 2-2: Volare Bus

The Quantum minibus are used for irregular routes which operate on an ad hoc basis, i.e., there are no set routes/timetables.

2.1.2 Routes

The UCT Shuttle operates on 21 routes, shown in Figure 2-3.

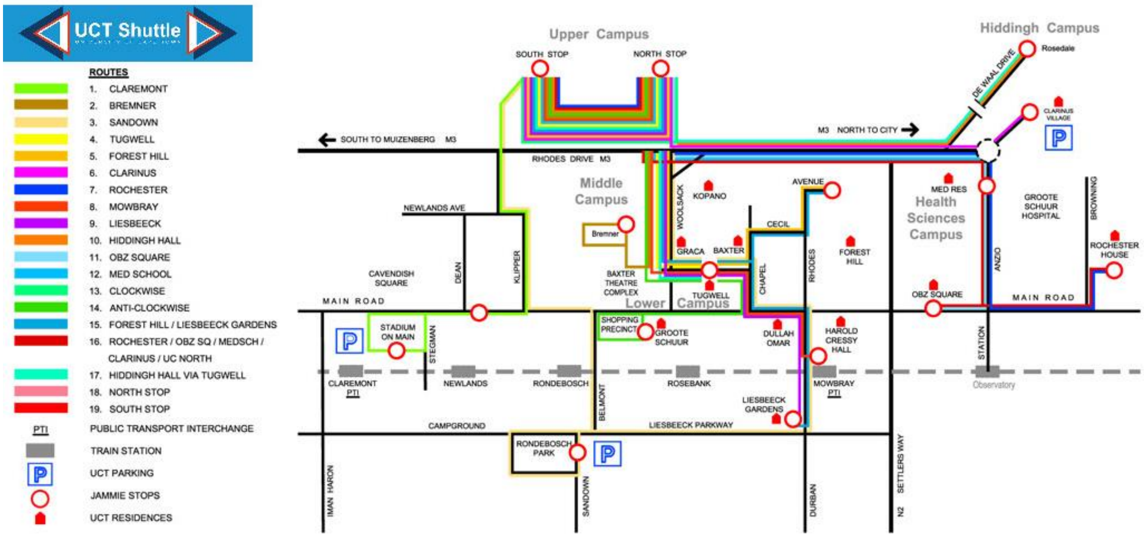


Figure 2-3: UCT Shuttle Routes

The routes operated and the timetables change depending on the academic calendar. Some of the routes are more utilised and are subject to change. The Operations UCT Map is out of date and no spatial mapping/shape file was available of the existing routes. Zutari mapped out the routes in collaboration with UCT staff as seen in the graphics of Figure 2-4.

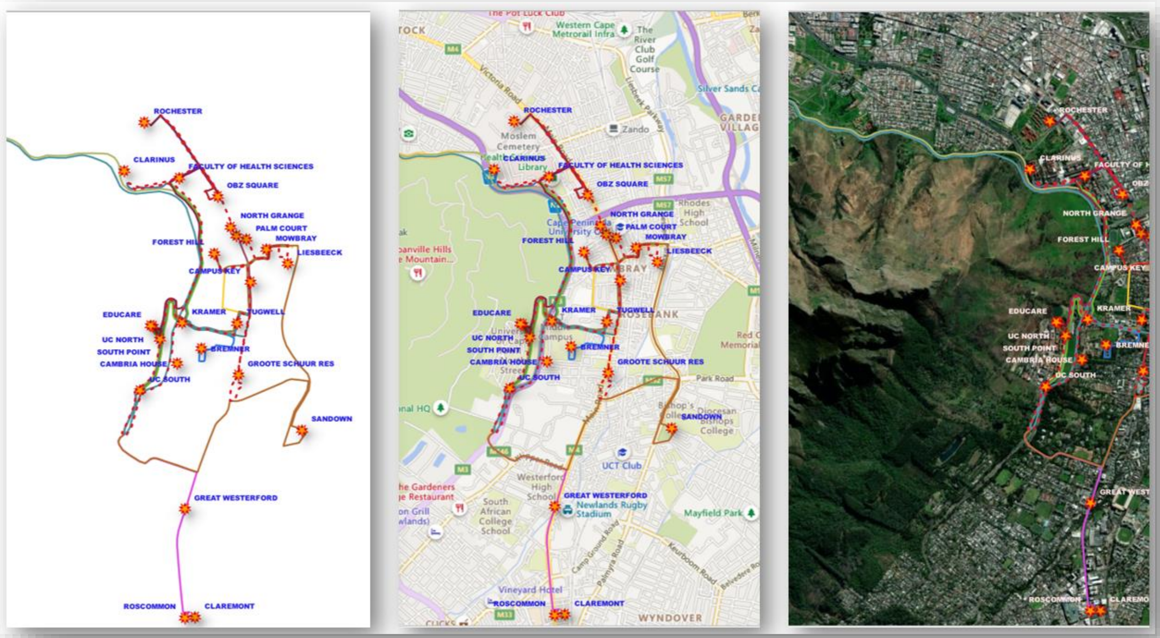


Figure 2-4: UCT Shuttle Routes Spatial (Bing Maps)

Spatial mapping was used to established route profiles per route (as attached in Appendix D). This was to establish both the highest instantaneous and greatest full route incline/decline that must be accommodated by the buses.

(Some distance discrepancy in the route profile and the Spatial mapping if based on the cartesian projection used. The projection used is EPSG :4326 – WGS 84 and the spherical difference between the route profile model using a more rounded spheric (discounts some spatial deviation) was deemed negligible in terms of route profile and gradient.)

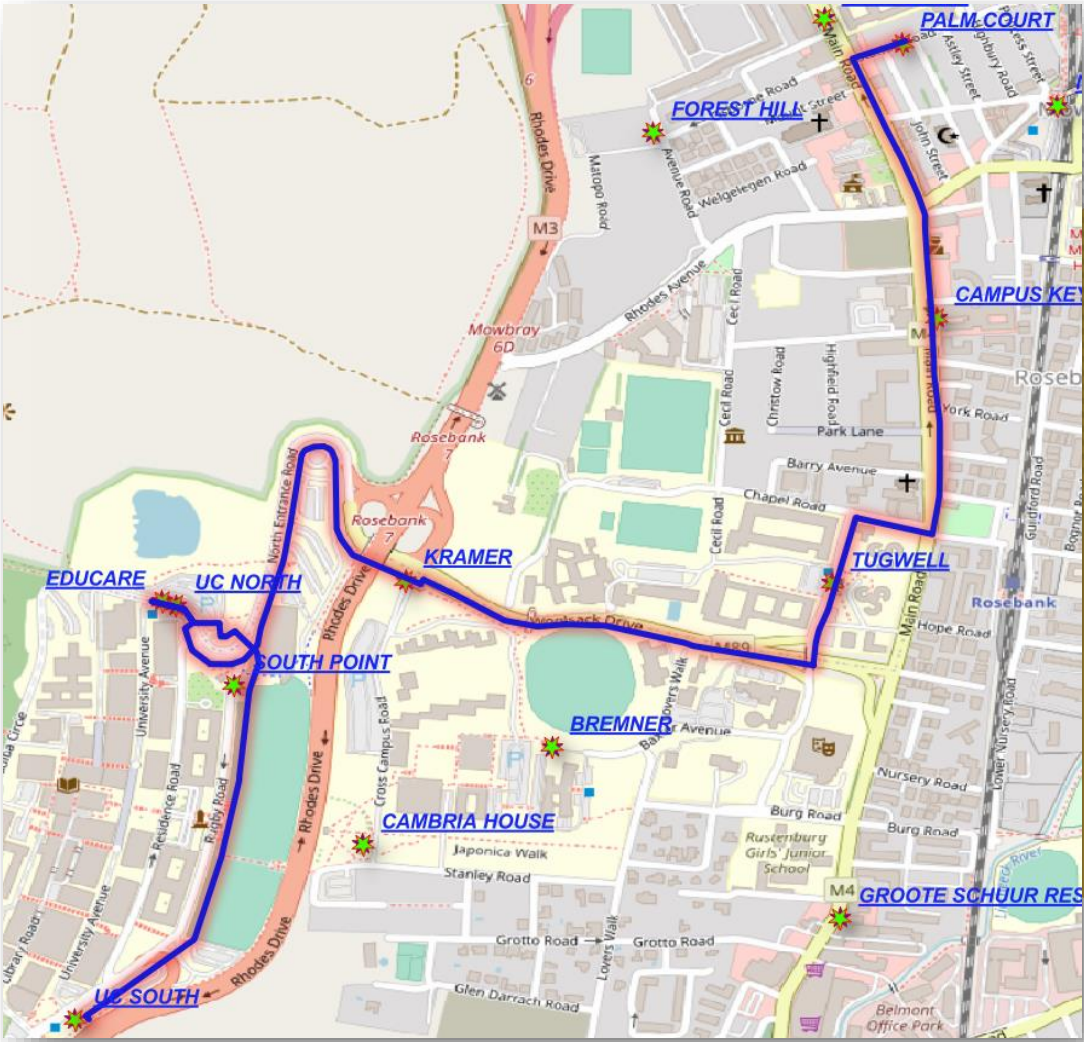


Figure 2-5: Mowbray Route

2.1.3 Stops

The UCT Shuttle service stops were provided by UCT and mapped out spatially in order to gain a holistic spatial view on the current stops and routes

The stops per route and the stop locations are in Table 2- and Figure 2-6 respectively.

Table 2-2: Routes and stops

No.	Route Name	Stops																			
		Bremner	Cambria House	Claremont	Clarinus	Educare	Forest Hill	Great Westerford	Groote Schuur	Hiddingh	Kramer	Liesbeeck	Faculty of Health Science (FHS)	Mowbray	North Stop	Obz Square	Palm Court	Rochester	Rondebosch Common/Sandow	South Stop	Tugwell
1	Claremont			Y																Y	Y
2	Bremner - Kramer	Y				Y					Y				Y					Y	Y
2a	Kramer-upper										Y				Y					Y	
3	Sandown																		Y	Y	
4	Tugwell														Y						Y
5	Forest Hill						Y								Y						
6	Clarinus				Y										Y						
7	Rochester														Y			Y			
8	Mowbray													Y	Y						
9	Liesbeeck											Y			Y						
10	Hiddingh									Y										Y	Y
11	Obz Square				Y								Y		Y	Y					
12	FHS												Y			Y				Y	Y
13	Res. Loop: Clockwise				Y		Y		Y			Y			Y	Y	Y	Y			Y
14	Res. Loop: anti clockwise				Y		Y		Y		Y	Y				Y	Y	Y		Y	Y
15	Forest-Lies Loop (S Loop)						Y					Y		Y	Y		Y				
16	Clar-Obz-Roch Loop (N loop)				Y										Y	Y		Y			
17	Hiddingh via Tugwell									Y										Y	Y
18	North Stop														Y					Y	
19	South Stop														Y					Y	
20	Greater Westerford							Y												Y	
21	Overnight				Y		Y		Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y

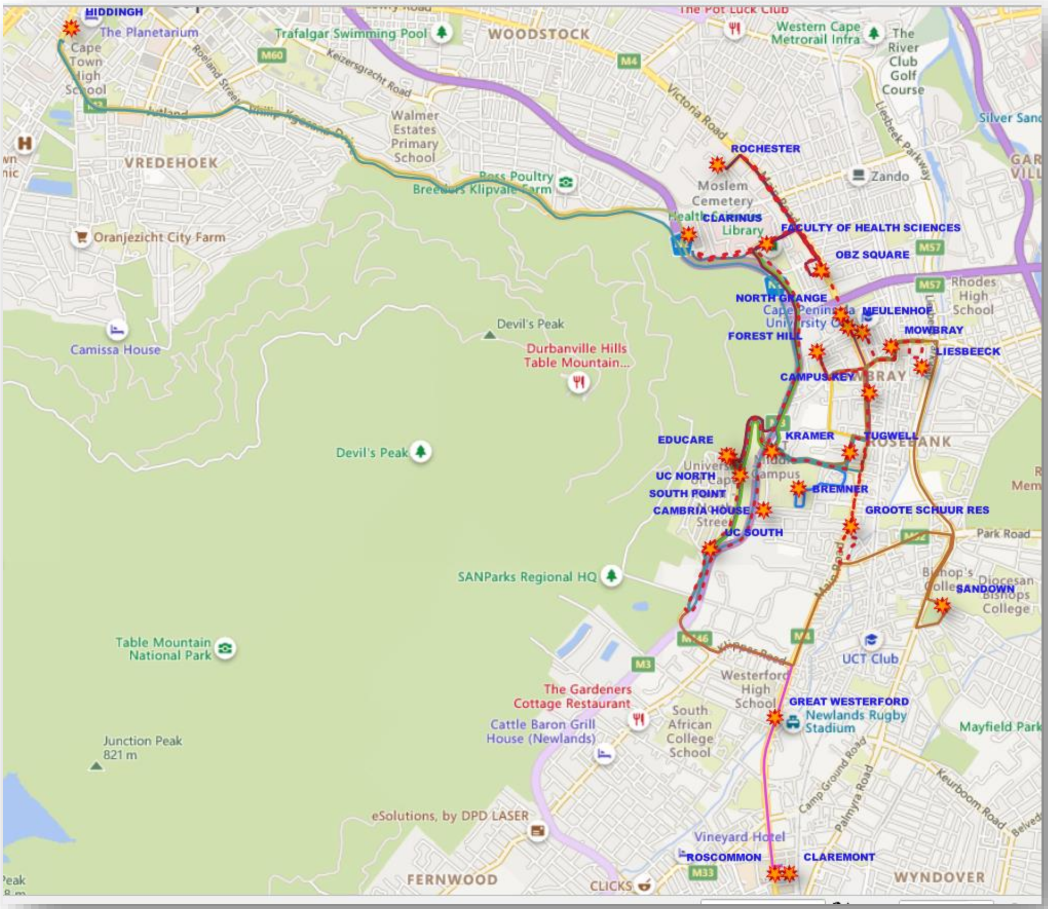


Figure 2-6: Bus stop locations

The following amenities are provided at busier stops, such as North and South stop:

- Pole and sign;
- Shelter;
- Seating; and
- Road markings.

Figure 2-7: North Stop

Figure 2-8: South Stop

Some stops use existing, historic bus stops (Figure 2-99) while other stops are unmarked with limited/no facilities (Figure 2-1010).

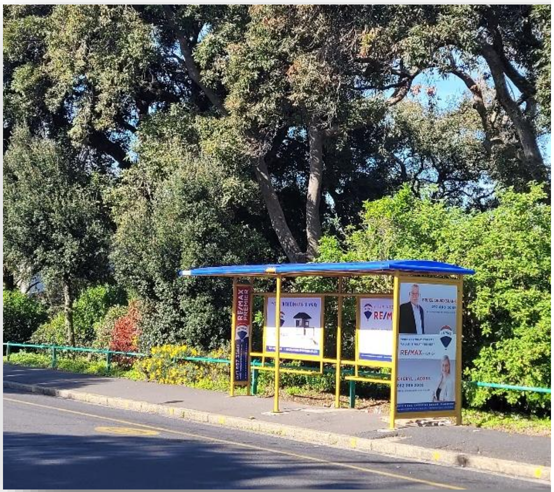


Figure 2-9: Sandown Stop

Figure 2-10: Hiddingh Stop

2.1.4 Holding Areas

Current Holding Areas

Buses are currently being held overnight at the P4 parking area on Upper Campus (shown in Figures 2-11 and 2-12 below). Drivers also stop at this location for breaks when not in use for other university needs, break locations are then handled on ad hoc basis.

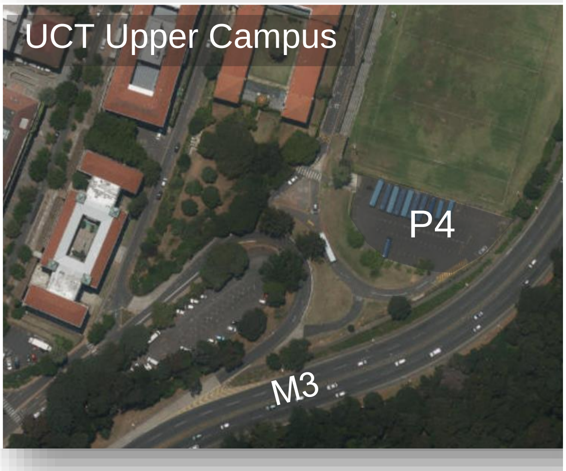


Figure 2-11: Aerial view of P4

Figure 2-12: Buses at the existing holding area (P4)

Future Holding Areas

UCT plans to build two new holding areas, referred to as the Forest Hill and North Stop holding areas. The locality of these two holding areas and cut outs of the concept design drawings are shown below. The concept design drawings are attached in Appendices B and C.

Forest Hill

The proposed new Forest Hill holding area, shown in Figure 2-13, will be able to accommodate 26 large buses. Access to the holding area will be via Broad Street and Avenue Road extension.

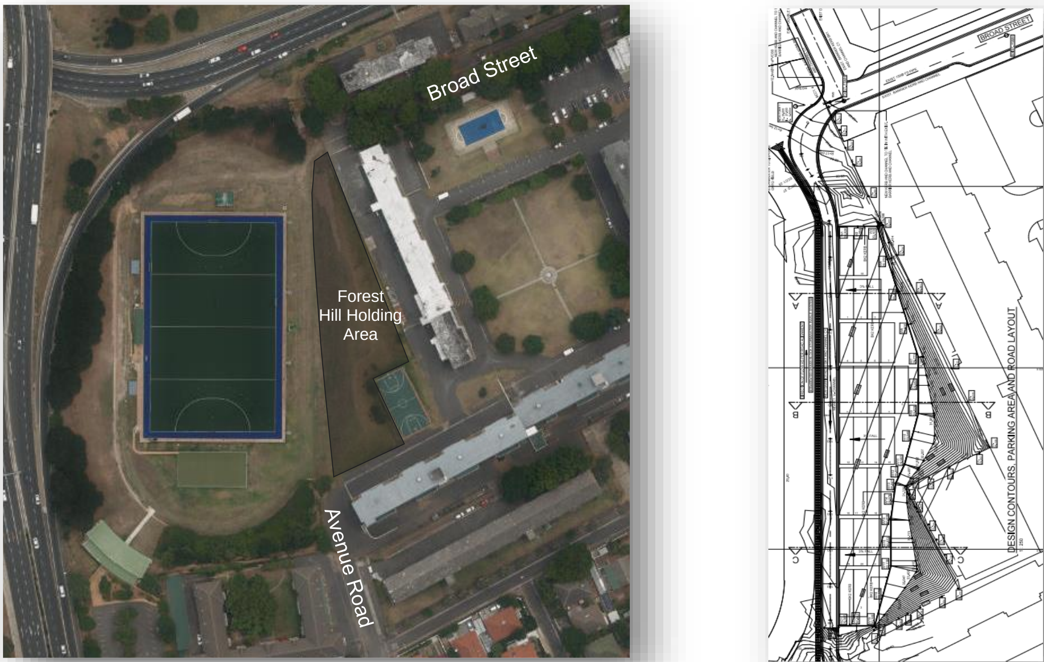


Figure 2-13: Proposed Forest Hill holding area

North Stop

The proposed holding area will be built north of the existing North stop, with buses accessing and leaving the holding area via North Entrance Road. The aerial view of the proposed North Stop holding area are shown in Figure 2-14.

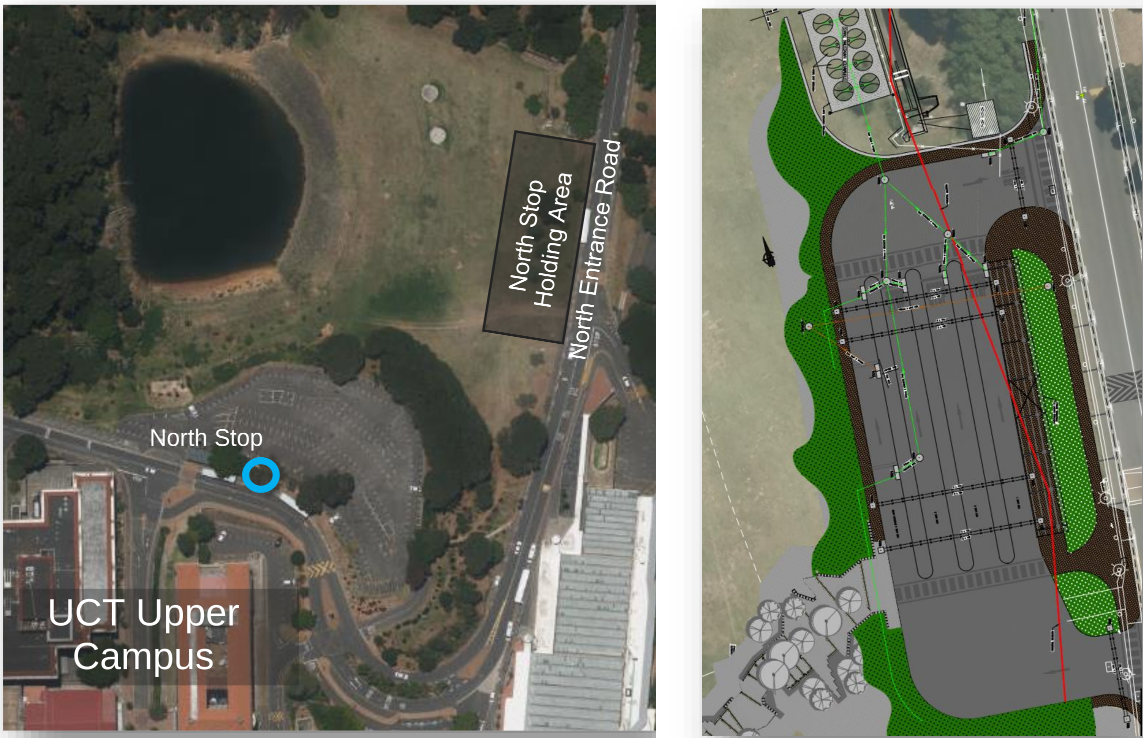


Figure 2-14: North Stop holding area

2.2 Operating requirements

2.2.1 Minimum vehicle power

The power requirements for buses are based mainly on their ability to operate at sensible speeds, including on inclines, such as encountered in the UCT operating environment. Based on work done by a member of the team some years ago, including for the specification of the first current format UCT Shuttle Service buses, acquired in 2004/5, and used widely since, a minimum power of 11kW per ton gross vehicle mass is recommended.

Based on a typical standard bus having a GVM of approximately 18 tons, a minimum of a 200kW power plant is recommended. This estimation has worked well for applications at UCT and many other bus systems around South Africa and is deemed the basis for bus power selection.

The same basic parameters applied to the nominal 9m midi-buses used in the UCT Shuttle Service system result in a power requirement of about 140kW

2.2.1.1 Gradeability of Route Profile

Motor vehicles generally have a gradeability value specified to give the user an indication of what gradients the vehicle can traverse safely. This is an important factor to consider when selecting vehicles that will be used in hilly terrain.

Although there are certain norms and standards applied to road design and construction that are generally applicable, a route profile was built of each of the UCT Shuttle service routes to establish some sense of the extent of incline and decline. The maximum incline represents the minimum gradeability of the buses deployed and the longest sustained incline indicates the minimum sustained power output capability of the vehicle. The declines influence the regeneration opportunities for electric buses.

On average the slope for the routes is graded at 4% with the downhill segments providing regenerative braking opportunities. (Regenerative braking feeds energy back into batteries). The steepest incline measured over a specific distance is the incline to upper campus that all buses traverse, this is a distance of 225m with a 17m incline/decline resulting in an 8% gradient that must be accommodated by any bus operating in the UCT environment.

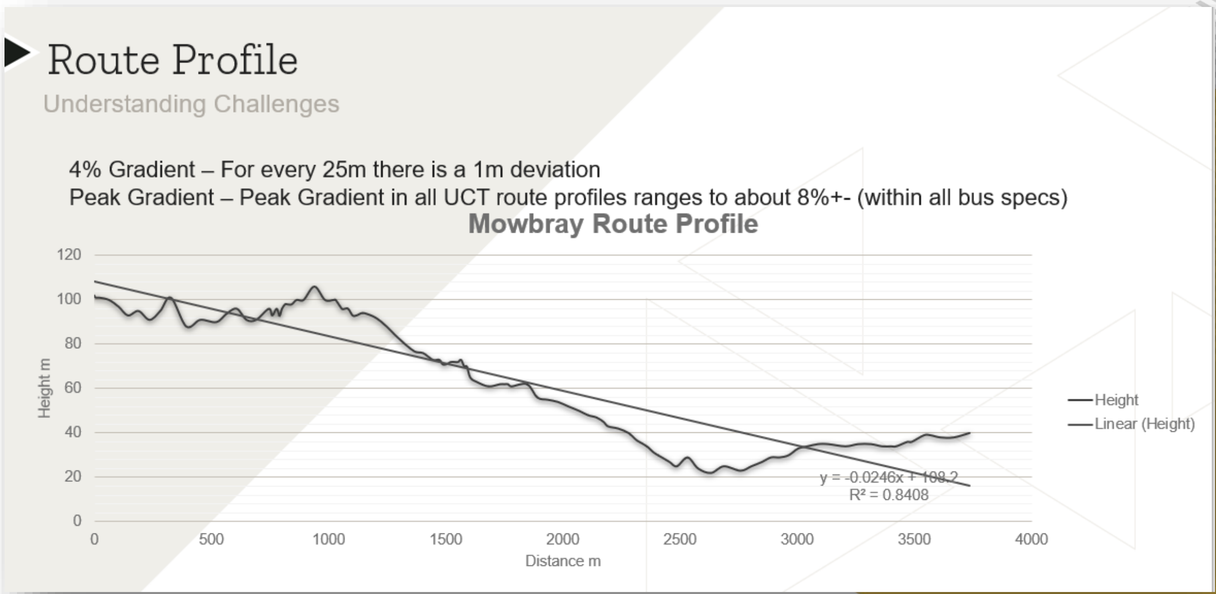


Figure 2-15: Mowbray Profile

2.2.2 Estimation of bus battery capacity

Although the motor power requirement is well understood, the amount of power used in kWh is more difficult to assess. It is possible to carry out calculations based on the terrain, typical vehicle speeds and loading and so on, but this is a complex and perhaps unnecessary exercise. As an approximation for the purpose of testing the market and sensitivity to this aspect, the typical fuel consumption of buses operating in this environment has been used instead. Based on 40 litres of diesel per 100km average fuel consumption for a standard bus and an approximate energy conversion rate of about 3kWh per litre of diesel, we can estimate that a bus is typically using about 120kWh per 100 kilometres travelled. Based on a first approximation of an average of 150km per day per bus, the expectation is that the bus power system must be able to deliver no less than 180kWh between charges, with at least 200kWh being the target usable battery capacity for each standard bus. A battery capacity of around 140kWh is required for the midi-buses. This is proposed as the basis for a minimum vehicle specification, noting that most market ready buses quite easily meet and often significantly exceed these minimum values.

2.2.3 Determination of bus hours operated

Given the approximate daily power consumption of the buses, the question becomes one of how many hours a day are available to essentially replenish the 200kWh capacity to each bus battery. For this purpose, the initial approach was to approximate the bus operating hours by looking at the driver duties.

A very high-level review was undertaken considering the charging options and times required for a 200kWh recharge and the limited opportunities for charging. The outcome of the analysis shows that both fast and regular charging systems could be considered based on the Bus charging technology. It is noted that the fast-charging systems are more expensive than regular or “slow” charging systems, but in the context of the price of a bus, are preferable to the acquisition of additional buses.

Modern smart charging technology allows a range of advantages in terms of power consumption, charging rates and sequential charging that will allow for an autonomous charging regime once the vehicles are present at the holding areas and connected to the infrastructure.

Based on the distances travelled and the time available for charging there is no requirement for additional chargers that need to be installed at remote locations unless vehicles are planned to be parked there overnight.

2.2.4 Bus market

In parallel to other work, separate research has gone into options in the electric bus market. It is clear from investigations, that there are electric buses that have characteristics meeting or exceeding the requirements of the standard buses for UCT operations in terms of motor power, battery capacity, passenger capacity and vehicle dimensions. Key in these observations is that the power and battery capacity estimates given earlier are practical and sensible in the context of what is available internationally. Further work is ongoing into the availability of similar vehicle specifications in South Africa. All the above efforts have been in the context of defining the parameter ranges within which it will be necessary to work. Having established that all parameters can be met with internationally available buses and charging technology, further refinement of each of the parameters may be required to avoid over or under specifying where there are options close to the approximated parameters.

2.3 Existing Electrical Supply

The source of electrical energy to all the university campuses is from the City of Cape Town’s electrical network. The municipal supply is derived from a mixture of sources; however, a large component of the existing supply is derived from Eskom.

The electricity on campus is distributed mainly using a medium voltage (MV) ring network that provides supply to the various loads at a lower usable voltage level of 400/230V. There are however some areas that derive their supply at a low voltage supply of 400V directly from the CoCT.

From data made available, there are four feeders from the CoCT substation to the UCT intake substation. There are a further five feeders present for sub-distribution, while a single feeder is used for power factor correction at the MV level.

The locations proposed for the bus holding areas have possible tie in points from which supplies can be derived for the EV charging and lighting infrastructure, each holding area is discussed further.

For the North Stop holding area, the charging electricity supply may be derived from either:

- Sports Centre Substation – 500kVA installed capacity
- RW James Substation – 1000 + 800 kVA installed capacities

The RW James substation is the more likely of the two substations due to its closer proximity to the North Stop holding area.

The Forest Hill holding area is located close to the University’s hockey field, where a low voltage supply is present from the CoCT to the University’s club house. This supply is of low capacity and is therefore not suitable for high power charging, the requirements of which are investigated further in this report.

3 Market Analysis

The EV bus market is an undeveloped market in the South African context, while this technology grows globally, its application on the African continent is significantly slower. This is due to various factors which could include the following:

a. Initial cost of the vehicle
b. Electricity stability and supply
c. Skills and understanding of the technology
d. Presence of EV manufacturers or partners on the continent
e. Significantly low number of EVs on the roads comparable to ICE vehicles

Despite this, there is an increasing interest in moving towards cleaner fuel sources and towards improving climatic conditions. Local Government policies incentivising and removing barriers of entry through tax reform and/or rebates can be a large driving force behind the adoption of cleaner, more sustainable forms of energy and their usage and creating demand to reach the critical mass for broad adoption.

3.1 Bus Suppliers & Models

Our local bus manufacturers have been involved with developments on EV based bus chassis, and other cleaner more efficient technologies, however, due to the smaller market size and to maintain their competitive advantage, this information is not easily shared. Busmark 2000 is the company that was involved with the outfitting of the BYD chassis that were brought into South Africa as pilot units and has experience with EV buses and the requirements of the local market.

The limitation with most European bus manufacturers is the fact that they may only supply completely built units (CBUs) to South Africa with the EV drivetrains. This may not meet the local content requirements. Companies like BYD (from China) have supplied bus chassis for our local market to a small degree of success.

Performance and operational data on the buses that are being tested for use in the Golden Arrow Bus Services (GABS) case is not readily available. Attempts to gather information related to specification and offering of future buses from BYD was also not very successful.

The requirements upon which the buses were specified are as follows:

Table 3-1: Standard bus application requirements

Variable	Value
Route length (daily)	200 km
Maximum gradient	8 %
Minimum speed at which to climb the above gradient	30 km/h
Minimum sustained speed on level surfaces	60 km/h or 80km/h
Minimum passenger capacity	85 (64 seated, 21 standing)

Details gathered from various EV bus OEMs from China and Europe give a good indication that vehicles are available for the application at hand. At this stage the EV market in South Africa is virtually non-existent in terms of manufacturing, and thus CBUs have been considered for the purposes of this study. In time and with investment from both Government and Private sector this should improve the environment and hence the costs of vehicles and associated equipment going forward.

Details extracted from the BYD website from the American offering, the Yutong E12 vehicle proposed by BAI and the Mellor Sigma 12 offering are as tabulated below.

Table 3-2: Standard EV Bus Technical data

Parameter	BYD Type D School bus	Yutong E12	Mellor Sigma 12
Length (m)	12.3	12.17	11.975
Width (m)	2.6	2.55	2.55
Height (m)	3.34	3.35	2.73
Curb weight (kg)	13099.8	-	-
Gross weight (kg)	17,759.50	18,500	19,000
Passenger Capacity	84 + 1	44 + 1 *	83
Top speed (km/h)	105	100	80
Max gradeability (%)	20	17	13
Motor type	Synchronous	Synchronous	Synchronous
Max Power (kW)	150 x 2	215	350/195
Max Torque (Nm)	550 x 2	1200	3500/1700
Battery type	Lithium Iron Phosphate (LFP)	Lithium Iron Phosphate (LFP)	LFP
Battery Capacity (kWh)	255	422	420
Charging capacity (DC)	110 kW	150 kW	200 kW max
Charging time (h)	2.1 – 2.6	2.8	2.1 (@200kW)

* These buses were the standard City Bus offering for the European market, thus the lower passenger capacity, however, we were assured that the numbers expected for the local conditions can be met, should these vehicles be selected for local deployment.

From the details extracted above it is evident that buses exist with the required technical specifications that are required for the UCT application.

Mellor was the only company that had suitable midi-buses suiting the UCT application. The Sigma 8 is a nominal nine-meter bus with specifications as presented below. Yutong is in the process of testing a nine-meter bus, which will only be released in 2024. For the purposes of this study only the Mellor Sigma 8 bus was considered.

Table 3-3: Midi EV Bus Technical data

Parameter	Mellor Sigma 8
Length (m)	8.725
Width (m)	2.35
Height (m)	3.1
Curb weight (kg)	-
Gross weight (kg)	13,000
Passenger capacity	Up to 54 passengers
Top speed (km/h)	78
Max gradeability (%)	20
Motor type	Synchronous
Max Power (kW)	150/80
Max Torque (Nm)	650/ 230
Battery type	LFP
Battery Capacity (kWh)	210
Charging capacity (DC)	150 kW max
Charging time (h)	1.5 – 1.8 (@150kW)

While EV buses, like conventional buses, can be ordered to customer specification, manufacturing time delays are expected with custom made vehicles. In most cases order quantities will justify the need to manufacture a custom-made vehicle. For this reason, small fleet owners generally order standard production models.

Customisations in terms of vehicles and drivetrain options will tend to increase the manufacturing time and are subject delays unless there are similar specifications that may be required by other users to make it feasible for the OEM to adjust their manufacturing processes.

Most manufacturers have a minimum order quantity that needs to be met before orders can be placed. This normally restricts smaller fleet owners to manufacturers that are willing to meet the smaller numbers. It is generally preferable if standard vehicles can be purchased in these instances.

3.2 Current Technology (EV Buses)

Standard production EV buses are available with various specifications from various manufacturers. While some manufacturers claim to offer a customised approach, this will generally require a large order to make the customisation feasible for the OEM to include on their production line.

With the relatively small number of buses that are required for the UCT fleet, the buses sourced may have to be from a mass-produced typical supply that is used in the mass market

3.2.1 Batteries for buses

BEV buses make use of Lithium based battery technology, with Lithium-Iron-Phosphate (LFP) batteries being the most popular technology at present. Bus manufacturers purchase batteries from reputable manufacturers and generally warrant the batteries for the lifespan of the bus.

Batteries are made up from raw materials that are sourced from various producers. There is a drive from the more established OEMs to manufacture or get involved in the manufacturing process of batteries from the early stages. This has seen OEMs getting involved in the purchasing process and in some cases purchasing raw materials directly from the producers. This is generally done to ensure that the materials used in the battery manufacturing process is responsibly sourced.

The four major raw materials associated with EV battery manufacturing are Copper, Lithium, Cobalt and Nickel. In most cases these resources are present in abundance globally. The biggest concern is however the sustainability and ethical sourcing of the materials.

Copper reserves are available in abundance in the South American regions, with Chile having enough copper reserves that can be mined at the present rate for another hundred years. Other abundantly available materials include Aluminium, which can be used as an alternative to copper. Should this need arise, alternatives are available.

Lithium is also available at large scales at present; however, production is not scaled to the expected levels. The majority of the lithium reserves are present in South America and Australia. Over the past few years Australia has been the largest producer of Lithium, with most of the material being bought up by China for their battery production.

Cobalt is one of the most contentious materials that is used for battery production. This is not due to the unavailability, but rather due to human-rights abuses in the DRC associated with the mining of the materials. Cobalt reserves are present in countries like Russia and Australia, while China also has local reserves available.

Presently, with the DRC accounting for 70% of global production, the question of human-rights and sustainability are brought to the forefront. China leads the way for refined cobalt production at 70% of global supply. Materials used by the Chinese manufacturers are usually sourced from mines in the DRC. However, other large vehicle manufacturers have already gone ahead with agreements with alternative suppliers to ensure that materials are sourced responsibly.

Nickel is another material that is required for EV battery manufacturing. There seem to be sufficient reserves available with the largest reserves shared between Australia and Indonesia. There are various reserves present in other parts of the world that could be sourced for EV battery manufacturing.

3.2.2 Battery disposal

Most EV batteries including bus batteries reach the end of lifespan when the ability of the battery to retain 70-80% capacity can no longer be sustained. This impacts the range capability of the vehicle and is therefore replaced at this stage. With improvements in battery technology, there is an expectation that some batteries may last the lifetime of the bus.

EV batteries can then enter a second life stage providing an opportunity for the batteries to be repurposed or remanufactured for further use. Only when the batteries are no longer feasible for any other application are they recycled to the extent possible given prevailing technologies.

As the market matures, and a significant percentage of batteries become available, the developing markets will also mature and so will the recycling processes.

Reuse is one of the focus areas considering the need for energy storage with the transition to renewable resources. However, when the battery can no longer be reused, recycling and disposal become the only options available.

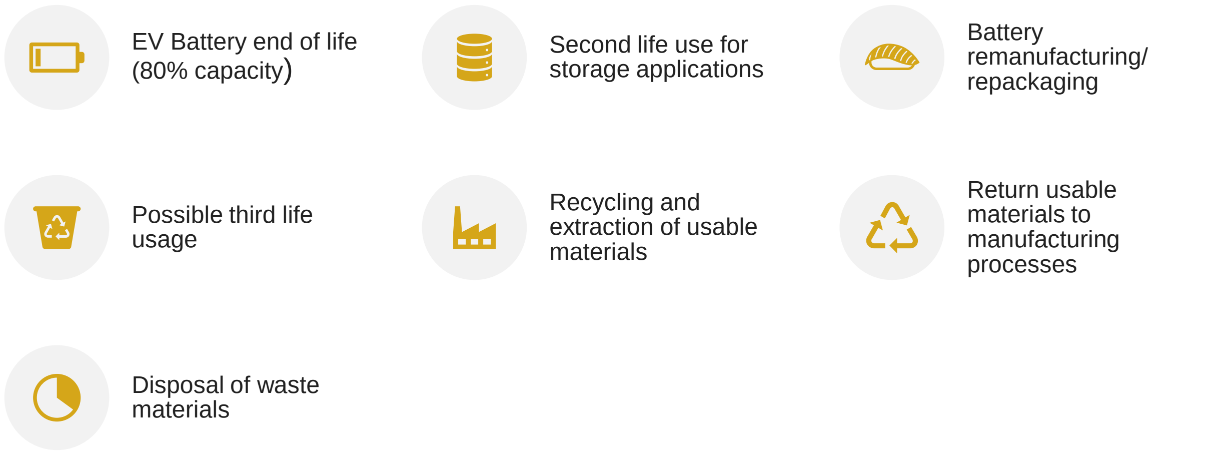


Figure 3-1: EV battery afterlife

Due to the current under-developed state of the EV market in South Africa, supporting industries are still to be developed. It is envisaged that as adoption of EVs increases, further development of supporting markets will also increase. The recycling and repurposing markets are however still at an early stage of development in countries that have already begun the EV transition as the first lithium EV batteries deployed are only now coming to the end of their useful life in any quantities. As the sector matures and the required R&D completed, a standardised approach can be implemented.

Presently the dumping of LIBs into landfill sites in South Africa is banned and there is a drive from the Department of Forestry, Fisheries and Environmental Affairs for economic opportunities to be pursued with the recycling of these items.

Inputs are required from the producers of the batteries to setup procedures, processes and resources to implement the measures at the post-consumer stage. These are linked to the collection, storage and transportation of products, recycling, recovery and treatment, thus putting onus on the battery manufacturer to supply a viable disposal route for consumers. The aim is to divert waste from landfill sites, increasing the recycling rate to achieve the objectives of the National Waste Management Strategy.

While no mention of EV batteries is made, the majority of EV batteries being lithium based will also fall under the above rules for disposal. It is envisaged that as the EV market matures in SA the LIB recycling industry will become more established. Presently there are no end-of-life EV LIBs that have joined recycling value chain. Implementation of the extended producer responsibility (EPR) regulations are set to transform the local LIB recycling industry.

The current recycling method that is presently employed is hydrometallurgy, which makes use of aqueous chemistry to recover metals from ores, concentrates and recycled residual materials. Products obtained from lithium-ion battery recycling include cobalt, nickel and copper. Most of the other materials are destroyed due to the high temperatures associated with the process.

At the end of the process, toxic gases and waste products need to be recaptured and disposed of in a responsible manner. It is noted that any lithium recovered from the process cannot be reused at this stage.

The recycling technology implemented at present is however not advanced enough for efficient recovery of materials. Research and development is being undertaken by various facilities to improve upon the recycling process.

Positives are, however, that there are various experimental battery technologies for storage and EV applications, both of which will benefit the drive towards reduction of GHG emissions. As battery energy density improves, smaller EV batteries can be used, and the impact on the environment should also be reduced.

3.3 Current Charging Technology

EV Chargers are critical for the charging of the EV bus batteries. There is a move internationally to move to a more standardised charging plug configuration and most EVs are being released with CCS type 2 charging ports.

There is a trend towards using DC fast chargers for fleets and vehicles which are used for longer distance operations. This comes with the advantage of shorter charging times and hence higher vehicle availability.

It is noted that charging of EVs is generally controlled within the limits that are set on the EV by the OEM. This will consider safety factors as well as longevity of the battery. When choosing a bus, the charging technology capability will be key to deciding on charging strategies and infrastructure requirements.

3.4 Charger types

Two types of chargers are available based on the supply that is provided to the vehicle. AC charging stations provide an AC supply to the vehicle and relying on on-vehicle charging equipment with limited charging capacity. DC charging stations provide a DC supply to the vehicle, facilitating significantly higher charging rates. For the purposes of this study, DC fast chargers were considered as the technology of choice for fleet applications.

3.4.1 Charger OEMs

EV Chargers from three suppliers were considered for the feasibility study. These included units from Schneider Electric, Siemens and ABB.

3.4.1.1 Schneider Electric

Schneider electric is presently only supplying AC chargers to the local market as their new range of DC chargers will only become available in 2023. The AC chargers are generally for domestic use and in some cases for public access charge points, however power outputs are limited between 7.4 – 22 kW. These are generally Mode 2 and 3 chargers.

These chargers are not fit for UCT bus fleet purposes and were not considered further for this study.

3.4.1.2 Siemens

Siemens has a range of chargers available in their portfolio. The holding area layout concept was based on using the Siemens Sicharge UC charging centre with the 5 charging dispensers that can be connected to the charging centre.

This unit is capable of being upgraded using modules. Cable lengths of up to 10m are available. The dispensers with air cooled cables were selected as charging power of 150 kW is available from these units, with a peak power of 200 kW.

The charging dispensers have a small footprint of 600 x 300 mm, and only weigh 95 kg. A 10m cable length is available from the dispenser and is suitable for applications where long cables are required. The CCS type 2 socket connection standard is suitable for use with buses from Europe or China.

User authentication using RFID is an option if required. PLC communications standards allows this unit to integrate into the electrical infrastructure with ease. Network connection using Ethernet interfaces or mobile network connectivity is possible.

These units have been on back order and are not available for pricing for this period. There seem to be delays with components at this stage. These charging stations will become more available as adequate components become available again.

Unit considered:

Table 3-4: Sicharge UC 400 (kW), with air cooled cables

Requirement	Technical data
Supply required:	400 V AC (3ph + E)
Nominal current:	456 A
Power Factor:	0.98
Peak power output:	400 kW @ 1000 V DC
Rated Power output:	300 kW
Voltage output range:	10 … 1000 V DC
Efficiency at full load:	>96%
Charging station Weight:	2780 kg
Charging Station dimensions:	1526(W) x 1109 (D) x 2000 mm (H)
Charging standards:	IEC61851-1/23/24, ISO15118 (DIN70121)
Dispenser Weight:	95 kg for floor mounting
Dispenser footprint:	600 (W) x 300 mm (D)
Communication std:	PLC
Number of dispensers:	up to 5 units for sequential charging
Authentication:	PIN (RFID optional)
Cable lengths:	10 m maximum for air cooled cables
Outlet option:	CCS Type 2
Ingress protection:	IP54
Impact protection:	IK10

Cloud based service packages are available for monitoring and analysis. Firmware updates are delivered remotely.

3.4.1.2.1 Installation requirements

The DC cable between the charging unit and the dispenser can be installed underground or above ground. Shielded cable is recommended when routing the cable above ground to reduce electromagnetic interference.

Electrical Protection provided includes the following:

- Overvoltage protection
- Overload protection
- Insulation monitoring since the EV has to be grounded during the charging process.

Table 3-5: Cable data for ground installation

Area	Function	Charging Station	Cable type
Main power supply	400V AC	2 x 4c x 95 mm^2	0.6/1.0kV Cu/XLPE/AWA/PVC
Charging station – Dispenser	750V DC	2 x 1c x 70 mm^2 (per-pole +/-)	0.6/1.0kV Cu/XLPE/AWA/PVC
Charging station – Dispenser	Earthing	1 x 1c x 35mm^2	Cu/ PVC (Y/G)
Charging station – Dispenser	230V AC auxiliary supply	1 x 3c x 2.5mm^2	0.3/0.5 kV, Cu/PVC
Charging station – Dispenser	Communication	RJ45 CAT 6 (TP) FO 50/125, OM4, 4fib	LIYCY (TP)

3.4.2 ABB

Internationally, ABB is one of the largest EV charger manufacturers. They have various solutions that are available from home charging units to fleet charging units with varying output capacities. The units that are suitable for fast, fleet charging were investigated as part of this study.

The Terra 360 EV DC Fast charger is a modular charging station that can be ordered with lower power value of 90 kW and upgraded as required in 30 kW steps using available modules. It can serve up to 4 vehicles at the same time, however the cable reach is limited to 5 m, as these are generally used for public charging of EVs.

Table 3-6: Technical data Terra 360 DCFC

Requirement	Technical data
Supply required:	400 V AC (3ph + E)
Nominal current:	
Power Factor:	>0.96 @ full load
Peak power output:	90 - 360 kW upgradeable in 30 kW steps
Rated Power output:	360 kW
Voltage output range:	150 … 920 V DC
Efficiency at full load:	>95% peak
Standby power	80W
Charging station Weight:	700 kg
Charging Station dimensions:	720 (W) x 710 (D) x 2200 mm (H)
Charging standards:	IEC61851-1, -21-2, -23, 24, IEC 62196-2, -3, IEC 61000, ISO 15118 ready
Communication std:	OCPP 1.6j +
Connectivity	Mobile network modem, RJ45 Ethernet
Number of ports:	4 for shared charging, else single charging up to 180 kW
Authentication:	RFID, App, PIN code, ISO 15118 using vehicle authentication
Cable lengths:	5m or 7 m, with retractable cable management as an option
Outlet option:	CCS Type 2
Ingress protection:	IP54
Impact protection:	IK10 (Cabinet), IK8 (touch screen)

3.5 Economic Benefit in the Market (Not UCT specific)

Noting that the capital cost of acquiring electric vehicles in general is relatively high at this stage in the technology life cycle and that thus, the economic benefit may not be seen for some time, nevertheless, the reduction in operating and maintenance costs should, over sufficient time, outweigh the additional capital cost while also providing, in the appropriate environment a reduction in GHGs. As the market matures, the expectation is that vehicle prices will drop relative to older technologies, improving the relative benefit of the EV vehicle.

The greatest benefit of using EVs in comparison with ICE powered vehicles can be achieved when charging of the vehicle is carried out from a renewable/ sustainable energy source.

At the present fuel and electrical energy costs it is evident that EV powered vehicles could provide a benefit of up to 77% in terms of fuel costs. Further benefits include the lower maintenance requirements of EVs in comparison with ICE vehicles.

The regular servicing and maintenance required by ICE powered vehicles is significantly reduced in EVs and the minor maintenance requirements for EVs will cost considerably less and should result in much lower downtime of vehicles.

4 Government Green Paper Regulation (Gazette 44606)

The green paper, (Auto Green paper on the advancement of new energy vehicles in South Africa (44606), was published on 21 May 2021 to establish a foundation for the long-term strategy for EV and component manufacturing. The strategy is complemented by the focus on increasing competition in the global race to transition to EVs.

4.1 Goals Of the Green Paper

The stated goal of the policy proposed in the Green Paper is:[5]

1. The creation of a high-yielding business environment, including an appropriate fiscal and regulatory framework, that makes South Africa a leading and a highly competitive location, not only within the African continent but globally, for electric vehicle production.
2. Support and investment in the expansion and development of new and existing manufacturing plants to support the production of new energy vehicles and components within South Africa and to grow the level of employment in the sector.
3. Development and investment in new energy vehicle component technology and expansion of the fledgling electric supply chain, by increasing support and investment in a set of unique NEV components.
4. Reinvestment and support towards reskilling and upskilling of the workforce to ensure the right skills are available for the design, engineering and manufacturing of electric vehicles and related components and systems.
5. Transition of South Africa towards cleaner fuel technologies available globally [CleanFuels2];
6. Adoption of new and sustainable manufacturing processes to significantly reduce greenhouse gas emissions and improve our environmental wealth.
7. Ensuring that Research and Development [R&D] investment is strategically targeted at activities that are likely to give South Africa a competitive advantage

[5] (AUTO GREEN PAPER ON THE ADVANCEMENT OF NEW ENERGY VEHICLES IN SOUTH AFRICA (Gazette 44606), 2021)

Figure 4-1: Government Goals with Green Paper

4.2 Key Extracts for UCT

The green paper covers a lot of aspects to consider in the process of mapping out this new technology in South Africa, and although it has not been approved to date (2022) the following are key extracts to focus on.

4.2.1 Using Tax reforms to support industrial policy ambitions

The Governments main intention is to use tax reforms to support industrial policy ambitions. Industry has set out a compelling business case to present before the National Treasury to stimulate greater domestic demand for vehicles in South Africa, by reducing the Ad Valorem duty as well as to address the fringe benefits on vehicles for employees of automotive companies. A standard rate per kWh could be used [e.g., the industry suggests an average rate of 2020 of 137$/kWh] to reduce the price of an EV in aligning it to be closer to the price of an ICE vehicle for a period of say five years in stimulating market demand for EVs. Government has noted the need to synchronise such reforms with active localisation of production. In this way, the Ad Valorem tax could be used as the instrument to tackle the demand side. This must be balanced with the need for Treasury to maintain a targeted tax collection from the Ad Valorum tax, which may require a restructuring of the tax, with one option to be considered of lower taxes on EV's balanced against higher tax levels for luxury vehicles over a certain price.

4.2.2 Local Manufacturing

Local manufacturing will be a key pillar in gaining a foothold on the Electric Vehicle value chain and ensuring South Africa's role as a local, and international exporter, focusing especially on the battery manufacturing. Eight percent of South Africa's GDP is based on vehicle manufacturing of which 2/3rd is for export, and to not loose position or regress in GPD growth, South Africa must take hold of certain aspects of the EV value chain in manufacturing. The government aims to do this is enhancing some of the current manufacturing policy as well as introducing new policy options, like reducing duties, determining value of VALA (Volume Assembly Localisation Allowance) credits and overall sunset clauses that would help stimulate growth till critical mass adoption is generated and a measure of parity with ICE is reached.

Some of the key point is mapped in Figure 4-2: UCT Extract Simplified

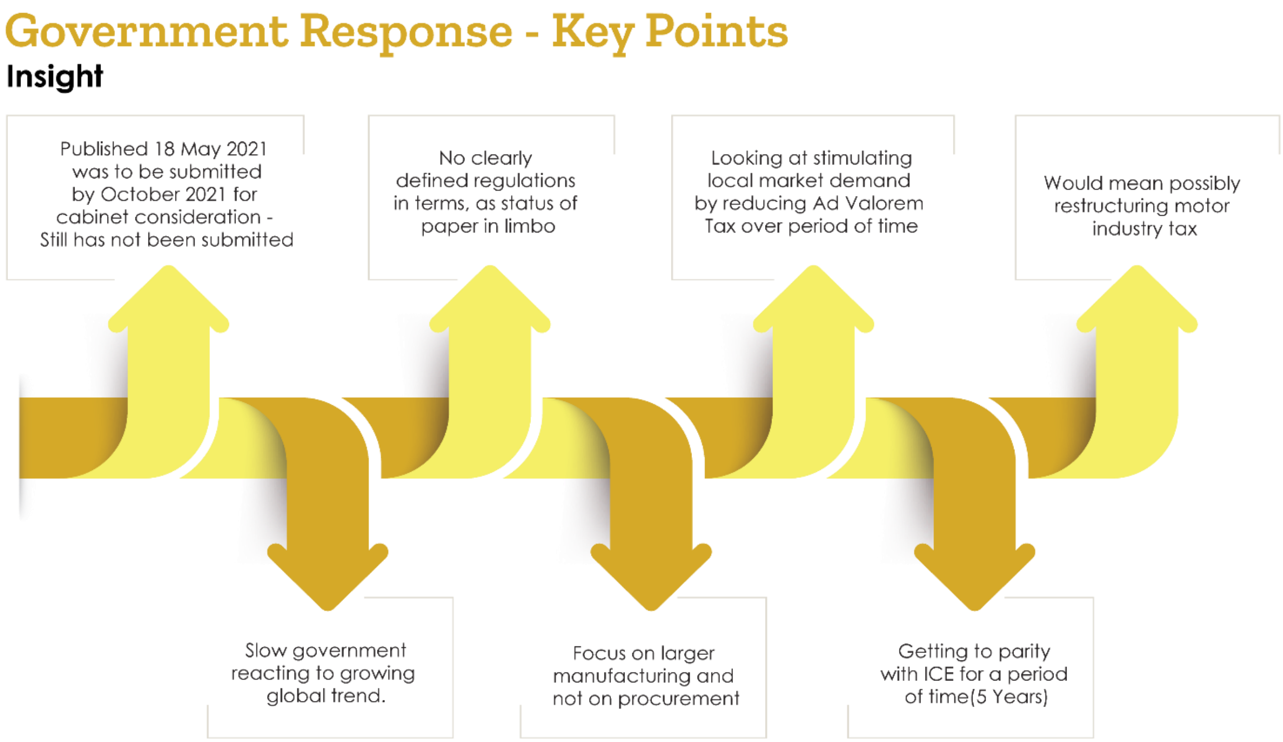
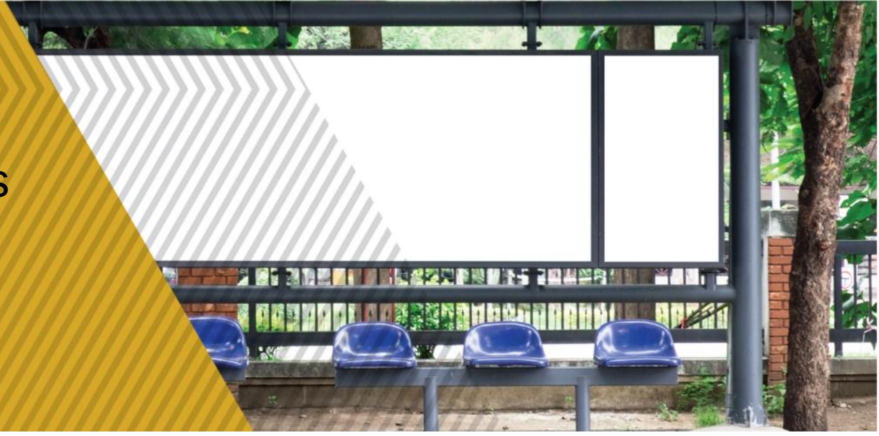


Figure 4-2: UCT Extract Simplified

5 Planning and Analysis



5.1 Infrastructure

While most civil infrastructure is being addressed prior to the inception of an EV bus project at UCT, provision is being made for the installation of the required electrical infrastructure going forward. The eventual transition to EV buses is relatively certain and planning for this is vital to prevent additional rework in the future. This part of the report identifies the electrical infrastructure that is required for the transition to EV buses.

5.1.1 Location

The two holding areas identified are listed in this section with electrical installation details outlined. A conceptual design for the infrastructure is present in section 5.1.2.

5.1.1.1 North Stop

The North stop holding area will house the midi-buses which are used on a more frequent basis.

For the North Stop holding area, the supply ring may be derived from one of the following existing substations:

- Sports Centre Substation – 500kVA installed capacity
- RW James Substation – 1000 + 800 kVA installed capacities

It is envisaged that a maximum of 10 Midi buses will be provided for at the North Stop. This will therefore require a capacity of 800kVA for the supply to the EV charging station and dispensers.

The RW James substation is closer to the location and could possibly be the choice for the tie in for the electrical supply for the EV charging infrastructure. The SLD overview shown below gives an idea as to what is required for this part of the network.

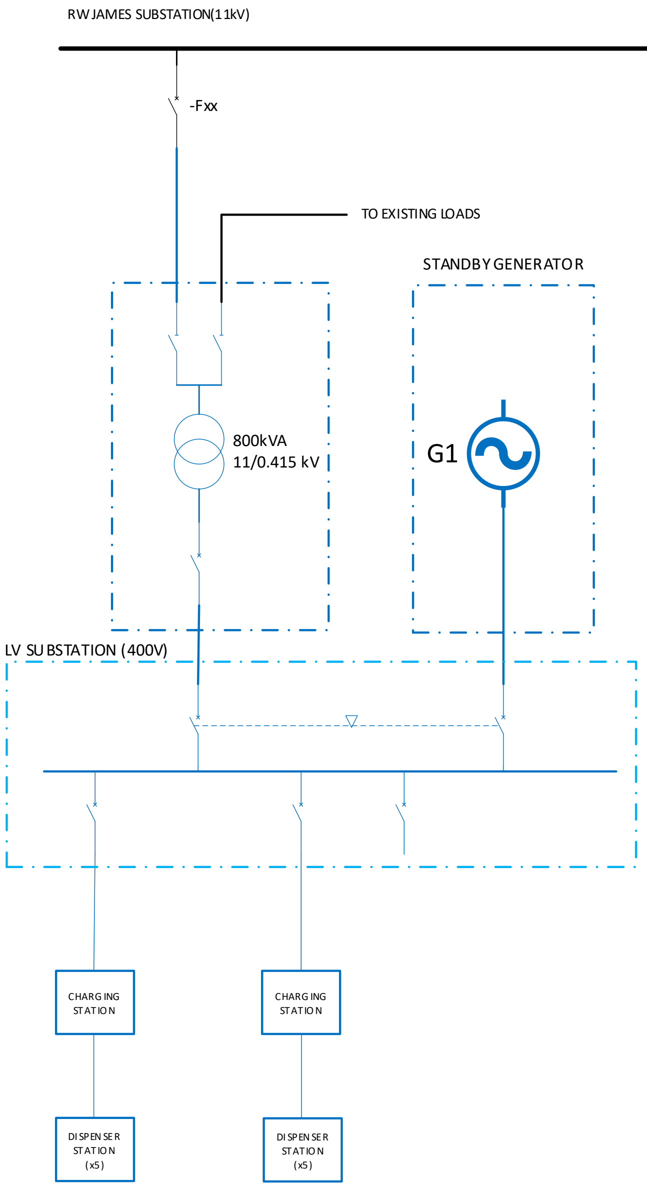


Figure 5-1: North stop electrical SLD overview

It is further noted that standard buses can also be parked at the North Stop holding area. Should there be need to charge the larger buses at this location, it is possible to do so, considering that similar DC Fast chargers can be used for both locations for the midi-buses and standard buses.

5.1.1.2 Forest Hill

The proposed Forest Hill holding area presently has a LV supply from the CoCT. This supply is provided to the club house near the hockey field at a voltage level of 400V.

It is envisaged that four large capacity charging stations with dispensing stations will be installed at this location. This requires a power supply with the capacity of 1600 kVA will for the charging of 20 standard EV buses. A sequential charging philosophy will be used to ensure that peak power demands are not exceeded.

A high capacity MV supply point will have to be provided for the purpose of this project. From site investigations by the UCT team, there is a CoCT MV Substation close to the location. Plans for an additional MV supply point will have to be discussed going forward. The final sizing of the mini substation will have to consider the supplies to the hockey field and club house. The final supply will therefore become an MV rated supply from the CoCT.

The figure below outlines the expected layout of the electrical infrastructure required for the charging of the buses at the Forest Hill holding area.

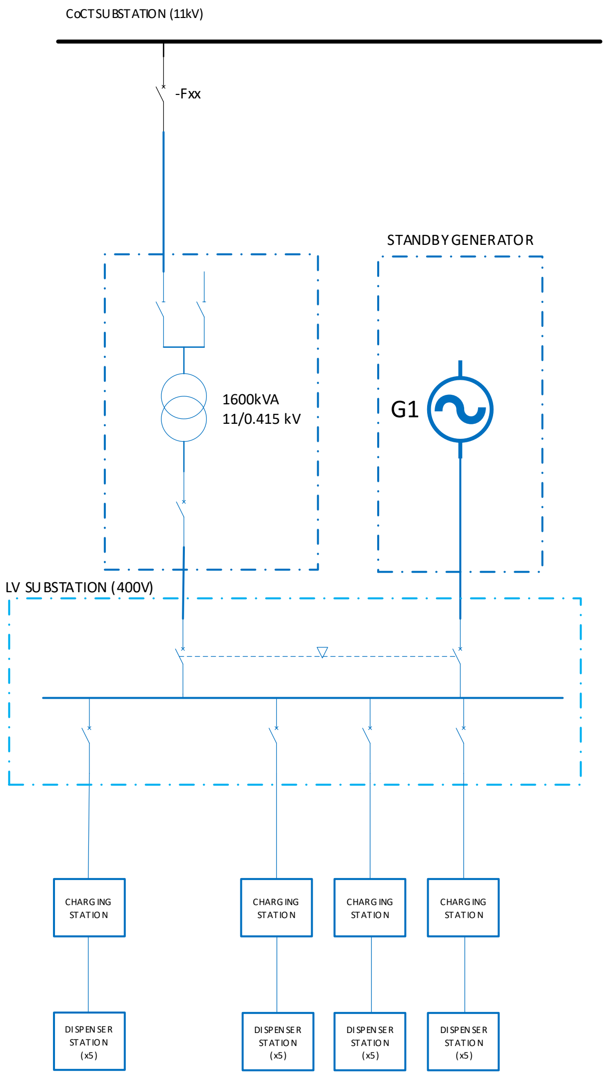


Figure 5-2: Forest Hill electrical SLD overview

5.1.2 Conceptual Design

Electrical supply will be provided from the ring network that is present on campus as far as possible. To ensure that bus availability is maintained, it is essential that a back-up power source is available for the charging of buses should power supply not be available from the electrical grid.

The charging stations will require a three-phase 400V supply per charging station, and a 230V auxiliary supply for auxiliary services. Due to the number of vehicles that will need to be charged at the higher power outputs, a high-capacity supply is required.

This will be derived from the MV supply that will be used to transform the power to a usable voltage level. The LV power will then be distributed via suitably rated LV distribution switchgear that will be installed within an existing substation building (should there be space) or new LV substation buildings. An alternative could be new containerised substation solutions that can be installed in a suitable location on campus.

Both holding areas will require the following additional infrastructure:

- MV/ LV transformer or Mini-substation.
- LV Substation with distribution for EV Chargers and lighting loads.
- A substation building or containerised substation solution.
- A generator for backup power
- Charging stations located near the substation
- Dispensing stations located at the holding areas
- Cable distribution system for the power to the dispensing stations
- Security fencing for access control to Substations and/ or holding area

5.1.3 Associated risks

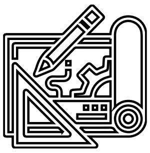
Additional costs outside the scope UCT associated with backup power that may be operated on an infrequent basis will have equipment procured for low cycle use. It would be beneficial if the added infrastructure can be included into a network that can be used to supply other building loads when required during power outages during campus hours.

5.2 Charging System

A charging system that incorporates a modular approach in terms of power output modules is recommended for the fleet charging. Equipment with small footprints that can be installed around the vehicle would be advantageous in terms of space usage as far as possible.

There must be some level of redundancy included in the system to ensure that the availability of the fleet is not compromised in the event of equipment downtime. This can be achieved by oversizing the charging stations to allow for additional load to be taken up and by duplicating equipment so that there are sufficient ports available for EVs to be connected to the charging source when required.

5.2.1 System Concept Design

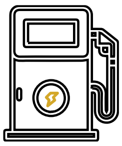


A smart charging concept that can schedule charging in a manner that will allow for sequential charging of vehicles is recommended. This will allow for the vehicles to be parked and connected with a charging dispenser, while the charger carries out the charging in a smart manner.

EVs generally restrict the amount of power that can be absorbed based on internal equipment ratings that are determined by the OEM. This therefore defines the maximum charge rate that the EV can absorb. On most EV buses this rate is between 100 – 200 kW.

The chargers selected can be used for both midi and standard buses. The charging rates will be determined by the vehicle and the strategy that needs to be implemented considering the constraints of the electrical installation and UCT's electrical consumption limits.

5.2.2 Charging Plan



Although there is some charging time available during the day off-peak period for topping up the batteries, the charging plan considered allows for all buses to be charged during the night-time hours when the vehicles are not in use and other electricity demand is low. This allows for a period of 8 hours that will allow the batteries to be replenished. As buses are returned to the holding area the drive shall connect them up to a charging dispenser as shown in Figure 5-3. This graph shows the bus availability for charging against the electricity tariff structure with the green line reflecting potential daytime charging.

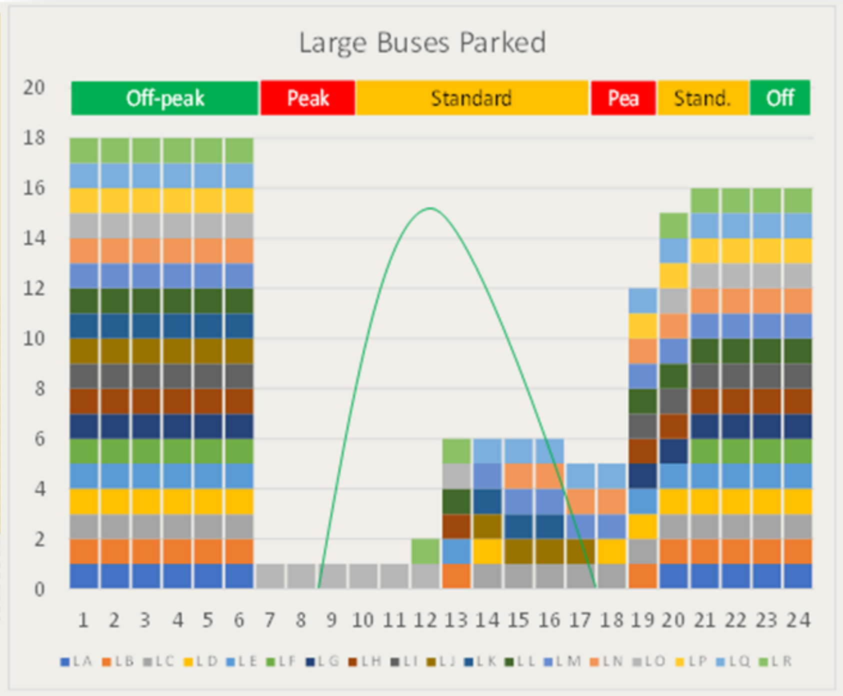
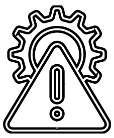


Figure 5-3: Standard Bus Charging Strategy

When the scheduled charging time is reached, the charging will begin at the pre-programmed rates. This will allow for the management of load currents and time of use to ensure that peak demands are not exceeded. Managed charging infrastructure is important for load management especially in cases where power is required for other critical areas or peak demand capacities are to be managed.

This charging strategy, as seen in section 7.3 is also vital in terms of costing as it starts influencing the Time of Use tariffs in City of Cape Town.

5.2.3 Associated risks



Stand-alone EV chargers are generally more accessible than higher end smart charging equipment. These units may not, however, meet all the requirements of smart charging.

With the electronic components and logistics value chains being affected by the Covid pandemic, the electronics manufacturing sector have been affected such that there are currently delays in getting equipment manufactured. There is an expectation that the challenges will be overcome, and that equipment availability will be improved. With many western countries increasing the speed of transition to EVs, EV related infrastructure equipment has become a demand item.

6 Business Case for transition to Electric Vehicles

This chapter sets out the Business Case considerations with the financial breakdown in Chapter 77.

6.1 Business needs

The University has the fundamental “business need” to facilitate student and staff access to its campuses and residences. This need has been addressed through the provision of the UCT Student and Staff Transport Service. Leading from this fundamental business need and the operating model used for providing the UCT Shuttle Service, the lease renewal for the bus fleet is a “business need” that has come to the fore as the current lease period approaches its end. In addressing this need, other UCT initiatives are taken into account that led to the consideration of so called “green technologies” as an alternative to the current diesel bus fleet. Although other technologies do exist, EV buses were selected, by UCT, as the most practical option for consideration in the current environment.

6.2 Benefits

The use of electric buses eliminates the local production of various harmful emissions and some level of noise pollution associated with diesel engines. Even though much of South Africa’s power is generated from fossil fuel sources, the production of electricity can result in more efficient and cleaner use of the fuel. It does need to be kept in mind of course, that modern diesel technology, in the form of EURO VI environmentally rated diesels are very significantly cleaner than older diesel technologies, but these can also be more expensive to maintain. UCT presently operates EURO V standard buses and EURO III midi-buses. Comparative emissions requirements are reflected in Table 6-1.

Table 6-1: Comparative environmental requirements for EURO I through VI heavy duty diesel engines.

Stage	Date	Test	CO	HC	NOx	PM	PN	Smoke
			g/kWh				*1/kWh*	*1/m*
Euro I	1992, ≤ 85 kW	ECE R-49	4.5	1.1	8.0	0.612		
	1992, > 85 kW		4.5	1.1	8.0	0.36		
Euro II	1996.10		4.0	1.1	7.0	0.25		
	1998.10		4.0	1.1	7.0	0.15		
Euro III	*1999.10 EEV only*	ESC & ELR	*1.5*	*0.25*	*2.0*	*0.02*		*0.15*
	2000.10		2.1	0.66	5.0	0.10[a]		0.8
Euro IV	2005.10		1.5	0.46	3.5	0.02		0.5
Euro V	2008.10		1.5	0.46	2.0	0.02		0.5
Euro VI	2013.01	WHSC	1.5	0.13	0.40	0.01	8.0×10^{11}	

[a] PM = 0.13 g/kWh for engines < 0.75 dm^3 swept volume per cylinder and a rated power speed > 3000 min^{-1}

Source: ***Emission Standards: Europe: Heavy-Duty Truck and Bus Engines (dieselnet.com)***

Although the EURO VI technology has made very significant inroads into the problems, one of the major benefits of moving away from diesel is the elimination of the NOx and particulate pollution associated with these vehicles. The particulate matter is of significant concern in respect or its health implications. Many studies have been undertaken and reported on this problem, for example the United States Department of Labour, Occupational Health and Safety Administration, (https://www.osha.gov/diesel-exhaust) reports:

"Diesel exhaust is a mixture of gases and particulates produced during the combustion of diesel fuel. The very small particles are known as diesel particulate matter (DPM), which consists primarily of solid elemental carbon (EC) cores with organic carbon (OC) compounds adhered to the surfaces. The organic carbon includes polyaromatic hydrocarbons (PAH), some of which cause cancer when tested in animals. Workers exposed to diesel exhaust face the risk of health effects ranging from irritation of the eyes and nose, headaches and nausea, to respiratory disease and lung cancer."

Emission from stationary power plant is more easily cleaned of these harmful pollutants thus making electric vehicles a theoretically cleaner option in this respect. In South Africa, electricity generation emissions control is limited, and present information suggests that EURO V and VI diesel engine buses remain a cleaner option that grid charge EVs. (The use of coal and diesel in ESKOM power plant incur similar environmental costs to the acquisition of diesel for vehicles.)

The above-mentioned emissions factor aside, transition to electric buses provides an opportunity to start using locally generated renewable energy to power the buses, essentially moving away from all forms of fossil fuel. To a limited extent, this can extend to independence from external power, be that direct use of fossil fuel or electricity from the national grid.

An outcome of following the electric bus transition path is that it allows the university to further explore the impact of this technology through academic programs using local data. As an early adopter of the technology, the University can provide a basis for studies of this technology in action and establish a leading position in this field.

6.3 EV Barriers to entry

Electric vehicles hold many promises, from reducing dependence on fossil fuels and lower maintenance requirements to decreasing greenhouse gas emissions. There are however some barriers to the transition from ICE vehicles to EVs. We will look through the topics to identify the perceptions behind each of the topics below and their relevance to the study.

6.3.1 Range anxiety

Early EVs introduced the concept of "range-anxiety". While this is applicable to personal transport, with public transport, the expected operation of vehicles is more structured. This allows for a managed approach for distances to be travelled and planning for downtime when the vehicles can be recharged for the next shift.

With improved battery charging and battery technologies, range is much less of a concern. The introduction of DC fast chargers allows one to recharge the battery to 80% capacity in a short period of time (usually a mattery of minutes on passenger EVs, while slightly more on larger applications).

With the technology that is available, range anxiety is therefore not a phenomenon that needs to concern the application of EV buses due to the structure and planning that will be in place for the application.

6.3.2 EV batteries

EV batteries are a topic that garners much discussion in the world today, for amongst other reasons, due to the perceived human rights abuses[6] and effects that are associated with environmental concerns. While many similar minerals are mined for existing fossil fuel refinement processes, these minerals attract a negative association when applied to batteries.

The battery manufacturing processes and chemistries have undergone refinement over the years, and continue to be improved. With ongoing research and development, this process is addressing the source of minerals, some of which are quite limited resources, as well as the disposal at the end of life.

As part of reducing emissions, reuse plays a major role that can extend the usable life of batteries. Battery recycling is being addressed at various levels. From private to grid connected storage solutions that will assist the renewable energy transition, used EV batteries have a potential to be reused beyond the EV application. Energy storage is a field that is growing rapidly and a second life option for batteries will result in reduced mining and other processes in the long run.

6.3.3 Battery Safety

There have been reports where EVs have come into the spotlight for catching fire while charging. The main culprit in most of these applications has been the battery through their chemistry and behaviour under charge and possibly high load conditions.

While battery management systems have improved and are able to monitor batteries more efficiently down to the cell level today, various advances in battery technologies have also reduced the risks. The use of Lithium-Iron-Phosphate (LFP) batteries have shown a considerable improvement in stability during the charging process and its ability to withstand overcharging. Overcharging tended to be the main culprit for older EV fires.

To further improve safety, some EV Bus OEMs have fire suppression systems and other safety and monitoring systems installed on their vehicles. This helps to shut the vehicle down and alert the users of any unsafe conditions that may arise.

6.3.4 Charging times

In the passenger EV world, charging time is still seen as a negative characteristic of EVs. Similarly, in fleet operations it is essential that there is a high availability of the fleet, and charging time is also of a major concern.

Improvements have been made in terms of charging technologies from the days of slow, low power charging to modern, high power fast chargers. The chargers today address various factors that are essential to the operation of a fleet, as well as other operations that require the use of electric power as in UCT’s case.

There is a need for faster charging times, however this must be managed within the constraints of the power capacity that is available. In many cases higher power capacities are required for fleet charging applications than would otherwise be required. The peak electricity demands have to be monitored and managed to ensure that loading is limited during peak demand periods, while managing loads not to create new peaks during operation.

Modern charging technologies allow for these features to be incorporated within fleet charging infrastructure that make use of DC fast chargers (DCFCs). This has become the trend for fleet applications, where DCFCs are the solution that most large vehicle (Bus and Truck) manufacturers are

[6] It is not a matter researched in this study, but there is considerable reference in the media to the use of child labour, in dangerous conditions, for the mining of some of the battery materials in countries like the Democratic Republic of the Congo.

implementing, this combined with smart charging can alleviate many concerns regarding EV charging times.

6.3.5 Electricity grid impact

The inclusion of EVs in general increases the load on the current electrical grid at UCT. From a passenger transport perspective, large vehicles require higher power chargers for replenishing their high-capacity batteries. When compounded with the number of vehicles in a fleet, the electrical power consumption increases drastically to levels where historic peak power demands can be exceeded should the charging not be managed.

Unmanaged charging could lead to increased costs during peak power usage periods and could also result in grid stability issues. Increased investment in additional infrastructure for power distribution may have to be carried out by utilities to ensure that equipment present is not overloaded during operation. This will require close collaboration between the fleet owners and the utilities.

Fleet owners will also need to invest in local electricity distribution infrastructure to supply the charging stations. Generally, grid connection points to the electricity grid will increase from kilowatts to hundreds of kilowatts or even megawatt scales. This needs to be managed between the utility, such as City of Cape Town and the charging infrastructure owner to determine what grid impact studies would be required and to what detail, to minimize any downstream negative impact on the utility grid.

6.3.6 Repair & Maintenance workshops

With ICE buses maintenance and repair is readily accessible as it is a mature market and the technology is understood more widely and, in most cases, supported by the OEMs. There is greater understanding of the technology and Fleet owners usually have in house support with OEM or other specialist support being easily accessed.

EV technology is much newer and skilled service providers will need to develop. Most EV Bus OEMs do not have a South African facility, thus support in the event of break downs could become a challenge until the market matures. In the interim however, most OEMs include training as part of the offer to provide the user with necessary skills for the operation and maintenance of the vehicles.

Since UCT is not a fleet operator and does not have these skills available in their operations, an external service provider will be required. This could be a risk, as presently there aren’t many skilled service providers available to execute the required services.

This will require investment into the development of skills to work on the EV buses for the UCT operations. The University will have to determine whether this will be fit for its purpose of transition at this stage. These discussions will have to be had with the OEM when the project implementation is planned, as the present environment has minimal support for the technology.

6.4 Swot Analysis of transition to BEVs

Understanding the possible internal and external advantages and disadvantages is needed to make a more informed analysis of the business case. Having a holistic view on what opportunities and challenges UCT would face in acquiring an electric bus fleet is thus vital.

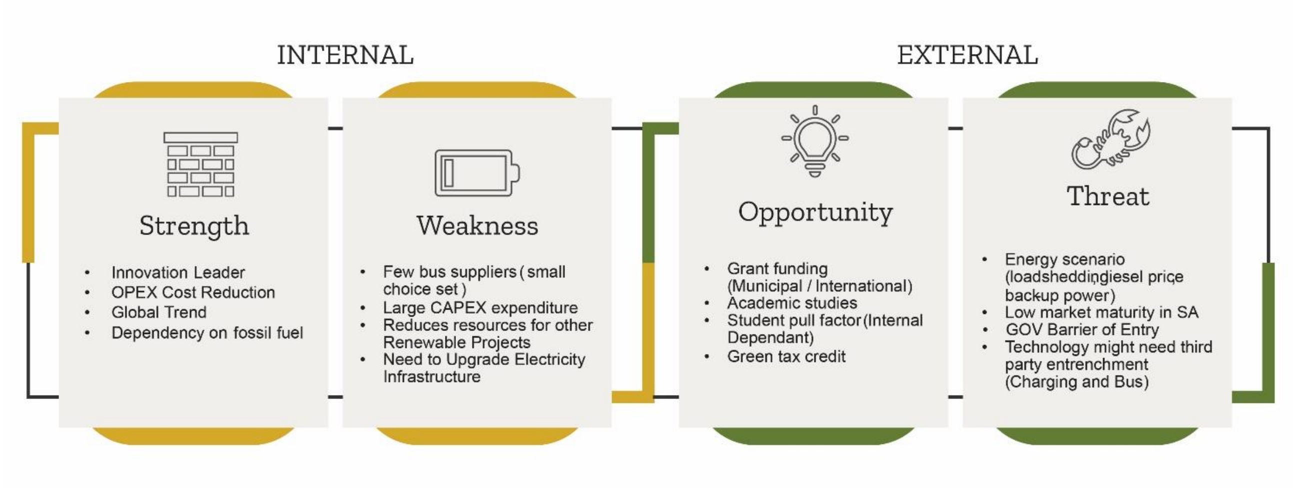


Figure 6-1: Swot Analysis

6.4.1 Strength (Internal factor and Helpful)

- Innovation Leader – UCT is one of the leading academic institutions in South Africa, Africa and globally. This Status is maintained through innovative projects of the University being at the forefront of global trends such as the adoption of EV vehicles globally. Academic research can be used to further develop the market.
- Operational Cost Reduction – There is a significant reduction in day-to-day cost due to the lower TOU electric tariffs and the cost of diesel per litre. This is a large reduction on operational cost for UCT as the current diesel buses consume almost 50000 litres of diesel per quarter. Electric vehicles have a lot fewer moving parts, which significantly reduces the service and maintenance cost of the vehicles although they are not without maintenance requirements.
- Global Trend – Electric Vehicles are on the rise across the globe and with an emphasis placed on mass transportation and carbon reduction, numerous bus fleets are transitioning to cleaner electric vehicles.

- Dependency on fossil fuel - Moving away from fossil fuel will help reduce UCT reliance on finite resource which is highly dependable on external global factors. This does caveat though in the means that the EV is charged, referring to Eskom reliance on “dirty power” or more sustainable renewable energy.

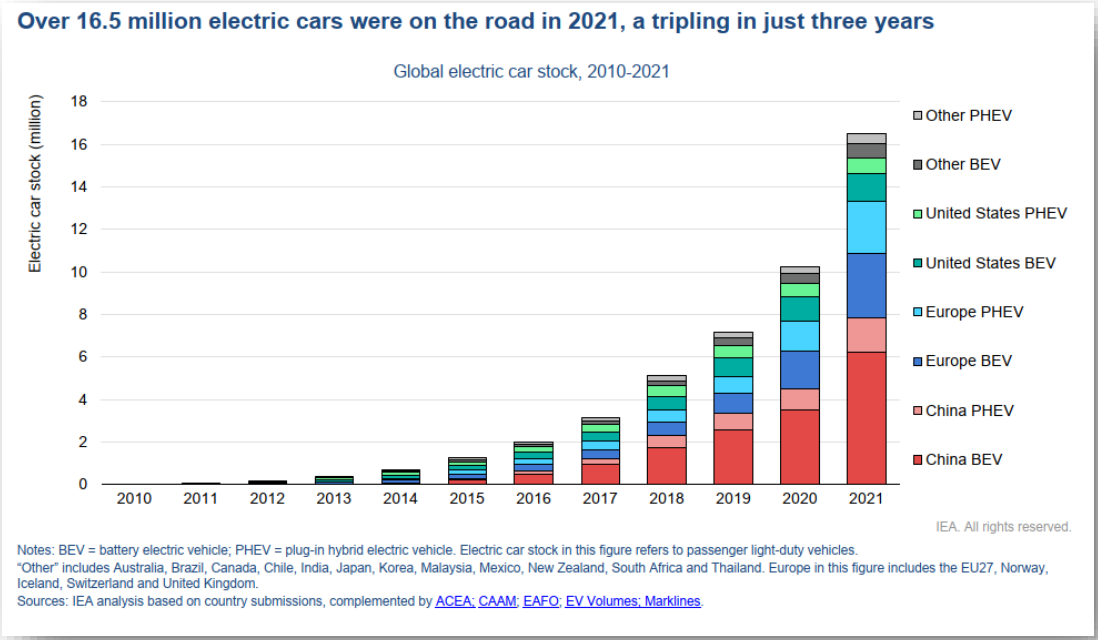


Figure 6-2: Global Trend EV[7]

6.4.2 Weakness (Internal factor and Harmful)

- Few bus suppliers – Currently all bus suppliers are international stakeholders as no part of the South African market is part of the value chain. These means that there are few bus suppliers to choose from that increase cost and dependency limiting the ability to shop around
- Large CAPEX expenditure – Due to international market being only suppliers UCT will be subjected to import cost and tariffs. This makes it the capital expenditure quite large.
- Reduces resources for other Renewable Projects – UCT has other renewable energy projects running and by investing large capital cost into a single project might harm funding for other renewable energy projects like load reduction strategies and PV solar and storage capabilities.
- Need to Upgrade Electricity Infrastructure – There might be the need to for electrical infrastructure upgrading at the new Foresthill holding area to be able to handle the charging load for the buses during the charging period.
- Grid Tied – The charging will be grid tie and with the current electricity challenges in South Africa, electrical redundancy should be supplied by UCT in order to ensure that service could be delivered independently of the external electricity supply if necessary.
- Grid Tied – The expectation of grid tied charging for the BEV’s, fed from the Municpal/Eksom grid, the energy genration mix currently in South Africa means that the emission in terms of CO2 is higher to generate the needed energy to charge the buses than the tail pipe CO2 emisissions from the diesel buses.
- Investment in appropriate skills development may be needed for adoption of BEV technology. Changes in operating procedures and disruption of current processes will require user buy in.

[7] (Global EV Outlook 2022 - Securing supplies for rlctric Futire, 2022)

6.4.3 Opportunity (External and Helpful)

- Academic studies – Having an electric fleet would help UCT build academic case studies on the use and impact of electric fleets. This can be in the any or all of the technical, environmental, social and governance arenas. Such an opportunitiy can promote further development with UCT academic and operational aspects overlapping.
- Student pull factor (Internal Dependant) – Having a fully operational and safe service that can operate on social and sustainable manner is a pull factor to potential students. The current fleet is highly utilised and provides students and staff with safe reliable transport for most of their day-to-day travel needs, alleviating parking, traffic congestion and need for single passenger vehicles. A battery electric fleet may add to the “attractiveness” on the basis of the novelty factor at this stage of the technology life-cycle in South Africa.
- Reducing Dependency on crude oil – If dependency could be reduced on global factors and combined with sustainable energy production and storage through a turnkey solution such as a large enough Solar generation and storage, UCT could reduce external global factors on operational cost.
- Future opportunities for grid stability when V2X[8] technologies are implemented.

6.4.4 Threat (External and Harmful)

- South Africa Energy Challenges – Currently South Africa is facing multiple challenges on the energy front. Loadshedding has become a day-to-day reality for most of South Africa. This lack of energy supply will impact a transition to an electric vehicle solution would be greatly impacted by this requiring UCT to ensure electricity redundancy through backup generators that would increase the need for diesel usage again.
- Global crude oil price – As mentioned in opportunity, UCT is affected by external global factors such as the crude oil price. OPEC decisions have direct cost impacts on UCT operational cost with no, and/or very costly solutions to mitigate that risk.
- Low market maturity in SA – The South African government has been slow to react to taking charge of the electric market value chain. The first green paper was introduced in May 2021 and has still not been presented or adopted by government. Multiple factors play a role in governments response. Reducing Ad Valorem tax and creating an opportunity for EV to reach parity with ICE could create larger demand and stimulate the market but by not doing anything and sustaining high import tax rates, government has become a barrier to the market maturity that will help private institutions.
- Technology might need third party entrenchment – Due to low market maturity and limited suppliers UCT could be entrenched by third party suppliers in terms of software solutions running on the required systems. This may lead to lack of choice, or opportunity, if the market does mature to more suppliers and more viable solutions. Discussing platform agnostic solutions with suppliers might be needed. (Charging and Bus)

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[8] V2X – Vehicle to Everything: Essentially technology that allow communication between vehicles and their surrounds and interacting equipment intended to optimise performance, efficiency and safety.

6.5 Misconceptions on Emissions

The overall emissions produced by traditional internal combustion engines and the energy needed to power an electric bus fleet, play a significant perceived beneficial impact factor in the switch between EV and ICE and the differences between them. Globally there are tax incentives and sustainability factors that help the drive factors for, or against, EV and ICE. UCT are limited by the South African parameters when it comes to two main factors as discussed below in terms of tax (capital incentives) and power generation (sustainability).

6.5.1 Tax/Capital Incentive

The South African Revenue Service dictates that Motor Vehicle Carbon dioxide (CO2) Emissions above a specified threshold deemed harmful to the environment are subject to the payment of an Environmental Levy if used in South Africa. The objective of the levy is to influence the composition of South Africa's vehicle fleet to become more energy efficient and environmentally friendly but at the moment is only applicable at the manufacture/purchase price of said vehicle.

These levies that are calculated at R132.00 per g/km CO2 emissions exceeding 95g/km[9] and are payable by the manufacturer of the vehicles in South Africa or when imported. This adds to the overall cost of the vehicles at purchase, buses included. This forms part of the overall cost and governments green paper (section4) on taxes that could possibly be targeted in lowering EV levy cost. The overall impact on this is that the day-to-day operations of vehicles on South African roads are not subject to C02 tax. There is thus no capital incentive for UCT in terms of emission on the day to day running of an EV fleet compared to an ICE fleet.

6.5.2 Sustainability

Any Electric Vehicle solution will have to factor in how much CO_2 is generated per kWh produced in South Africa[10] which hovers around a 1080 grams CO_2 per kWh sold. (1040 grams per kWh 2020[11] and 1080 grams 2021[12] which grew due to the substantial decline in efficiency in coal fired power stations in 2021). Due to South Africa's large dependency on coal fired power stations, as shown in Figure 6-3: Installed Capacity This greatly impacts the sustainability of energy production and all associated sustainability initiatives reliant on Eskom, grid tied electricity generation. The following calculation shows the emissions comparison.

The reader is reminded that whether ICE or BEV, the original fuel is sourced in the same way and is thus not accounted for here.

6.5.2.1 CO_2 Emissions Per km -ICE Vehicles (Diesel)

Diesel

Emissions per km (EPK)	=	Total CO_2 grams per Litre*Total diesel spent per km travelled
	=	2620*0.40
EPK	=	1048.00 g/km
UCT Total Annual CO_2	=	EPK * Total Annual km
	=	1048.00 * 566416.8 km (Standard and Midi Total)
	=	593.60 Ton CO_2 per year

Total Diesel Tied Annual CO_2 = 593.60 Tons CO_2

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9 (SARS, 2022/04/06)
10 (Eskom Integrated Report, 2020)
11 (Eskom Integrated Report, 2020)
12 (Eksom Integrated Report, 2021)

6.5.2.2 CO2 Emission Per km -Electric Vehicle (kWh)

Energy Grid Tied Standard

Emissions per km (EPK) = Total CO_2 grams per kWh*Total kWh spent per km travelled
= 1080*1.61(AVE over Standard buses reviewed)
EPK = 1738.80 g/km

Standard

UCT Total Annual CO_2 = EPK * Total Annual km
= 1738.80* 343937.8 km (Standard Total km)
= 598.03 Ton CO_2 per year

Energy Grid Tied Midi

Emissions per km (EPK) = Total CO_2 grams per kWh*Total kWh spent per km travelled
= 1080*0.88 (Mellor Bus)
EPK = 950.4 g/km

Midi

UCT Total Annual CO_2 = EPK * Total Annual km
= 950.4 * 222479.9 km (Standard Total km)
= 211.44 Ton CO_2 per year

Total Grid Tied Annual $C0_2$ = 809.48 Tons $C0_2$

From the EPK we can see that the the CO_2 generated per km is a good metric to measure for a basic comparison between EV and ICE. This calculation shows that grid tied EV solutions emits an additional 206.82 tons of CO_2 emission per annum compared with traditional ICE buses due to aforementioned factors. This highlights that switching over to any grid tied solution for electrical vehicles does not constiture a “greener” solution if certain criteria are not met. Carrying out the same calculation on an estimated Solar Generated power supply results in a significant difference (50 grams per kWh[13] for complete life cycle/value chain of solar panels, not storage. This is not inline with the ICE and EV complete lif)

Energy Solar produced Standard

Emissions per km (EPK) = Total CO_2 grams per kWh*Total kWh spent per km travelled
= 50*1.61(AVE over Standard buses reviewed)
EPK = 80.50 g/km

Standard

UCT Total Annual CO_2 = EPK * Total Annual km
= 80.50* 343937.8 km (Standard Total km)
= 27.68 Ton CO_2 per year

Energy Solar produced Midi

Emissions per km (EPK) = Total CO_2 grams per kWh * Total kWh spent per km travelled
= 50 * 0.88(Mellor buses reviewed)
EPK = 44 g/km

Midi

UCT Total Annual CO_2 = EPK * Total Annual km
= 44* 222479.9 km (Midi Total km)
= 9.78 Ton CO_2 per year

Total Solar Charged Annual $C0_2$ = 37.46 Tons $C0_2$

[13] https://www.world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity.aspx

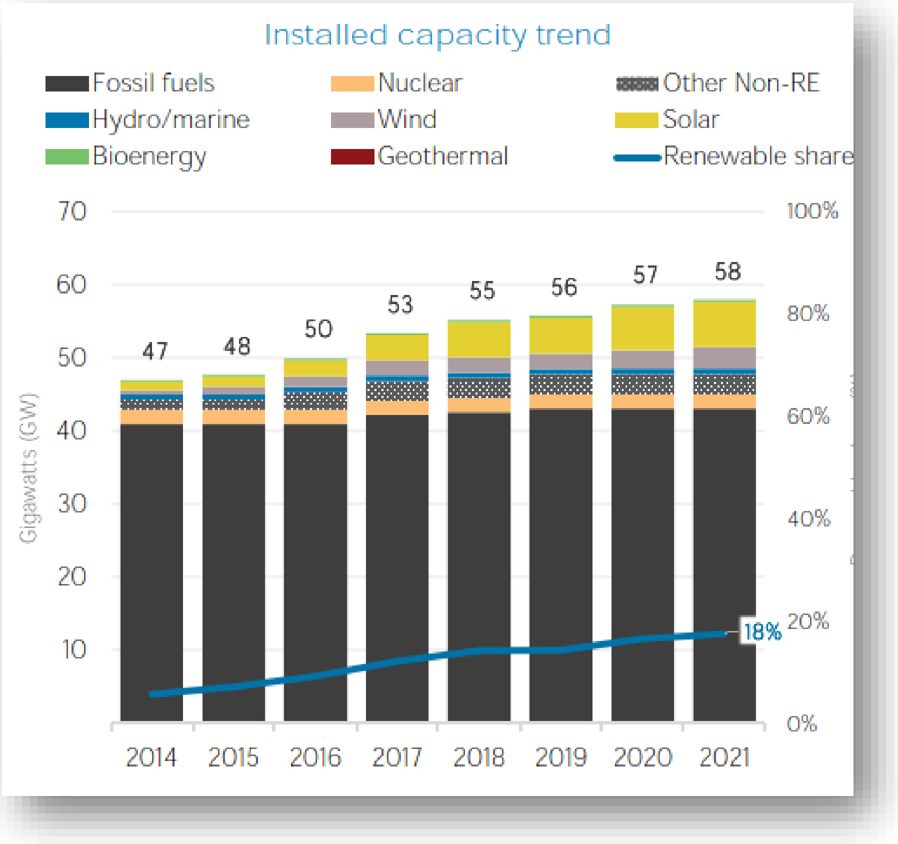


Figure 6-3: Installed Capacity[14]

This calculation shows that by introducing a renewable energy source that will deliver the full charge of the electrical needs of the BEV will achieve 37.46 CO_2 tons per annum. This greatly reduces the CO_2 emissions to 1/15th of diesel emissions and 1/20th of grid tied/Eskom power generation.

6.5.2.3 Energy system challenges

The South African energy grid has been under major stress for many years, this stress has not yet been alleviated. While the country grapples with the effects of insufficient electrical energy availability, Government has indicated plans to help recover the energy deficiency in various publications. The Integrated Energy Plan (IEP) document mentions plans for sustainable power supply and transition of the energy grid to address the energy situation with various scenarios being considered. In this document There is mention that EVs will only make a significant contribution after 2030.

There is mention of increasing the generation assets with additional nuclear generation capacity. With coal still being a commodity that this widely available in South Africa there is mention that the reliance on coal will continue in the long term, with cleaner technologies being investigated in line with international research and experience.

While the inclusion of Nuclear will improve on the emissions numbers and energy availability for grid generated electricity, this technology comes with a high cost. In the interim lower cost clean alternatives are being investigated, however, it seems that the idea of a later implementation of nuclear will probably be realised in the long term.

Presently, Eskom's generation fleet is under pressure with several coal powered power stations reaching the end-of-life stage. While some of the stations are being refurbished to extend their operational lifespan, there are plans for decommissioning of identified assets as per Eskom's Medium

[14] (South Afica Energy Profile 2021 - International Rewewable Energy Agency, 2022)

term system adequacy (MTSAO) 2022 report. It is expected that there will be 5.288 MW of generation capacity removed from the grid between 2023 and 2027.

While this could improve the emissions outlook in terms of reduced coal emissions from older technologies, further investments in renewable energy on a large scale will be required to replenish the reduction of coal-powered generating assets, while also addressing the needs for additional capacity for industrial and other applications with the South African context. There is however a positive outlook that the country will increase its renewable energy capacity, and this will improve the emissions outlook for grid generated power in the long term.

7 Costing of Business Case

The SWOT analysis highlighted the broad range of considerations influencing the decision whether to pursue an EV solution, including issues such as UCT's strategic intent and its green agenda. But a foremost consideration is the financial implication of the selected option. If more expensive, then the strategic benefits need to be weighed up against the cost premium paid.

Figure 7-1 depicts schematically how the cost of the EV vs. ICE options was assessed. On the left, the starting point is that either option must deliver the same output (level of service) as achieved by the current UCT bus operation. The same routes, bus frequencies and bus capacity (vehicle size) are provided. This is not controversial, because as demonstrated previously, the EV buses can indeed technically deliver the required output, i.e. more buses or a different mix of large vs. midi buses is not required.

Whichever bus technology, the same real (present-day) business sustaining cost (overhead) will apply, and even if the overhead amount changes, it will therefore not affect the relative costing of EV vs. ICE.

The same principle applies to the common bus terminus infrastructure. Although operations will be consolidated at two locations (North Stop and Forest Hill) with related improvement in facilities, as a starting point, the same facilities are required for both bus technologies. However, in addition, the EV solution requires charging infrastructure, including in the case of Forest Hill back-up power generation to overcome inadequate power supply there. Such EV-specific infrastructure costs are added to the EV costing.

As regards the fleet, the same fleet size and mix applies for both options. But there is a purchase price differential, with EV buses costing somewhat more than ICE equivalents. And the two technologies also have quite different energy carrier supplies (electricity vs. Diesel) and which confer different energy cost requirements. These bus purchase price and energy requirements are at the heart of the comparison between the EV and ICE options.

All the above common and technology-specific costs are aggregated and compared per EV and ICE solution. This can be done by financing the buses in two ways, either as up-front purchase or amortised through an operational lease over a longer timeframe. Leasing is the current arrangement and also the preferred option for UCT going forward. The two financing approaches give essentially the same relative cost answers, but the option with the highest bus cost also incurs a relatively larger interest component in its lease rate so that its relative cost is then higher.

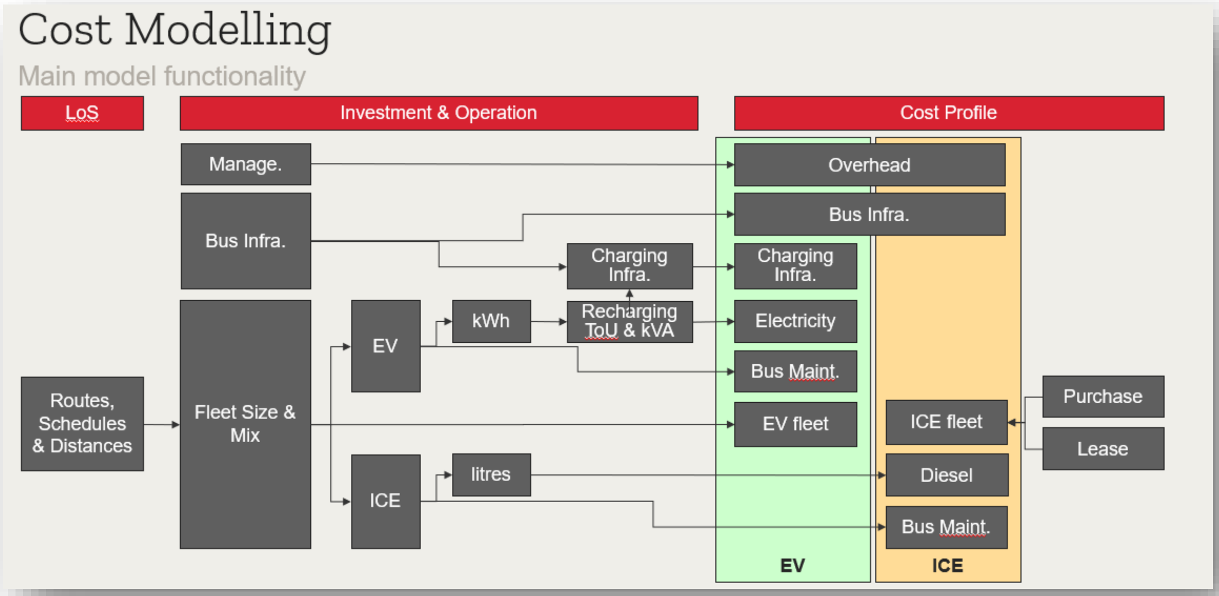


Figure 7-1: Holistic Costing Model

7.1 Fleet Selection

Operations are currently conducted with 18 standard and 9 midi-buses, and this arrangement is also the basis for comparing the EV vs. ICE energy platforms. The vehicle options were previously presented in section 3.1, where it was confirmed that all makes, and models considered comply with the required technical performance specifications.

The EV bus purchase prices are shown in Table 7-1. These are indicative prices as provided by the OEMs. The comparative ICE Scania (standard) and Marcopolo Volares (midi) prices are R3.1 mill. and R 1.5 mill. respectively. The EV buses have a wide price range, but throughout are noticeably pricier than the ICE equivalent.

Table 7-1: EV Bus Purchase Prices

Size	OEM	Model	Price (R mill.)
Standard	BYD	Type D School bus	8.000
	Yutong	E12	10.000
	Mellor	Sigma 12	12.230
Midi	Mellor	Model Sigma 8	8.720

In the business case cost estimation, the large BYD EV and the [first Yutong model] (which has a slightly longer battery life) were assumed on a rough order of magnitude amount due to uncertain pricing models, which is an assumption of achieving EV prices at the lower (optimistic) end of the price spectrum.

7.2 Terminus Infrastructure

The infrastructure requirements, lay-out and design considerations were previously discussed in section 5.1.

Accordingly, Table 7-2 shows the estimated capital expenditure outlay. The table firstly distinguishes the terminus locations at Forest Hill (midi buses) and North Stop (standard buses). Some of the terminus improvements are common to the ICE and EV operations, but then there are EV-specific requirements related to the power/recharging requirements and the housing of such. For Forest Hill, the cost differential is roughly the cost of two midi EV buses and for North Stop the cost of one large EV bus.

Table 7-2: Terminus Facility Investments (R million)

Terminus	Component	Common	EV-specific	Tot. EV	Tot. ICE
Forest Hill	Structures		2.0	2.0	
	Civils	0.2		0.2	0.2
	Power Supply	2.0	2.5	4.5	2.0
	Recharging		5.0	5.0	
	Total	2.2	9.5	11.7	2.2
North Stop	Structures		1.0	1.0	
	Civils	0.2		0.2	0.2
	Power Supply	1.0	2.0	3.0	1.0
	Recharging		5.0	5.0	
	Total	1.2	8.0	9.2	1.2
Totals for Both Stops		**3.4**	**17.5**	**20.9**	**3.4**

7.3 Cost of Electrical Usage Requirement

The charging requirements and implications for the design of the terminus facilities were previously discussed in section 5.1. The deployment of the fleet across the routes imply that buses are available (parked) for charging as indicated in Figure 7-2 (standard buses at North Stop) and Figure 7-3 (midi buses at Forest Hill). Importantly, during the electricity off-peak price TOU (time-of-use) slots, as shown in section 5.2.2, the whole fleet is stabled and available for recharging. If required, however, through the day, at least some buses are free for a battery top-up. Each coloured box indicates a separate bus and the hours that they are available for charging. The green line indicates a peak time for possible solar charging, and as indicated in the two graphs, they do not coincide with the optimal charging time and thus do indicate the need for electric battery Storage, as discussed in the section below.

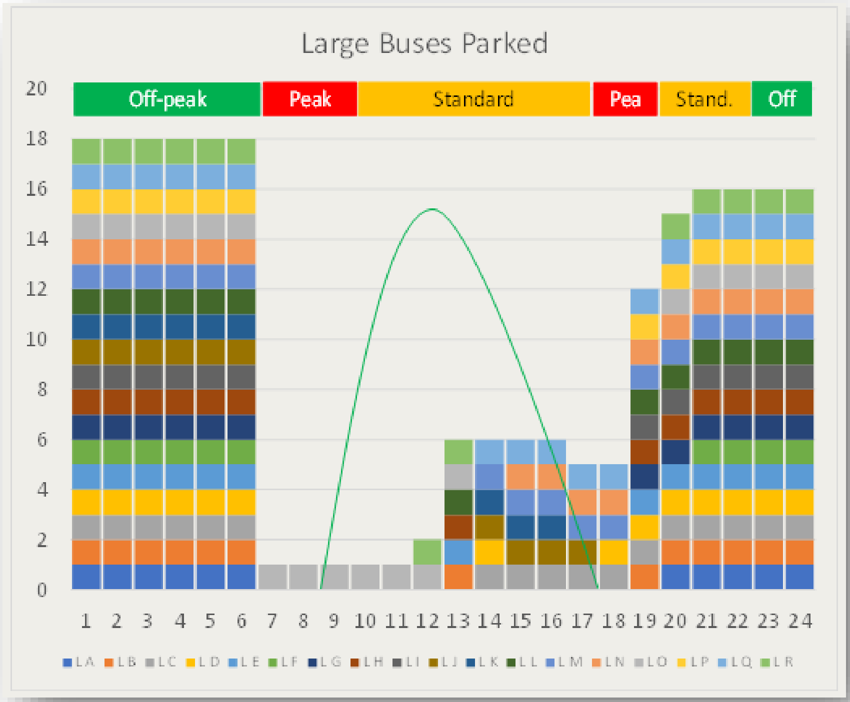


Figure 7-2: Number of Standard buses Available for Charging over 24 hrs (weekday)

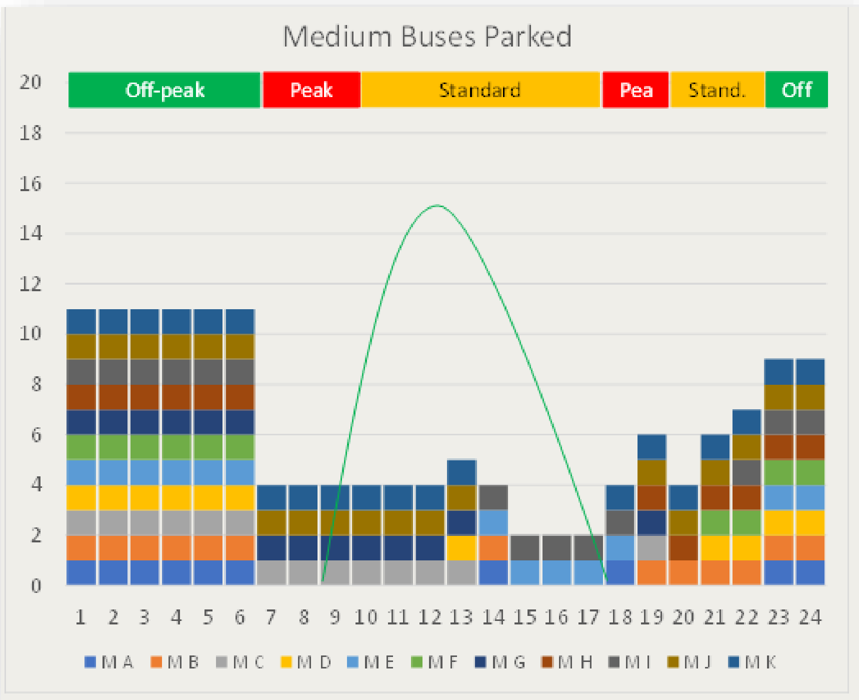


Figure 7-3: Number of Midibuses Available for Charging over 24 hrs (weekday)

The average daily energy requirement would be in the range of 2.9MWh to 3.3MWh, having taken into account weekday vs weekend schedules.

For interest, a typical photo-voltaic irradiance pattern is shown (the green curve) indicating that real-time PV availability is highest when buses are operational – which obviates the potential of PV charging except if backed up by a Battery Energy Storage System (BESS).

When considering renewable resources there are various requirements that need to be considered, including technology to be used, location and effectiveness through the year. Solar PV is the most used technology that is seen as a solution for most energy grids, mainly due to the pricing and affordability, however, this also brings up environmental concerns in the longer run.

Generally, a combination of solar and battery storage is seen as the most effective method of maintaining electrical continuity to loads. For the purposes of this study, renewable resources were excluded, however a high-level analysis to determine the Solar PV requirements was carried out with the following high-level results for North Stop, based on the existing fleet size. BESS was based on the use of existing Lithium-Ion Battery technology.

Table 7-3: North Stop Renewable Energy Estimation

Number of Buses	Estimated daily power consumption	PV Rating	BESS rating
9	978.912 kWh	2 MW	1.5 MW, 4MWh

The estimated cost for the PV solar is R40.322m, while a BESS will cost in the region of R97.5m. The estimated rooftop space required for the estimated power is 14,286 m^2.

For the application at Forest Hill, where the standard buses will be located, the following high-level estimation has been carried out.

Table 7-4: Forest Hill Renewable Energy Estimation

Number of Buses	Estimated daily power consumption	PV Rating	BESS rating
18	2.769 MWh	5.5 MW	3.5 MW, 4MWh

The estimated cost for the PV solar is R 111.078m, while BESS will cost in the region of R292.5m. the estimated rooftop space required for the power above is 39,286 m^2.

The above estimates require huge space and capital expenditure, alternatives such as partnerships with Independent Power Producers (IPP) and possibilities of wheeling power over the network should be considered if the will to transition to renewable energy supply is present.

7.4 Phase Expenditure

Whereas the spending on the fleet and terminus infrastructure happens up-front, the ongoing operations take place over nearly a decade. The backdrop macro-economic environment therefore needs to be projected specifically for unit operating costs that could inflate faster/slower than the general norm. Accordingly, Table 7-5 shows the inflation scenario applied. A general baseline inflation rate of 5%/annum is assumed, with key unit rates deviating from that. It is assumed that the diesel price, which is at an historic high presently, will not increase at the same differential as ESKOM-linked tariff increases. The bus price differential is included as it affects the end-of life terminal value. The interest rate (for lease purposes) is assumed to remain at the current premium above inflation.

Table 7-5: Inflation Base Rate & Deviation

Inflation	Common
CPI (Base)	5%/ann.
Vehicle differential	+3%
Diesel differential	+2%
Electricity differential	+5%
Interest rate above inflation	4.45%

The detailed assumptions about operational expenditures are listed in Appendix C. In summary:

- Bus management overheads (including driver salaries) have a starting value of R 1.8 mill/month
- Facilities (terminus) operating, and maintenance cost is around R 80,000/month, with an additional R 70,000/month for the EV solution
- Electricity cost (for EVs) is about R 60,000/month and diesel (if ICE) is about R440,000/month
- Service cost (including tyres) fluctuates because of different service interventions and frequencies, but is around R144,000/month for the EV option and R493,000/month for ICE.

7.5 Bus Financing

UCT's preferred bus acquisition approach is to obtain the bus fleet, not via outright up-front purchase but rather by means of an operational lease as is used for the fleet presently. A lease introduces a third-party financier (lessor) who acquires the buses itself and makes them available to UCT (lessee) at an amortised cost spread over several years. An "operational" lease (as opposed to a "financial" lease) implies that ownership and related accounting privileges/obligations remain with the lessor, and the parameters of the lease must therefore fall within the scope of an operational lease (the lease term must not exceed 75% of the expected life of the asset, and the net present value of total lease payments must be less than 90% of the asset purchase price).

As is the case presently with the Bidvest lease, the lease will be in the form of a full-maintenance lease. UCT will have the obligation to operate the buses according to proper operational standards, including the checking of lubricants, tyres, etc. UCT will also arrange the maintenance and based on the prior approval of such by the lessor, the lessor shall pay for the reasonable repairs and maintenance required.

For the cost comparison, essentially the same lease conditions are assumed as currently apply to the Bidvest lease arrangement. In the absence of more precise information about EV vehicle availability it is not yet possible to test the market on whether more advantageous lease conditions may be extended to EVs (although this may be possible given the green premium involved). The key terms assumed therefore are:

- Lease terms of 9 years
- End-of-term residual value of 20%
- Interest rate of 9.75% (current prime rate).

The calculation of the resultant lease rate is shown in Appendix C. For a standard bus, it amounts to R123,000/month for EV vs. R 38,000/month for ICE, and R 107,000/month for EV midi vs. R 18,000/month for ICE midi.

7.6 Total Financial Cost Compared

The total cost of each bus technology option is the sum of the various cost components discussed in the previous sections incurred over the analysis period. This period is set at 9 years, which is the duration of the leases of the existing ICE fleet (before the lease term was extended). Because this period is shorter than the expected useful life of the bus, the calculation provides for a terminal value which may be thought of as a potential income from the sale of the bus at that point. To compare like-with-like the bus life (and therefore contribution of terminal value) is assumed the same for EV and ICE, but since there is a potential for the EV life to be longer than ICE, the effect of extending the EV life (and increasing its terminal value) is tested in section 7.7). As long as the bus lives are the same, then changing the analysis period (the 9 years) does not affect the relative cost of the EV vs. ICE options.

The expenditure is not the same every year. At the outset, there is infrastructure and bus capital expenditure. During the operating life there is inflation (inflation in general but also differential inflation between diesel and electricity) and differing vehicle-related spending (maintenance and tyres, but not batteries since battery replacement falls outside the analysis timeframe). To have a single comparative number for each of EV and ICE, the uneven stream of costs is collapsed to its net present value (NPV). The discount rate applied to reduce future costs to the 2022 base year is 10%, which is roughly the same as the medium-term risk-free interest rate in South Africa.

Figure 7-4 presents the comparative NPV values and also shows the constituent cost categories, with the bus values shown on a purchase basis. It is clear that the initial fleet acquisition cost dominates the result. In the case of EV, the bus cost makes up 69% of the total, i.e., the sum of the “Bus Purchase” and “Bus Terminal Value” components in the graph. For ICE, the share is only 26%. The next most prominent cost components are the “Energy” (diesel) and “Service” (maintenance) costs for ICE, in which areas EV operations are substantially more cost competitive. Overall, the EV option is 42% financially more costly than ICE.

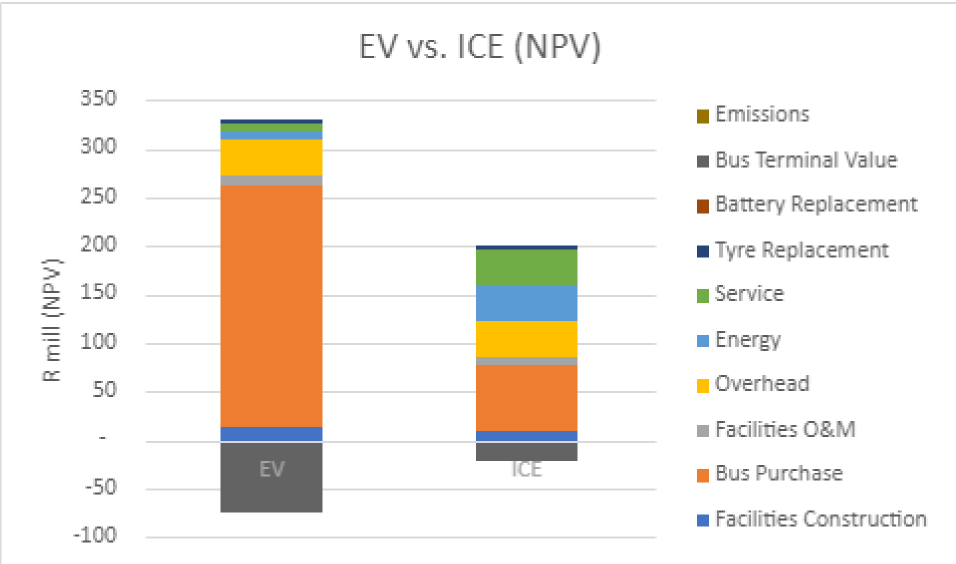


Figure 7-4: EV and ICE Total Cost Profile, Purchase Basis (NPV, R mill.)

Accordingly, when stripping out the bus cost, Figure 7-5: EV and ICE Operational Cost Profile, Purchase Basis (NPV, R mill.) shows that once the EV fleet is in place, it is more than a third less costly to keep on the road. However, because the up-front EV bus price (Table 7-1: EV Bus Purchase Prices) premium is so large, the annual operational savings do not cause an inflection point where the total ICE cost overtakes the total EV cost in a reasonable timeframe.

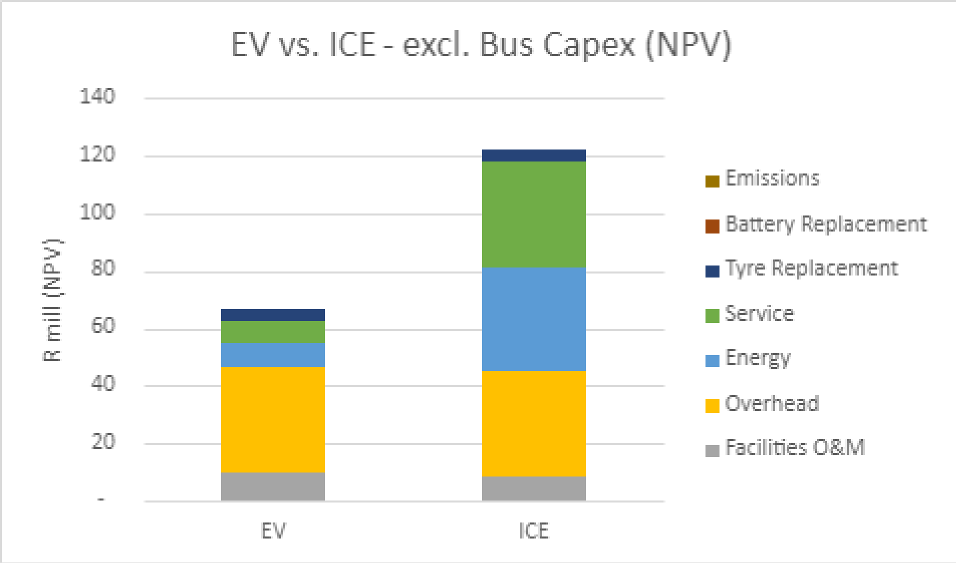


Figure 7-5: EV and ICE Operational Cost Profile, Purchase Basis (NPV, R mill.)

Figure 7-6: EV and ICE Operational Cost Profile, Lease Basis (NPV, R mill.) represents the total cost result, but in this case calculated on a lease basis (i.e., the buses are not purchased up-front but leased for the analysis period). Although the cost structure is quite similar as before, in this case EV is 49% financially more costly. Its increased costliness is because of the higher interest amount (within the total lease rate) paid on the more expensive EV buses.

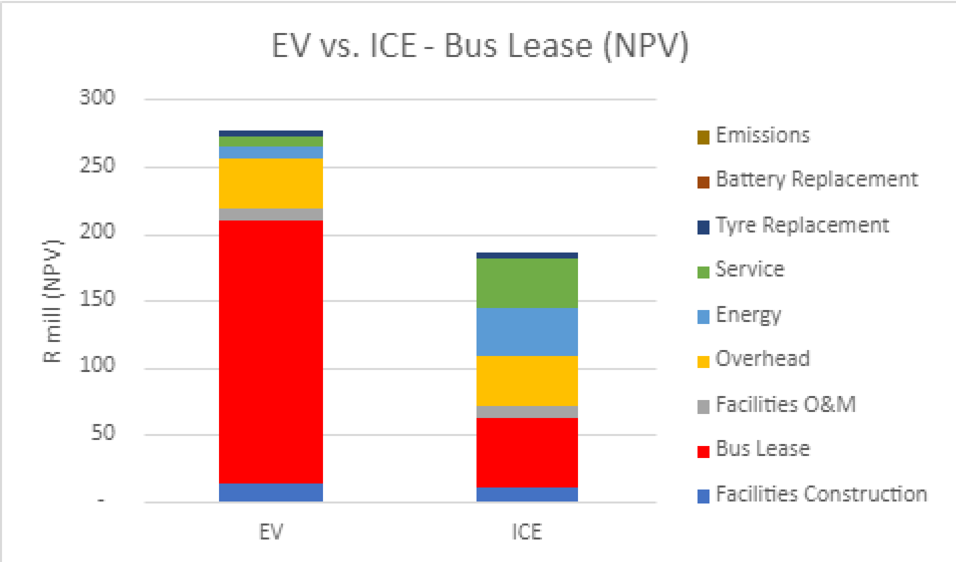


Figure 7-6: EV and ICE Operational Cost Profile, Lease Basis (NPV, R mill.)

Figure 7-7 presents the annual EV vs ICE cost profile, based on the leased approach. The initial facility investment to accommodate EV is slightly higher than for ICE (light green area vs. yellow bar). Thereafter, the annual EV running cost (green area) is substantially lower than for ICE (light orange bars). However, the higher up-front cost of the EV buses translates into a higher lease rate (dark green area vs. Dark orange bars) to the extent that the overall EV costs exceed the ICE costs. The years that the difference is smaller is because of the timing of major ICE maintenance services.

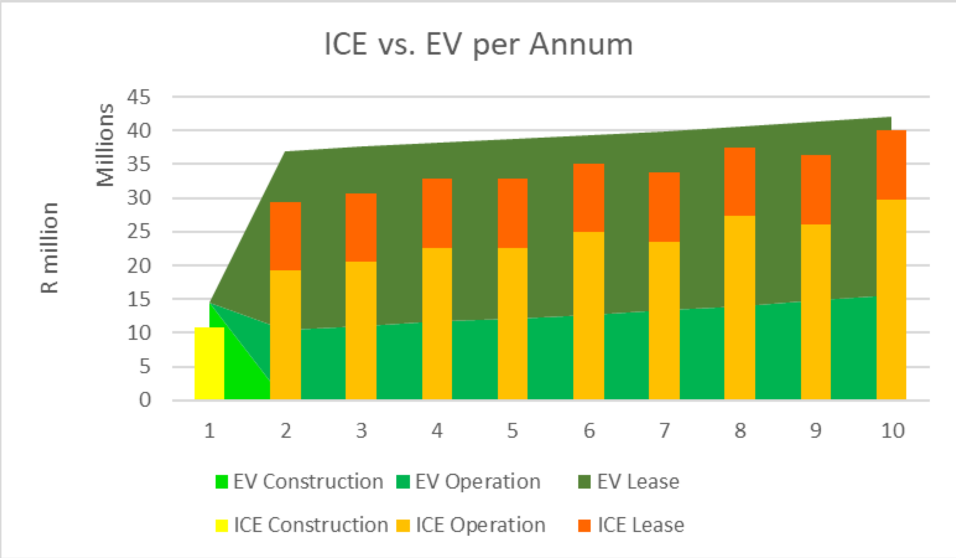


Figure 7-7: EV and ICE Annual Operational Cost Profile, Lease Basis (R mill).

7.7 Sensitivity Analysis

The calculations presented above wrap together a variety of performance and cost assumptions which are quantified at roughly a pre-feasibility level of reliability. As long as the future actual numbers change synchronously, the relative costs and the financial preference for ICE will remain. But it should be tested how resilient the ICE preference is if costs were to change more variably.

The key cost drivers are shown in Table 7-6. Two rounds of sensitivity testing are done:

- The first tests a reasonable deviation from the original assumption per cost driver. So, the assumption is increased/decreased by 10% to see the effect of the assumption being a little higher/lower than expected. A 10% test is a typical reliability range. Where a percentage change is not possible, then a unit of input (e.g. one bus, one year) is tested. These tests are carried out one-by-one and quickly show which assumptions have the most leverage on the overall outcome.
- The second tests the extent to which the assumption needs to change to equalise the EV and ICE cases. It is therefore not constrained to the selected percentage, but allowed to change until changing that one assumption gives indifferent results (i.e. EV and ICE are the same).

The question being asked is whether the EV cost can plausibly drift into the ICE cost range so that the relative cost premium disappears. The starting point is therefore the 42% premium under the bus purchase and the 49% under the bus lease approach. The first round of testing (e.g. 10% increase/decrease) is shown in the column headed “Factor” and the effect on the cost premium in the “Ratio EV/ICE” column. For example, increasing the distance (km) operated by the fleet changes the EV/ICE ratio from 42% to 37%. In other words, 10% more distance reduces the EV premium paid by 5 percentage points.

The second round of testing is to determine how much the individual driver itself would have to change to erase the cost premium. The required change is shown in the "Break-Even Factor” column. In this case, the distance operated would have to increase threefold for EV to equalise with the ICE alternative.

Table 7-6: Sensitivity Testing

Input	Factor	Ratio EV/ICE	Break-Even Factor
Purchase Approach		+42%	
Term Days	+10%	+37%	N/A
Distance Operated	+10%	+39%	x3 times
Facilities Construction	-10%	+42%	N/A
Bus Fleet (No of each)	-1	+38%	N/A
EV Bus Purchase Price	-10%	+32%	-40%
Electricity Tariffs	-10%	+42%	N/A
Diesel Price	+10%	+39%	x2.5 times
EV Bus Life	+1	+36%	doubled
Lease Approach		+49%	
EV Bus Life	+1	+44%	N/A
EV Lease Term	+1	+42%	N/A
EV Lease Interest Rate	-10%	+45%	N/A

The result of the first tests (moderate changes) is that the cost premium indeed reduces somewhat, but always less than the change in the factor tested (a 10% change leads to a less than 10% change in the premium). The second tests show that substantial – and quite unrealistic – changes are required in factors individually to achieve cost parity.

In the initial analyses, it seemed possible to obtain EV bus prices which were not significantly higher than for ICE buses. Finally, though, based on factors such as high midi-bus costs, it became clear that the EV bus premium could not be wished away. So, whereas it initially appeared possible to construct a scenario of a combination of factors working together to make the EV cost competitive, this is not possible in the final analysis.

8 Scenario Mapping

This section aims to come up with three prospective scenarios that the University of Cape Town could follow in order to ensure that the institution stays ahead of a growing global curve. It is undeniable that the market is shifting to reduce reliance on ICE for modes of transport and globally Battery Electrical Vehicles are the most advance in terms coming to mass production.

The transition to alternative energy sources such as electricity for modes of transport is on the rise is unlikely to be regressing to ICE in future. This assures that there are some measures that UCT should take in order to future proof the institution to a global trend that is shifting to a more electric powered market.

- The market transition to EV will happen in future and the South African Market is changing (slowly).
- Future Proof Infrastructure – This will allow UCT flexibility in terms of their options in each scenario.
- Globally, countries are commiting to ending the sale of ICE vehicles which are thus expected to become less available over time due to the global trend of phasing out ICE sales in the medium to long term future.
- Technology improvements promoting the use of EVs going forward.

8.1 Full Transition to EV: All out approach

This involves a full transition whereby UCT goes to market, based on the costing model presented and gets favourable terms and rates from the vendors and financial institutions.

8.1.1 Positives

- Leading in the technology implementation front.
- Understanding the technology and way forward.
- Large reduction on carbon footprint based on current fleet output if the renewable enrgy charging stations, such as solar with storage capacity, can be secured. This factor turns to a negative if grid tied.
- Lower Operational cost in running the fleet (Maintenance and fuel)

8.1.2 Negatives

- High cost of implementation will require funding models that will need to be further investigated.
- Electrical grid impact should the necessary upgrades not be implemented. City of Cape Town restrictions on existing electrical infrastructure for upgrades.
- If the charging stations are grid tied then the emssions of a full fleet swap will be larger than the current ICE fleet

8.1.3 Dependencies

- Availability of vehicles that meet the requirements for the application.
- Existing infrastructure from the City of Cape Town to support upgrades, especially in the Forest Hill application where there are no high-capacity connections present.
- Cost competitiveness and finance options to go forward with the project would be needed making it dependent on approval for additional funding received for intial capital expenditure.

8.2 Semi-transition & Extend lease

This scenario will be a hybridized approach to the transition towards the EV technology. This will take the approach of using EV and ICE technology together and will allow the user to make investments as required for a smaller fleet. With ICE buses usually being specified to operate for 1,000,000 kms, the existing fleet will have to be assessed to verify whether they are suitable to be kept in service for a few more years at least up until 2030. This will have the positive effect of not requiring new buses and possible carbon reduction in terms of that.

UCT is then able to trial and become familiar with the requirements of the EV technology. The learning will allow for future replacement of the ICE fleet with practical experience with BEV vehicles.

8.2.1 Positives

- Maintaining the leadership role in EV application for tertiary institutions in SADC.
- Transitioning into the EV landscape and understanding the requirements going forward to full transition.
- Putting into place the basic infrastructure, systems and understanding for transition to EV technology.
- Operational experience with EVs and identifying bottle necks that can be addressed when the fleet sizes systematically increases.
- Fewer vehicles will not require large investment in electrical infrastructure changes in the short term (e.g. Modular charges)

8.2.2 Negatives

- Possibly not meeting the requirements for accelerated carbon neutrality.
- Economy of Scale – Ordering fewer buses would increase the cost significantly from manufacturers that work on scale. An off-the-shelf option would be only option.

8.2.3 Dependencies

- Partnerships and possible funding structures to facilitate the semi-transition.
- Electrical infrastructure availability to support the smaller scale charging loads.
- Cyclability of the EV buses that are included in the fleet.

8.3 Status Quo: Waiting for Market Maturity

Keep the existing fleet as is, however, where infrastructure changes are being carried out changes will have to be implemented for the transition of technologies going forward. Make provision for charging stations and other infrastructure. With ICE buses usually being specified to operate for 1,000,000 kms, the current fleet will have to be assessed to verify whether they are suitable to be kept in service for a few more years. This will have the positive effect of not requiring new buses and possible carbon footprint reduction in terms of that.

8.3.1 Positives

- No need for new buses, thus not adding to the impact that new ICE vehicles may have on the environment.
- Provision is made for new technology to be implemented in the future.
- Market should mature offering options in the South African Market
- Give opportunity to invest in other sustainable energy projects Load reduction Strategies/ Solar Power investment.

8.3.2 Negatives

- Possibility to not be seen as innovation leader to other institutions that may adopt EV technologies before UCT.
- Could increase maintenance budget
- Dependency on fluctuating diesel prices

8.3.3 Dependencies

- Will to move forward with the changes.
- Market to mature in South Africa
- Energy security – South Africa moves to more secure and reliable energy transition (No Loadshedding)

9 Final recommendations

The change to EV for mass transportation is inevitable. The present climate which has fuel prices at an all-time high is a driver for most people to consider alternative fuel sources for mobility. With the present electricity costs at a more stable price in comparison with fossil fuels, transition to EVs is bound to be accelerated soon.

UCT could use a few approaches to facilitate the transition and develop a leading position in EV transition in its sector.

Since diesel buses are generally specified with a 1,000,000 km lifespan, and this can be achieved should proper servicing and maintenance be carried out, the existing fleet could be retained until a stage that the EV technology matures. This can provide an opportunity for a test / experimental transition to the EV technology to be introduced with minimal investment.

UCT can consider partnering with OEMs for bus and charger infrastructure to garner support for the transition with preferential pricing and technical support. This will require communication of the University’s intention to transition to EV technology with large players in the sector. Once support is gained, this transition or study thereof could be accelerated towards a partial transition which will provide the foundation for a larger scale deployment of EV buses into the fleet.

Presently, the technology for transportation and charging is available and can be implemented. This will however require a significant once off investment for infrastructure related to EV charging. However, the preparations for the infrastructure implementation can be planned with the future transition in mind and can be implemented in a phased manner.

Considering an incremental transition commencing with only a few EV buses, the following can be considered. Since charging stations are available in modular designs that can be upgraded as and when required, the possibility of using the North Stop for a few standard EV buses should be considered. This function, in conjunction with exploring other, renewable energy sources alternatives such as partnerships with Independent Power Producers (IPP) and possibilities of wheeling power should be incorporated in medium to long term planning to ensure more environmentally friendly outlook

The EV buses can be integrated into the fleet to provide a training ground for operations and management resources alike. Scheduling and operation of the new technology vehicles will give the existing resources an opportunity to become future ready.

10 Implementation Strategy

Some infrastructure investments are already being undertaken to rationalise the UCT bus terminus arrangements, and to centralise these at two locations. Appropriate accommodation of charging facilities is provided for, and these can be activated at the time a decision is made to convert to an EV fleet. The infrastructure activities will therefore continue and remain unaffected whatever the ICE vs. EV decision is in the short term.

The assessment presented in this report is that although there are many considerations supporting the switch to EV, currently it is not financially prudent especially given that EV buses are not yet commoditised locally, and they have a high-ticket price. But the general view is that the horizon is not that distant for these drawbacks to resolve. So, the EV implementation strategy is all about managing the situation up to the horizon event.

There are three main considerations in this period:

- There is some speculation about when the technology tipping point will occur, i.e., when EV economics will trump that of ICE. This point probably relates more to commercialisation factors than improvement in EV technology itself, specifically when the local EV bus supply system develops some economy of scale and EV buses become off-the-shelf items and the financial package becomes commoditised. This situation is not imminent but is at least expected within the next decade.
- The lease on the current fleet has already been extended, but the utilisation rate has been moderate and physically the current ICE buses are expected to be able operate until around 2030. The financing arrangement will have to be refreshed or restructured, but the fleet should be capable to serve well into the horizon period.
- The current bus lease was originally for seven years and then extended by another two years. Nearly a full lease cycle may therefore be squeezed into the horizon period.

The proposed strategy is therefore to make an interim arrangement to secure the continued use of the existing ICE fleet after expiry of the current (extended) lease. This would “buy time” and move the ICE vs. EV decision on to about 2028.

In the meantime, UCT should continue to monitor EV developments for major changes or opportunities. There are bound to be opportunistic openings to introduce an individual vehicle in the fleet (e.g., consider the second-hand EV buses on offer by BYD which may be purchased by the City of Cape Town), or where an academic initiative may lead to the need to experiment with EV. From a fleet management perspective, these opportunities do not need to be actively pursued, but just reacted to when they arise and incorporated into operations if appropriate.

It is acknowledged that five or six years from now UCT will find itself in a risk period where the current fleet condition may become physically poor, and the local EV supply system is not yet properly in place. Circumstances at that point will dictate how to proceed, but the fall-back option would be to engage in another seven-to-nine-year ICE supply cycle.

Figure 10-1 shows a framework for moving from the current diesel to an electric bus fleet in line with the above approach.

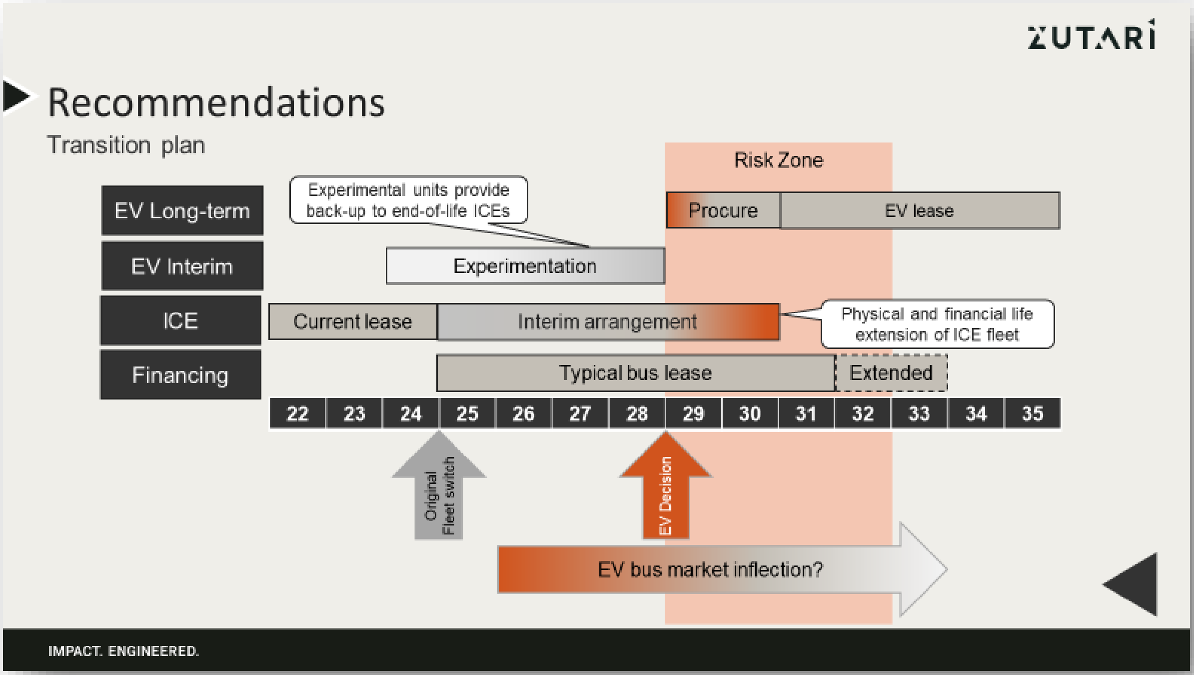


Figure 10-1: Schematic representation of Business Case recommendation.

In terms of the practical steps that are required now, Appendix B gives an overview of the UCT procurement landscape. Three procurement packages are foreseen, package A for the bus fleet itself, B for charging and C for terminus infrastructure.

10.1 RFP Document Incorporating specs

As noted, before, package C (terminals) is proceeding in any event, independent of the ICE vs. EV decision. Design inputs have been made for that contract, including determining the battery limit for EV charging and reserving the required charging space.

Package B (charging) has been broadly described in this report. The technology is stipulated to be competitive in that it is not bespoke to a specific supplier and is also not attached to a specific bus manufacturer. Procurement would proceed when the decision is made to proceed with EV.

10.2 Draft Lease Agreement

Package A (buses) is also left in abeyance with respect to EV. Given EV's green credentials and the expected longer bus life, a more competitive lease may be available than is available for ICE buses. However, the current ICE supply-and-finance arrangement will have to be rolled over or restructured. This must be done in the next year or so. The appropriate procurement approach for any opportunistic or experimental EV procurements in the horizon period will have to be decided on a case-by-case basis.

Appendix A - Summary of UCT-Bidvest Full Maintenance Lease Agreement

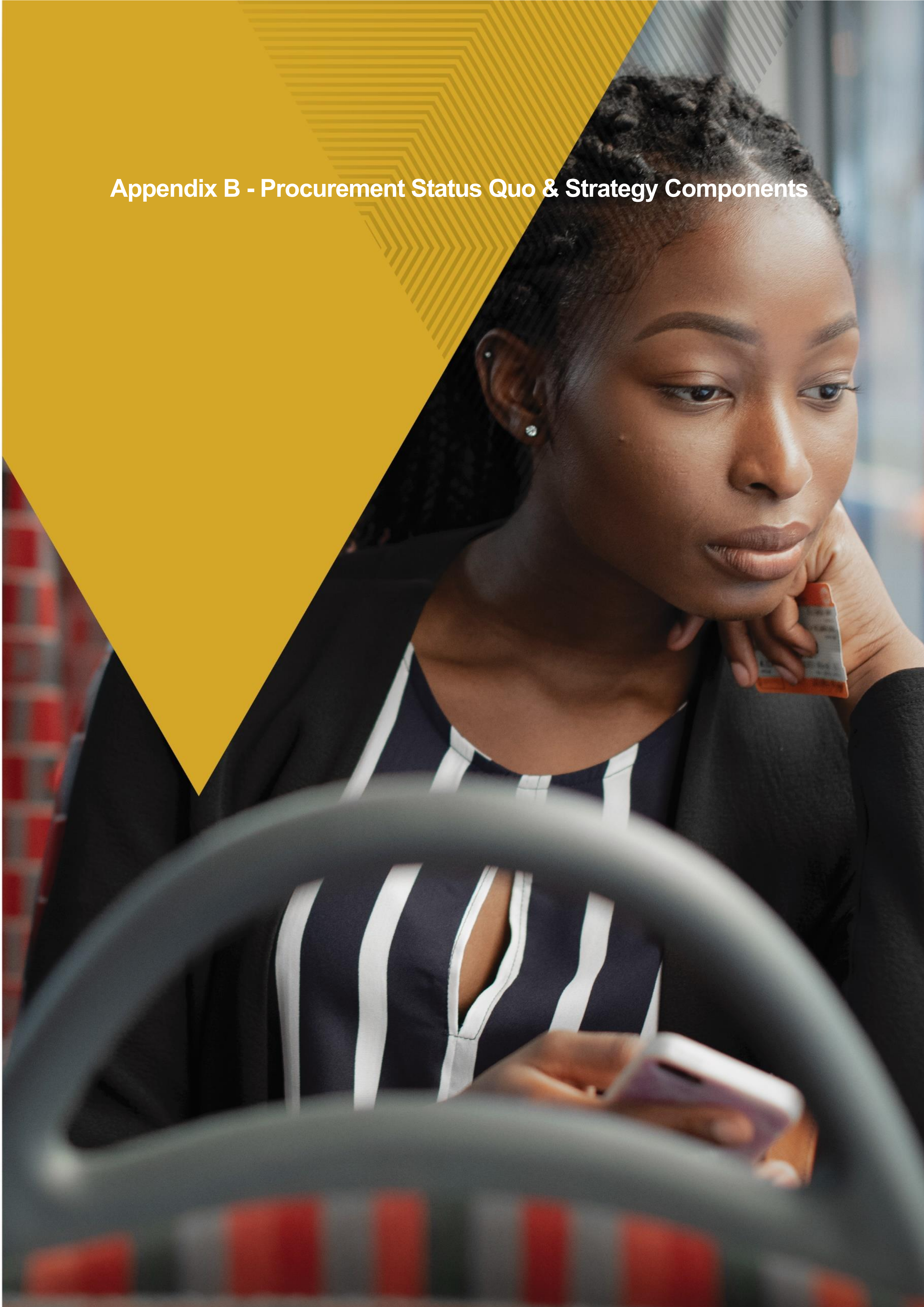
Summary of Current UCT-Bidvest Full Maintenance Lease Agreement for Diesel Buses

Table 10-1: Summary of current Bidvest vehicle lease agreement

Descriptor	Contract
Parties	
Lessor	Bidvest Bank
Lessee	UCT
Term	
Contract	7 + 2 years
Life of Asset	20 - 25 years (diesel bus)
Vehicle	
Ownership	By Lessor
Possession	By Lessee
Risks	To Lessee
Insurance	Comprehensive insurance by Lessee covering all risks of loss, damage, destruction. Proceeds of insurance claim ceded to Lessor
Lessee Use Obligations	Operate vehicle according to specs
	Maintain vehicle in good repair/condition
	Checking of vehicle fluids, battery, tyres, etc.
	Service and maintain vehicle at authorised service provider (at Lessor's cost), i.t.o. "maintenance sticker" issued by Lessor
	Pay for fuel and topping-up oil between specified services
	Arrange for replacement of tyres
	Pay for rectification of defects/repairs related to accidental damage; effects of non-sanctioned use/actions; missing items; replacement of windscreens/windows/headlights/etc. not covered by insurance; modifications required by law; effects of any Lessee non-compliance; vehicle licensing/registration; replacement of tyres not specifically provided for
	Comply with all laws regarding possession, operation, etc.
	Properly house vehicle, prevent its loss/theft
Lessor Obligations	Authorise maintenance
	Pay for reasonable repairs, maintenance, service
Operating vs. Financing (Capital) Lease	[all must be "yes" to qualify as operating lease]
Lease term < 75% of asset life?	Yes
No transfer of ownership to lessee?	Yes
No "bargain price" option at lease end?	Yes
Lease payments ≤90% of vehicle fair market value?	Yes? (TBC against lease agreement schedule)
Payment	
Basic	Rate/km up to estimated monthly km (confirmed at least every 6 months). [Is there a floor price?]
Excess	Rate/km for distance exceeding estimated monthly
Frequency	Monthly
Indexing/Adjustment	Linked to change in prime rate, insurance premiums, or other taxes, etc.
Extension for Use	Until earliest of max allowed kms reached or additional 6 months
Termination	
Early by Lessee	On terms agreed by Lessor

For Lessee Actions	Contract breach, insolvency, etc.
Upon Maximum Use	If total use >200,000km Lessor may retake possession (without affecting Lessee's obligation to make payments)
For Loss/Destruction	Vehicle removed from contract (may be replaced)

Appendix B - Procurement Status Quo & Strategy Components



Procurement Rules and Current Lease agreements

Procurement Concept

The term procurement is commonly used to refer to the initial purchasing and taking possession of something provided by someone else. A broader interpretation is that it entails choosing and executing a "delivery model" for a service, considering how risks should be apportioned to achieve an overall, lifetime efficient solution. This interpretation allows for a trade-off between internal and external provision, combining goods (including facilities) and services (such as operation and maintenance), and other mixing-and-matching opportunities to achieve the best value-for-money (VFM).

Overview

This note reviews UCT's procurement approach and procedures and finds that, although created to deal with "purchasing" rather than "procurement" in the above sense, the approach is principle-based and quite flexible and should not detract from achieving the lifetime VFM objective. Next, the procurement timeframes for the EV bus arrangements are defined, which are the immediate focus on a technical pilot and the longer-term comprehensive solution – which is then the focus of the remainder of the note. The range of procurement options is unpacked in principle, and then applied to the suit of activities to be performed. The conclusion is that there are three main components ("contracts") that need to be procured, against the background of various activities that UCT will perform itself. The details of and relation between these three contracts is what will be addressed in the procurement strategy proper later-on.

UCT Procurement Framework

Overview

The University is not subject to general public sector procurement rules, emanating from (for example) the Public Finance Management Act (PFMA). Notwithstanding, as a good corporate citizen acting in the public interest, it supports general government policy which, in the case of procurement, implies adhering to objectives and principles of competition, value for money, transparency, accountability, and economic inclusion and development. Its approach to procurement is formalised in various policies and procedures, the key ones which are discussed below.

Role of PURCO

Before turning to its own policies, it should be noted that UCT is a member of PURCO (Purchasing Consortium Southern Africa), which is a non-profit procurement consortium supporting the higher education sector. PURCO's aim is to save time and money through professional and focused collaborative procurement amongst members. PURCO conducts collaborative national tenders (for common products and services) itself and assists members to manage individual tenders they execute themselves.

Most of the components making up the EV bus procurement package (possibly except for items such as fuel, tyres, insurance) will be of an "individual" (non-common) nature. The role of PURCO is therefore to attend the development of the EV bus solution and its procurement, and to advise where required, but not to manage the actual procurement process.

Procurement Policy & Procedure [PUR004][1]

PUR004 applies to the procurement of all goods and services. The process entails registering a tender request, preparing tender documents, inviting tenders, receiving tenders, evaluating tenders, adjudicating tenders, and awarding the tender.

The following roles are provided for:

- Specification Committee, to compile unbiassed specifications, prepare evaluation criteria, and determine any applicable special conditions
- Evaluation Committee, to evaluate tenders in terms of the criteria
- Tender Adjudication Committee[2], to consider the Evaluation Committee recommendations, to confirm that due process was followed, and to make a final award or recommendation.
- Procurement and Payment Services (PPS) is represented on all the committees and provides support to the overall procurement process.

Although PUR004 does not exclude a two-stage process (RFI/RFQ/shortlisting and RFP), the usual process appears to be single-stage (RFP only). The tender comprises technical specification and commercial (price schedule, payment terms, etc.) aspects. A one or two-phase approach may be applied, with bidders achieving a minimum functional score proceeding to the financial evaluation phase. For this purpose, a two-envelope bid may be used (one for functionality and the other for price and B-BBEE status).

The actual technical scores of bidders who achieved the minimum functionality are not considered further, i.e. they were found to be “sufficient” and passed through the technical “gate”, and the “excess” score does therefore not offset a higher price. So, in a value-for-money context, “value” is settled before assessing “money”.

The financial evaluation is based on the 80/20 or 90/10 B-BBEE preference point system[3], the selected ratio depending on the value of the tender. The tender value is firstly expressed relative to the lowest (technically compliant) bid, and then up to 20 or 10 points are added for B-BBEE status.

PUR004 does not require the bid to be awarded to the highest financial score, although it notes that this would be an “unlikely event”. The Evaluation Committee compiles a shortlist based on the financial points and the Adjudication Committee decides to either approve or reject the recommendation or revert to the Evaluation Committee for further clarification.

As regards competition, procurement can be open or restricted (“closed”) in the case of specialised services (these are usually preferred vendors of PURCO). There may also be direct negotiating with vendors for the purchase of goods or services, for example if these can only be supplied by a particular vendor due to no reasonable alternative or substitute being available or in the absence of competition for technical reasons. These considerations may conceivably apply for the procurement of EV buses and related aspects. It is not clear from PUR004, but it is assumed that a decision to procure directly would still have to be endorsed by all the committees involved in a competitive bidding process.

The overall impression is that procurement follows a structured process without being overly prescriptive. The integrity of the process relies on transparency, separation of roles (non-overlapping responsibilities between committees), and the declaration of conflicts of interest. It appears to be sufficiently flexible to deal with more complicated forms of procurement (e.g. multi-year PPP-type contracts), although some additional steps may then be required, specifically:

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[1] UCT Finance Department: Policies & Procedures for Quotations, Tenders and Requests for Proposals
[PUR004], 2020

[2] There may be cross membership between the Specification and Evaluation committees, but no member of the Evaluation Committee may serve on the Tender Adjudication Committee

[3] Note that these ratios do not refer to the quality: price weighting commonly used in procurement

- Supporting the specification step with a more fully-fledged feasibility study to define the acceptable/desired outcomes better (which is what is already being done for EV buses)
- Confirming UCT's ability to pay for (and if necessary, support) the contract (referred to as "affordability" in the PPP domain)
- Making risk assessment a more pertinent aspect of the evaluation, i.e. likelihood of achieving desired outcomes, risks retained by UCT, etc.
- Introducing a time value aspect to the financial evaluation (for prices to be compared on an NPV basis).

B-BBEE (Preferential Procurement) Policy [PUR005][4]

PUR005 gives effect to UCT's support of B-BBEE and SMME development. UCT gives preference to those suppliers that have a valid B-BBEE Certificate or affidavit but will not exclude non-compliant suppliers of goods and services where it is in the interest of UCT to use such a vendor.

For tenders above R1m, if open bidding then 90/10 and if closed then 80/20 preference points systems apply.

Other Policies

Other procurement policies referred to in PUR004 and which may apply to the procurement of EV buses are:

- Delegated Authority Limits [GEN002] specifies who has the authority to contract on behalf of the University, which for financial and budgetary (including purchasing) is the Executive Director: Finance, and for Properties and Services (P&S) is the Executive Director: Properties & Services. A schedule sets out the approvals required and conditions to be met depending on the type (e.g. contract, lease) and value of spending involved.
- Threshold values for purchasing procedures [PPP002], which determine that for tenders between R1-5m bids may be open (90/10 B-BBEE applies) or closed (minimum three bidders, 80/20 B-BBEE), and above R5m bids must all be open with 90/10 B-BBEE.

Contract Strategy Document

The CSD is a summary document of the style of a "head of procurement". It presents the highlights of the particular procurement event and the tender execution plan.

The CSD contains:

- Tender key attributes (title, end user department, value, budget approval status, commencement date, etc.)
- Needs statement (scope of work required, alternatives considered, supplier factors, issues, and risks, B-BBEE considerations)
- Selected tender approach (whether open or closed, and if closed the vendor list)
- Tender evaluation team (presumed to be the Evaluation Committee referred to under PUR004)
- Implementation schedule.

The CSD is presumably prepared by PPS, and is signed off by the applicable Department, Head of Department (for contracts greater than R2m), budget holder, and a PPS manager.

For the EV bus programme, there is likely to be a portfolio of CSDs that make up the overall procurement plan, i.e., one CSD for every discrete part of the overall implementation.

[4] UCT Finance Department: B-BBEE (Preferential Procurement) Policy [PUR005], 2019

Pilot Stage vs. Long-Term Period

The timeline of the EV bus contractual arrangements is book-ended by the following considerations:

- The current bus lease arrangement would originally have expired in 2022 but was extended for a further two years (to 2024). This would therefore be when the succeeding arrangement should be in place.
- UCT is embarking on a green energy (solar/PV) programme. However, this is not a pre-condition for the EV project and will continue regardless of the EV bus initiative and does therefore not affect the project timeline.
- A typical vehicle lease would be for a period of seven to nine years, but an EV engine is expected to last longer than a diesel one. However, the EV battery must be replaced approximately every ten years. The term for the EV bus component of the procurement package could therefore be 10 years or slightly longer but will ultimately be determined by the vehicle provider/lessor. At the Start Strong Workshop it was proposed that a ten-year contract duration be applied (although there may be room for a longer period).
- Some components of the bus package (stabling and other buildings, possibly the charging infrastructure) will have a useful life substantially beyond that of the actual buses. It is unlikely (e.g. buildings) but not impossible (e.g. charging) that these could become obsolete or stranded upon expiry of the EV bus contract.

In summary, there are three time periods to keep in mind. An initial two years to get EV arrangements in place (short-term), a decade or so to see through an EV bus provision arrangement (long-term), and the time after that where sunk investments can continue to be used, repurposed, or scrapped.

Short-Term Pilot Stage

It has been UCT's intention to utilise the short-term window to do an EV bus test case, and to set up the longer-term arrangements. The test would be at the scale of one or two buses. Ideally, competing battery technologies should go head-to-head, but the pilot may have to be carried out with whatever vehicle/battery is available (like the BYD e-bus used by GABS and TBRT, lithium iron phosphate battery, with 37+20 pax capacity).

The test can confirm vehicle/technology capabilities, such as operating range, peak performance achievement, and recharging frequency and practicality. "System" design aspects such as fleet size and mix, location of recharging infrastructure, possible route/schedule changes, etc. cannot be assessed, but the operational characteristics of the individual EV bus should greatly assist to understand and plan these aspects.

The availability of suitable bus/es at short notice, reliance on whatever charging equipment is required for that bus, the short period required (much shorter than a typical lease), and the fact that there will have to be some "goodwill" from the provider/lessor to participate, imply that the pilot will have to be procured in a "closed", as-available manner. The contract will be very specific (it will not look like a typical lease). It will comprise both vehicle and charging equipment. Other aspects of the current (diesel bus) lease that are the responsibility of the lessee may have to remain with the bus provider, and these will have to be negotiated one-by-one. The specification should emphasise the performance data outputs that are expected from the bus/es. A premium may have to be paid for this short-term arrangement.

Long-Term Bus Fleet Stage

The long-term arrangement will allow more scope for UCT to dictate requirements, and to expose some aspects of the procurement package to competition and risk transfer. The subsequent sections of this document attempt to start putting some structure to those options.

Forms of Procurement

As noted in the introduction, procurement is not just the action of initially acquiring a good or service but entails how the good or service is going to be delivered and managed over its contract life. There is a range of available delivery models from which the appropriate one/s must be selected for each component, and combinations of components of the EV bus "package".

Error! Reference source not found. provides a simplified overview of delivery models. A comparison like this is usually done for either equipment or infrastructure procurement, but because the EV bus package includes both categories, here these are treated together. The column headings show the broad delivery models, ranging from internal, self-provision ("Own") across different external mechanisms to complete cession ("PPP"). The "PPP" category includes a whole sub-range of options (availability franchise, lease, concession, etc.) which – amongst other – entail different ownership rights, but these can be investigated as required later. The row headings are the differentiating aspects of the models, i.e. the main obligations. These are sorted so that the "fault line" of how responsibilities are shared between UCT ("Self"), and a third party ("Other") can be seen across the models.

Table ***Error! No text of specified style in document.****-1: Broad Procurement/Delivery Models*

Obligation	Internal	External			
		Use			
	Own	Financial Lease	Rent/ Operating Lease	Service	PPP
Ownership & Reinvestment	Self	Other	Other	Other	Self/Other
Asset Accounting Privileges	Self	Self	Other	Other	Other
Maintenance	Self	Self	Self/Other	Other	Other
Possession, Operation, Repairs	Self	Self	Self	Other	Other
Insurance	Self	Self	Self	Other	Other
Revenue pertains to	Self	Self	Self	Self	Other

Contract Packages & Choice of Procurement/Delivery Model

Although the detailed content of all the aspects of the EV bus requirements is still being defined, at a high level at least the main components are quite clear. These are shown in **Error! Reference source not found.**, but excluding the short-term pilot stage contract which is a bespoke procurement (as discussed in section **Error! Reference source not found.**). The table further shows the results of a preliminary discussion with the Director: Procurement & Payment Services (PPS) division (2 June 2022) regarding a starting point for aggregating requirements into procurement components ("contracts"). Some additional perspectives were provided by the Director: Environmental Sustainability (24 June 2022). And it is expected that further responses will be made on the write-up presented here.

Some responsibilities currently reside with UCT itself and should remain as-is (marked as "Self"). For some activities there is a "preferred" procurement, but the content and implications need to be fleshed out. Sometimes there is a "possible" alternative to consider in competition with a preferred option. And there is one case where there is a preference for an external model of which the form remains to-be-decided ("TBD").

The components for which there is no clear preference are numbered (A, B, etc., roughly in order of importance), and these are the ones that should receive attention in the EV bus procurement plan. The selection of the various procurement models is discussed in the following sub-sections.

*Table **Error! No text of specified style in document.**-2: Preliminary Identification of Procurement Contracts*

Requirement		Procurement				Package Component
		Internal	Lease/ Rent	Service	PPP	
Service Planning & Oversight		Self				
Operations, Management, Scheduling	Administration	Self				
	Crew	Self				
	Fleet	Self				
	Info/telematics	Self?	Possible Other			A
Vehicles	Insurance	Self				
	Ops, repairs	Self				
	Maintenance		Prefer Other			A
	Ownership		Prefer Other			
Facilities	Charging	Preferred not self	TBD		TBD	B
	Fuelling			Other		
	Stabling/depot	Prefer Self			Possible Other	C
	Crew/staff	Prefer Self			Possible Other	

Service Provider Role

UCT currently does the bus service planning, management, scheduling, duties, operation, etc. and appoints bus drivers and (presumably) some other staff to look after the vehicles day-to-day. It is not the intention to change this approach, and the way that these resources, skills, etc. are procured will remain as-is. There will therefore be no further investigation of these aspects from a procurement perspective.

Vehicle Lease

The “primary” contract (together with recharging) will be to secure the buses. This may of course be a mixed bus solution, with some conventional (diesel/ICE) and some EV vehicles.

Current Lease Contract

The key provisions of the existing vehicle full maintenance, operating lease contract with Bidvest Bank (who own and avail the vehicles) are summarised in the Annex. In short, Bidvest owns the vehicles and pays for their maintenance. UCT carries all operating risk, including insurance and day-to-day items like refuelling, tyre replacement and repairs. UCT pays on a per kilometre basis, subject to a maximum use cap. The tariff is linked to changes in financing cost. There are some provisions in place to ensure that the arrangement stays an “operational” (rather than “financial”) lease.

Future Lease/s (Component A)

A future agreement for EV buses is expected to be of very much the same nature as the current contract, but probably adjusted for EV-specific requirements such as life-of-bus, battery replacement, and recharging requirements/standards.

The minimum technical requirements/specifications will be developed from UCT’s perspective. A major decision point is the selection of battery/recharging technology, and it will have to be determined whether the optimal/desired technology is readily available, or whether a compromise solution should be selected. Another aspect that needs to be investigated is how the EV bus performance recording system works and what he respective responsibilities should be in that regard.

From a legal formulation perspective it is expected that the relevant financial leasing company will prescribe most of the contract terms. The commercial aspects (term, rate, etc.) underpinning value-for-money will be as established through competitive bidding – anticipating that the technical specifications can be drafted, and that the potential EV bus lessor market is active enough to enable competition.

Facilities-based Services

Refuelling

There could be some diesel buses still required in future. UCT currently has an arrangement to refuel buses at an off-site private fuel retailer. This arrangement will stay in place (although the activity level will probably be lower).

Charging (Component B)

EV charging is the next key component to resolve in the EV bus procurement package. Work is ongoing to assess the required technology (in combination with the EV bus specifications), and to match this with where buses require or are available for recharging.

The recharging solution must obviously be coordinated and compatible with the EV bus solution. It is not clear at this point to what extent the buses and the recharging gear come as a package or can be procured distinctly. The charging contract may therefore be linked to or combined with the bus contract (e.g. the buses and charging solution may be provided by the same supplier).

Similarly, the geographic distribution of charging points is not yet known (e.g. it may be sufficient to centralise points at the depots, or possibly points also need to be provided at main stops), and the requirement may change over time (e.g. equipping smaller stops). There may therefore be a need to link the recharging contract with the facilities contract/s discussed below (e.g. the charging solution and facilities may be provided by the same supplier).

Whether it is beneficial to eventually tie the charging contract to the bus or facilities contracts remains to be decided. For now, the charging investigation needs to determine an optimal/ideal technology and location solution, which then needs to be coordinated with practical constraints (depot and stops locations, locations of appropriate power source, etc.).

If the charging arrangement is not meshed with the bus or facility/ies contracts, then the procurement options can be any along the spectrum in **Error! Reference source not found.**. However, UCT would prefer it to be provided by an external party (whether as a rental or full-on outsourced solution). Procurement VFM will hopefully be achieved through competition, but it there is some chance that direct negotiation with a single supplier may be required.

Stabling & Crew Centre (Component C)

"Stabling" refers to places for long-period parking of buses (e.g. overnight, lunch breaks). "Crew centre" refers to one or more places where crew log on, rest, etc. and which can also be used for service administration. Crew centre/s can be more or less formalised. The stabling and crew centre/s can but do not have to be combined.

The Director: Capital Planning & Projects has indicated that the stabling should be on-campus and expressed a preference for two locations (Forest Hill and North bus stop). There are also other stops (on-campus) which have both parking space and power supply, and which may be considered.

UCT would probably procure the facilities conventionally, as one or more construction contracts probably of a turn-key nature, and then maintain and operate the facilities itself in an insourced manner and as an extension of its existing facilities management capability. Procurement VFM will be achieved through competition driving cost and delivery time.

However, until the facilities' requirements, costs, etc. have been assessed, the possibility of outsourcing these under a longer-term PPP arrangement should be kept open. Drivers for an outsourcing solution would be a large up-front capital cost (an affordability issue) and/or the prevalence of specialised elements (e.g. charging, battery maintenance) that UCT cannot or does not want to manage.

Summary Procurement Strategy Components

From the above discussion there are foreseen to be three components (contracts) making up the procurement package:

A. Buses. There will be an operating lease contract for the supply of EV buses, not dissimilar to the current arrangement with diesel buses. The technology selection and supplier community will direct whether it can be procured competitively.
B. Charging. The charging solution will also be procured externally, but the procurement convention (rent, lease, concede, etc.) needs to be determined. It may be combined with the bus, but more likely with the facilities contract.

Facilities. The facilities are likely to be procured via a conventional construction procurement, with internal operation. Depending on the size and content of the required facility/ies there may be a need to outsource provision, but this appears not very likely.

Appendix C - Costing Model

UCT EV vs. ICE

SUMMARY

Item	Class		Reporting	NPV	Annual															
	Cost	Allocation	Unit		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
				10%																
EV Solution																				
Facilities Construction			R nom	13,107,849	14,418,634	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large EV	Construct	EV Large	R nom	11,033,246	12,136,571	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi EV	Construct	EV Midi	R nom	2,074,602	2,282,063	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Purchase			R nom	176,727,273	194,400,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large EV	Purchase	EV Large	R nom	141,381,818	155,520,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi EV	Purchase	EV Midi	R nom	35,345,455	38,880,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Facilities O&M			R nom	10,100,342	-	1,623,919	1,705,115	1,790,370	1,879,889	1,973,883	2,072,577	2,176,206	2,285,017	2,399,267	-	-	-	-	-	-
Large EV	O&M	EV Large	R nom	6,733,562	-	1,082,612	1,136,743	1,193,580	1,253,259	1,315,922	1,381,718	1,450,804	1,523,344	1,599,512	-	-	-	-	-	-
Midi EV	O&M	EV Midi	R nom	3,366,781	-	541,306	568,372	596,790	626,630	657,961	690,859	725,402	761,672	799,756	-	-	-	-	-	-
Overhead	Overhead	EV	R nom	36,451,557	-	5,860,629	6,153,661	6,461,344	6,784,411	7,123,631	7,479,813	7,853,803	8,246,494	8,658,818	-	-	-	-	-	-
Electricity			R nom	8,448,643	-	1,131,823	1,258,425	1,384,267	1,521,316	1,644,214	1,796,365	2,004,705	2,229,376	2,456,456	-	-	-	-	-	-
Large EV	Electricity	EV Large	R nom	7,725,487	-	1,034,531	1,151,294	1,266,423	1,391,814	1,502,187	1,641,099	1,832,735	2,039,587	2,246,883	-	-	-	-	-	-
Midi EV	Electricity	EV Midi	R nom	723,156	-	97,292	107,131	117,844	129,502	142,027	155,266	171,970	189,789	209,573	-	-	-	-	-	-
Service			R nom	7,692,939	-	1,353,975	1,422,046	1,563,518	1,427,517	1,437,377	1,594,177	1,440,836	1,625,854	1,452,908	-	-	-	-	-	-
Large EV	Service	EV Large	R nom	5,104,763	-	902,650	900,000	1,113,518	900,000	902,650	1,144,177	900,000	1,175,854	902,650	-	-	-	-	-	-
Midi EV	Service	EV Midi	R nom	2,588,177	-	451,325	522,046	450,000	527,517	534,727	450,000	540,836	450,000	550,258	-	-	-	-	-	-
Tyre Replacement			R nom	4,004,893	-	-	266,913	1,178,881	299,574	1,711,280	-	2,019,720	-	2,347,251	-	-	-	-	-	-
Large EV	Tyre	EV Large	R nom	3,079,375	-	-	-	1,178,881	-	1,375,047	-	1,635,012	-	1,907,078	-	-	-	-	-	-
Midi EV	Tyre	EV Midi	R nom	925,517	-	-	266,913	-	299,574	336,233	-	384,709	-	440,173	-	-	-	-	-	-
Battery Replacement			R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large EV	Battery	EV Large	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi EV	Battery	EV Midi	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Terminal Value			R nom	- 53,508,796	-	-	-	-	-	-	-	-	-	- 138,788,036	-	-	-	-	-	-
Large EV	TermVal	EV Large	R nom	- 42,807,037	-	-	-	-	-	-	-	-	-	- 111,030,428	-	-	-	-	-	-
Midi EV	TermVal	EV Midi	R nom	- 10,701,759	-	-	-	-	-	-	-	-	-	- 27,757,607	-	-	-	-	-	-
EV Total Excl. Terminal Value			R nom	256,533,496	208,818,634	9,970,346	10,806,158	12,378,380	11,912,706	13,890,386	12,942,933	15,495,271	14,386,740	17,314,700	-	-	-	-	-	-
EV Total Incl. Terminal Value			R nom	203,024,700	208,818,634	9,970,346	10,806,158	12,378,380	11,912,706	13,890,386	12,942,933	15,495,271	14,386,740	- 121,473,335	-	-	-	-	-	-
Emissions			R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large EV	Emission	EV Large	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi EV	Emission	EV Midi	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EV Capex			R nom	189,835,122	208,818,634	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EV O&M			R nom	66,698,374	-	9,970,346	10,806,158	12,378,380	11,912,706	13,890,386	12,942,933	15,495,271	14,386,740	17,314,700	-	-	-	-	-	-
EV Total Excl. Bus Purchase			R nom	79,806,223	14,418,634	9,970,346	10,806,158	12,378,380	11,912,706	13,890,386	12,942,933	15,495,271	14,386,740	17,314,700	-	-	-	-	-	-
Bus Lease			R nom	138,897,183	-	26,530,000	26,530,000	26,530,000	26,530,000	26,530,000	26,530,000	26,530,000	26,530,000	26,530,000	-	-	-	-	-	-
Large EV	Lease	EV Large	R nom	111,117,747	-	21,224,000	21,224,000	21,224,000	21,224,000	21,224,000	21,224,000	21,224,000	21,224,000	21,224,000	-	-	-	-	-	-
Midi EV	Lease	EV Midi	R nom	27,779,437	-	5,306,000	5,306,000	5,306,000	5,306,000	5,306,000	5,306,000	5,306,000	5,306,000	5,306,000	-	-	-	-	-	-
ICE Solution																				
Facilities Construction			R nom	9,807,324	10,788,056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large ICE	Construct	ICE Large	R nom	8,675,723	9,543,295	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi ICE	Construct	ICE Midi	R nom	1,131,601	1,244,761	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Purchase			R nom	68,040,000	74,844,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large ICE	Purchase	ICE Large	R nom	54,785,455	60,264,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi ICE	Purchase	ICE Midi	R nom	13,254,545	14,580,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Facilities O&M			R nom	8,416,952	-	1,353,265	1,420,929	1,491,975	1,566,574	1,644,903	1,727,148	1,813,505	1,904,180	1,999,389	-	-	-	-	-	-
Large ICE	O&M	ICE Large	R nom	5,050,171	-	811,959	852,557	895,185	939,944	986,942	1,036,289	1,088,103	1,142,508	1,199,634	-	-	-	-	-	-
Midi ICE	O&M	ICE Midi	R nom	3,366,781	-	541,306	568,372	596,790	626,630	657,961	690,859	725,402	761,672	799,756	-	-	-	-	-	-
Overhead	Overhead	ICE	R nom	36,451,557	-	5,860,629	6,153,661	6,461,344	6,784,411	7,123,631	7,479,813	7,853,803	8,246,494	8,658,818	-	-	-	-	-	-
Diesel			R nom	36,508,970	-	5,456,867	5,882,725	6,294,516	6,727,031	7,109,040	7,554,170	8,185,305	8,828,384	9,470,362	-	-	-	-	-	-
Large ICE	Diesel	ICE Large	R nom	25,213,372	-	3,765,453	4,067,830	4,352,578	4,650,531	4,899,368	5,201,814	5,650,930	6,104,716	6,548,184	-	-	-	-	-	-
Midi ICE	Diesel	ICE Midi	R nom	11,295,597	-	1,691,414	1,814,895	1,941,938	2,076,500	2,209,672	2,352,356	2,534,374	2,723,668	2,922,178	-	-	-	-	-	-
Service			R nom	36,841,353	-	6,567,695	6,783,809	7,168,757	7,255,167	7,343,439	6,811,750	7,388,365	7,093,146	7,314,059	-	-	-	-	-	-
Large ICE	Service	ICE Large	R nom	30,238,705	-	5,415,900	5,600,885	5,821,859	6,064,429	5,881,000	5,644,177	6,178,598	5,672,509	5,988,170	-	-	-	-	-	-
Midi ICE	Service	ICE Midi	R nom	6,602,648	-	1,151,795	1,182,923	1,346,898	1,190,738	1,462,439	1,167,573	1,209,766	1,420,637	1,325,889	-	-	-	-	-	-
Tyre Replacement			R nom	4,004,893	-	-	266,913	1,178,881	299,574	1,711,280	-	2,019,720	-	2,347,251	-	-	-	-	-	-
Large ICE	Tyre	ICE Large	R nom	3,079,375	-	-	-	1,178,881	-	1,375,047	-	1,635,012	-	1,907,078	-	-	-	-	-	-
Midi ICE	Tyre	ICE Midi	R nom	925,517	-	-	266,913	-	299,574	336,233	-	384,709	-	440,173	-	-	-	-	-	-
Battery Replacement			R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large ICE	Battery	ICE Large	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi ICE	Battery	ICE Midi	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Terminal Value			R nom	- 20,600,886	-	-	-	-	-	-	-	-	-	- 53,433,394	-	-	-	-	-	-
Large ICE	TermVal	ICE Large	R nom	- 16,587,727	-	-	-	-	-	-	-	-	-	- 43,024,291	-	-	-	-	-	-
Midi ICE	TermVal	ICE Midi	R nom	- 4,013,160	-	-	-	-	-	-	-	-	-	- 10,409,103	-	-	-	-	-	-
ICE Total Excl. Terminal Value			R nom	200,071,048	85,632,056	19,238,457	20,508,035	22,595,473	22,632,757	24,932,292	23,572,881	27,260,698	26,072,204	29,789,879	-	-	-	-	-	-
ICE Total Incl. Terminal Value			R nom	179,470,162	85,632,056	19,238,457	20,508,035	22,595,473	22,632,757	24,932,292	23,572,881	27,260,698	26,072,204	- 23,643,514	-	-	-	-	-	-

Emissions			R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Large ICE	Emission	ICE Large	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midi ICE	Emission	ICE Midi	R nom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ICE Capex			R nom	77,847,324	85,632,056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ICE O&M			R nom	122,223,724	-	19,238,457	20,508,035	22,595,473	22,632,757	24,932,292	23,572,881	27,260,698	26,072,204	29,789,879	-	-	-	-	-	-
ICE Total Excl. Bus Purchase			R nom	132,031,048	10,788,056	19,238,457	20,508,035	22,595,473	22,632,757	24,932,292	23,572,881	27,260,698	26,072,204	29,789,879	-	-	-	-	-	-
Bus Lease			R nom	53,475,416	-	10,214,050	10,214,050	10,214,050	10,214,050	10,214,050	10,214,050	10,214,050	10,214,050	10,214,050	-	-	-	-	-	-
Large ICE	Lease	ICE Large	R nom	43,058,127	-	8,224,300	8,224,300	8,224,300	8,224,300	8,224,300	8,224,300	8,224,300	8,224,300	8,224,300	-	-	-	-	-	-
Midi ICE	Lease	ICE Midi	R nom	10,417,289	-	1,989,750	1,989,750	1,989,750	1,989,750	1,989,750	1,989,750	1,989,750	1,989,750	1,989,750	-	-	-	-	-	-

EV vs ICE NPV

	O&M EV	R nom		-	8,239,955	16,358,782	24,813,382	32,210,235	40,050,996	46,692,767	53,921,425	60,022,808	66,698,374	66,698,374	66,698,374	66,698,374	66,698,374	66,698,374	66,698,374
EV	Capex EV	R nom		189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122	189,835,122
	Emissions EV	R nom		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total excl. Terminal EV	R nom		189,835,122	198,075,077	206,193,904	214,648,504	222,045,357	229,886,118	236,527,889	243,756,547	249,857,929	256,533,496	256,533,496	256,533,496	256,533,496	256,533,496	256,533,496	256,533,496
	O&M ICE	R nom		-	15,899,551	31,307,542	46,740,554	60,793,715	74,867,344	86,963,959	99,681,276	110,738,436	122,223,724	122,223,724	122,223,724	122,223,724	122,223,724	122,223,724	122,223,724
ICE	Capex ICE	R nom		77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324	77,847,324
	Emissions ICE	R nom		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total excl. Terminal ICE	R nom		77,847,324	93,746,875	109,154,866	124,587,878	138,641,039	152,714,668	164,811,283	177,528,600	188,585,760	200,071,048	200,071,048	200,071,048	200,071,048	200,071,048	200,071,048	200,071,048
	O&M ICE > EV	y/n		-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Capex ICE > EV	y/n		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total ICE > EV	y/n		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Technology Comparison (NPV Build-Up)

						Total		Excl Bus Capex	
Cost Item		EV	ICE	EV - ICE	EV/ICE	EV share	ICE share	EV share	ICE share
Facilities Construction	R nom mill	13	10	3		6%	5%	16%	7%
Bus Purchase	R nom mill	177	68	109		87%	38%		
Facilities O&M	R nom mill	10	8	2		5%	5%	13%	6%
Overhead	R nom mill	36	36	-		18%	20%	46%	28%
Energy	R nom mill	8	37	-28		4%	20%	11%	28%
Service	R nom mill	8	37	-29		4%	21%	10%	28%
Tyre Replacement	R nom mill	4	4	-		2%	2%	5%	3%
Battery Replacement	R nom mill	-	-	-		0%	0%	0%	0%
Bus Terminal Value	R nom mill	-54	-21	-33		-26%	-11%		
Emissions	R nom mill	-	-	-		0%	0%	0%	0%
Total	R nom mill	203	179	24	1.13	100%	100%	100%	100%
Bus Lease	R nom mill	139	53	85	1.18				
Total Bus Cost	R nom mill	123	47			61%	26%		
Excl Bus Capex	R nom mill	80	132					-40%	

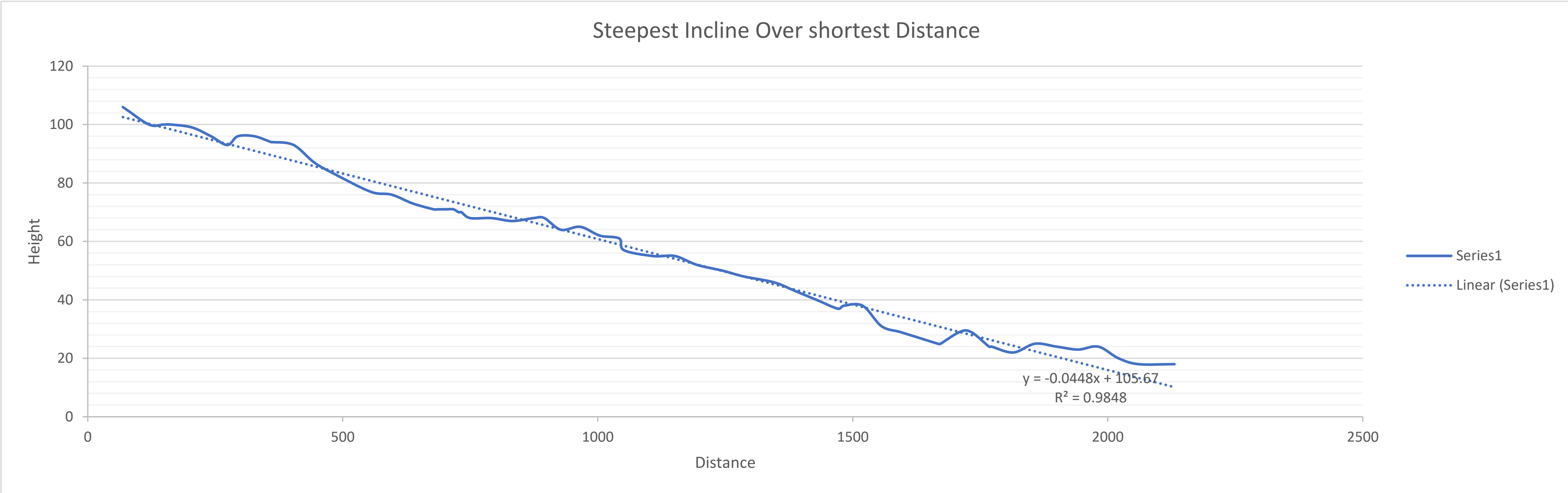
Sensitivities

	Operator	Factor		EV	ICE	Ratio	Break-Even	Scenario
Purchase Approach			R nom mill	203	179	1.13		
Term Days	x	1.00	R nom mill	203	179	1.13	1.37	1.10
Distance Operated	x	1.00	R nom mill	203	179	1.13	1.65	1.00
Facilities Construction	x	1.00	R nom mill	203	179	1.13	N/A	1.00
Bus Fleet (No of each)	-	-	R nom mill	203	179	1.13	6	0.00
EV Bus Purchase Price	x	1.00	R nom mill	203	179	1.13	0.82	0.90
Electricity Tariffs	x	1.00	R nom mill	203	179	1.13	N/A	1.00
Diesel Price	x	1.00	R nom mill	203	179	1.13	1.58	1.00
EV Bus Life	+	-	R nom mill	203	179	1.13	5	1.00
Lease Approach			R nom mill	219	186	1.18		
EV Bus Life	+	-	R nom mill	219	186	1.18	7.5	1
EV Lease Term	+	-	R nom mill	219	186	1.18	4.5	2
EV Lease Interest Rate	x	1.00	R nom mill	219	186	1.18	0.4	0.85

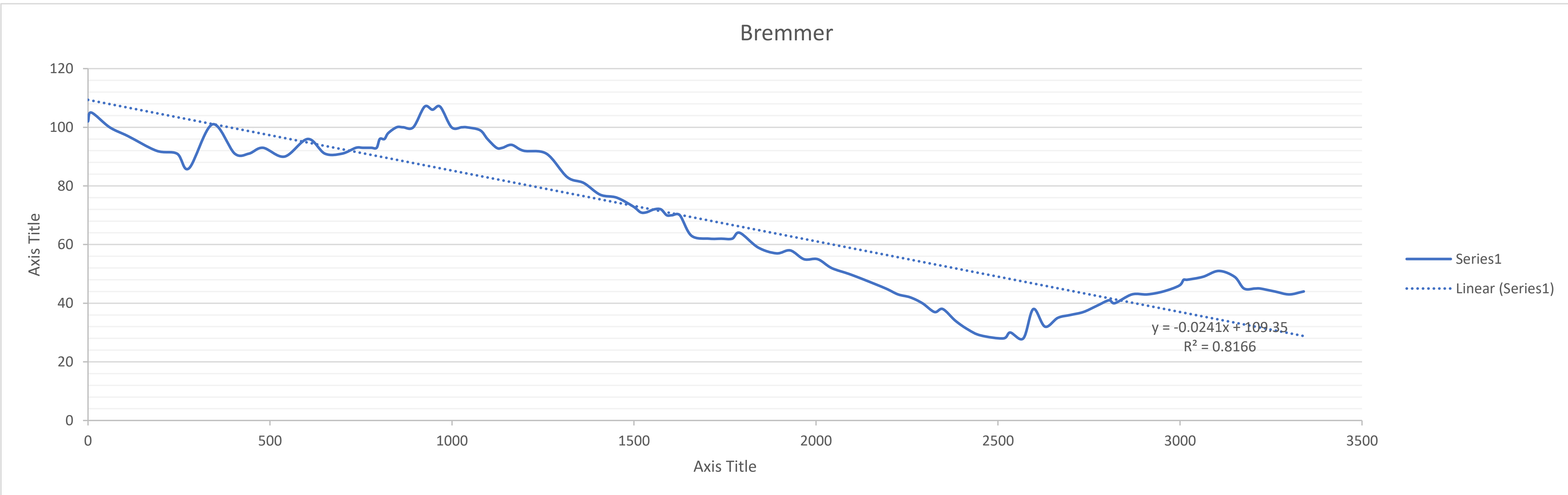
END

EV Service & Tyre	143,539	-	1,353,975	1,688,959	2,742,399	1,727,091	3,148,657	1,594,177	3,460,557	1,625,854	3,800,159	-	-	-	-	-	-
ICE Service & Tyre	493,553	-	6,567,695	7,050,721	8,347,638	7,554,741	9,054,718	6,811,750	9,408,085	7,093,146	9,661,310	-	-	-	-	-	-

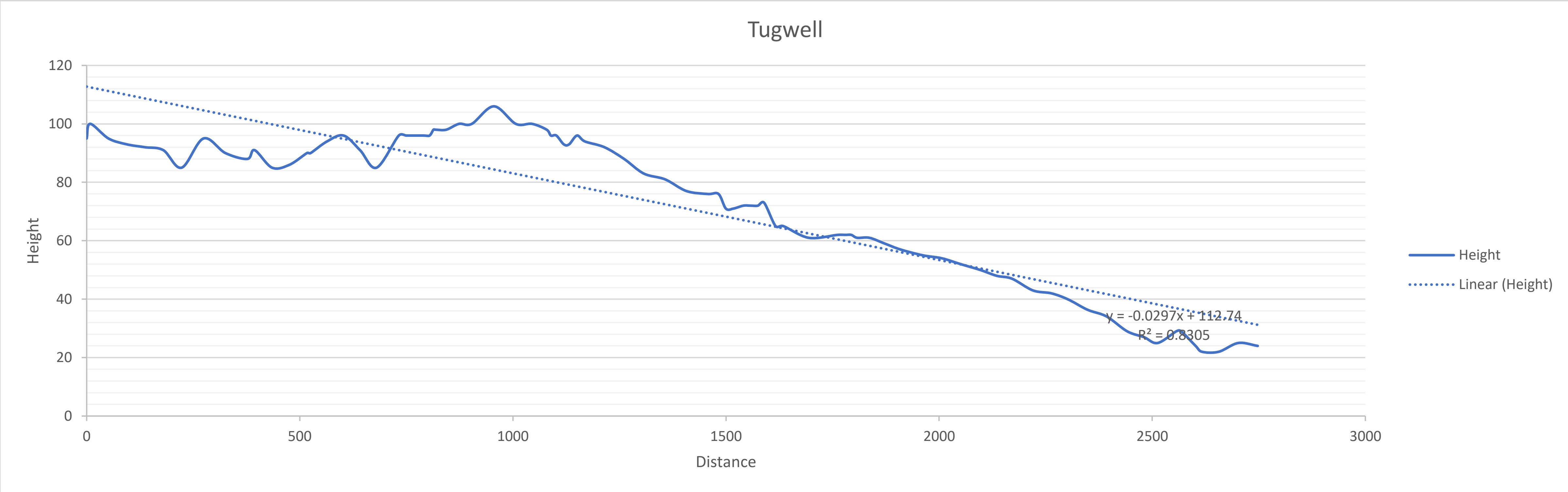
Appendix D - Route Profile

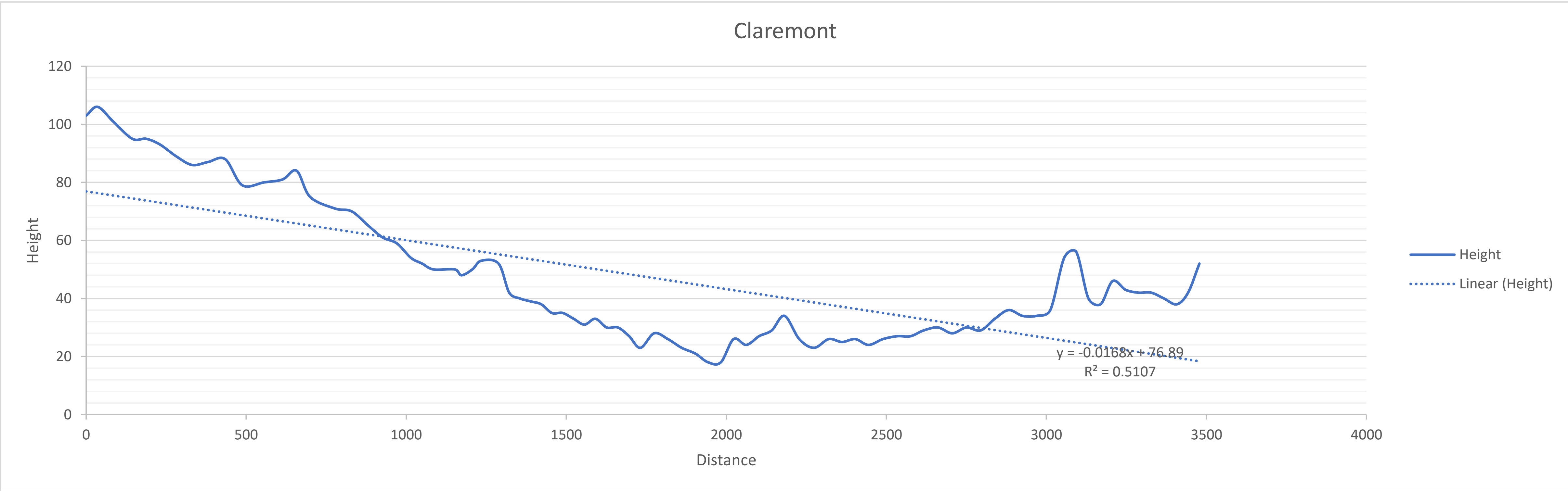


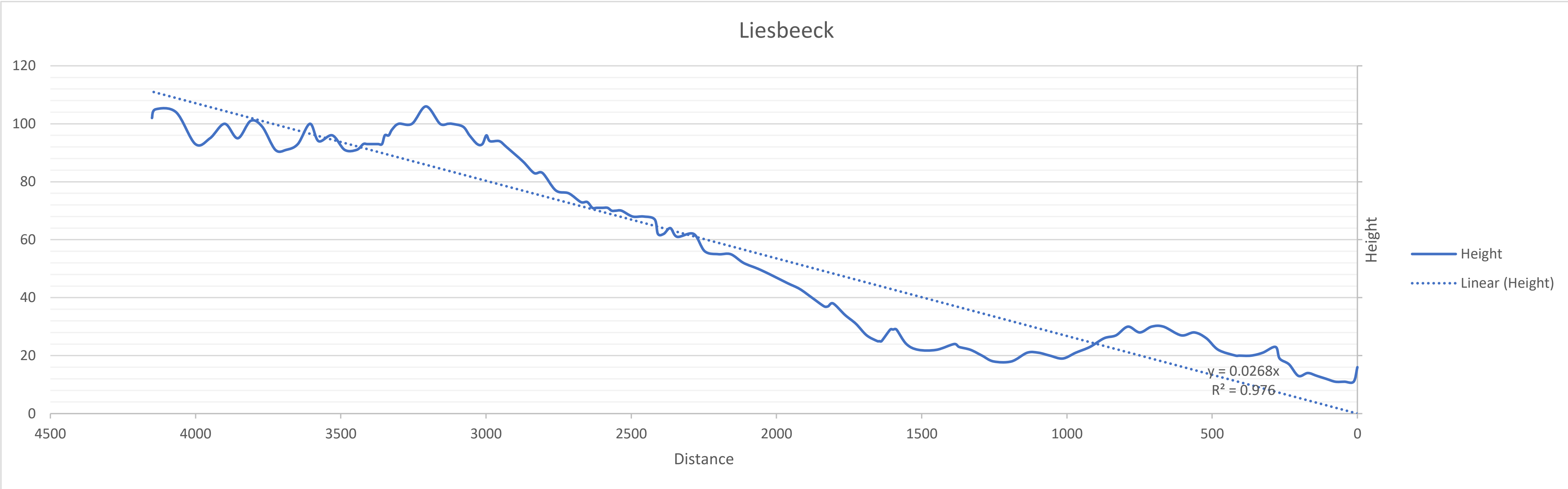
Steepest Incline Over shortest Distance
Height
Distance
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
y = -0.0448x + 105.67
R² = 0.9848
Series1
Linear (Series1)

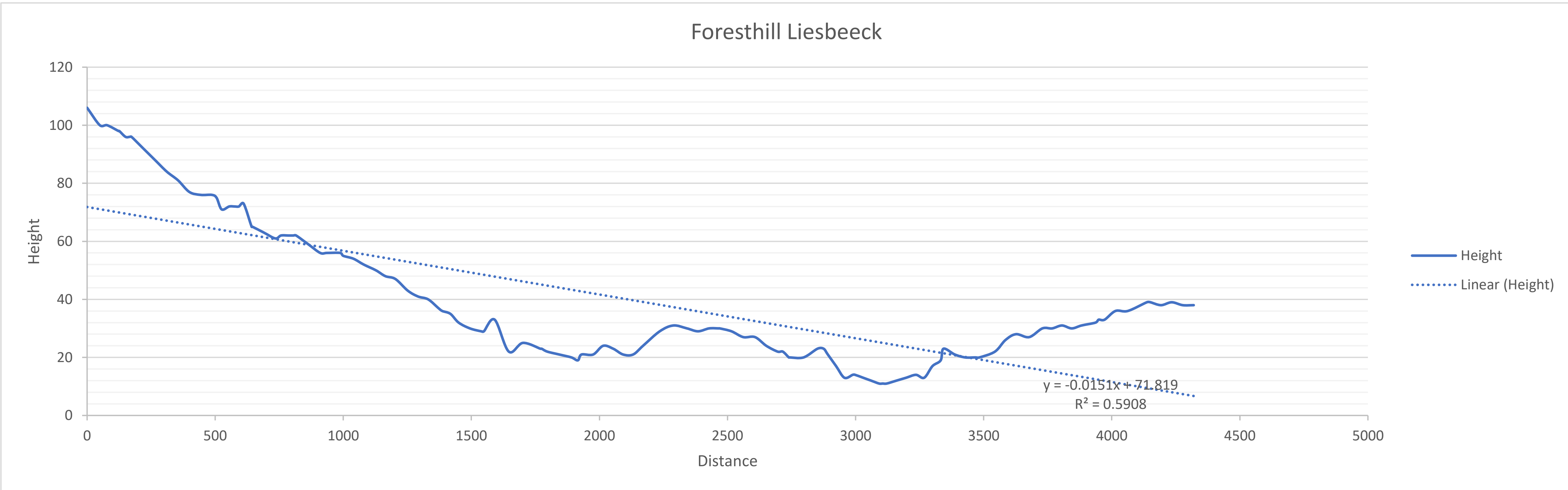


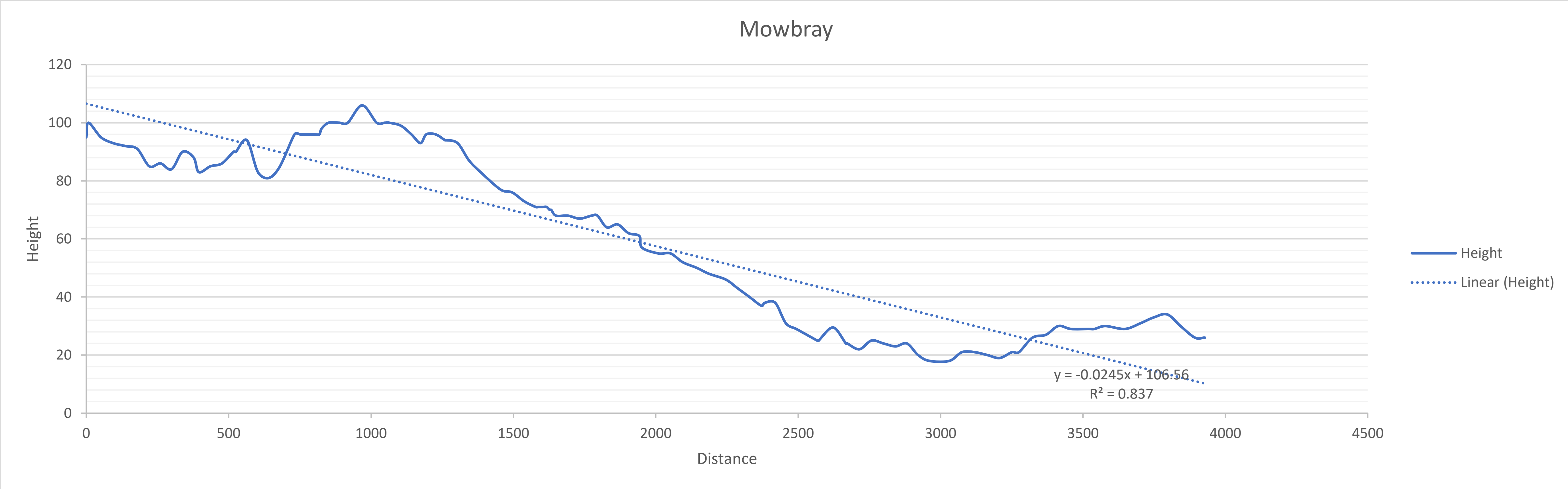
Bremmer
Axis Title
Axis Title
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
y = -0.0241x + 109.35
R² = 0.8166
Series1
Linear (Series1)


Tugwell
Height
Distance
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
y = -0.0297x + 112.74
R² = 0.8305
Height
Linear (Height)

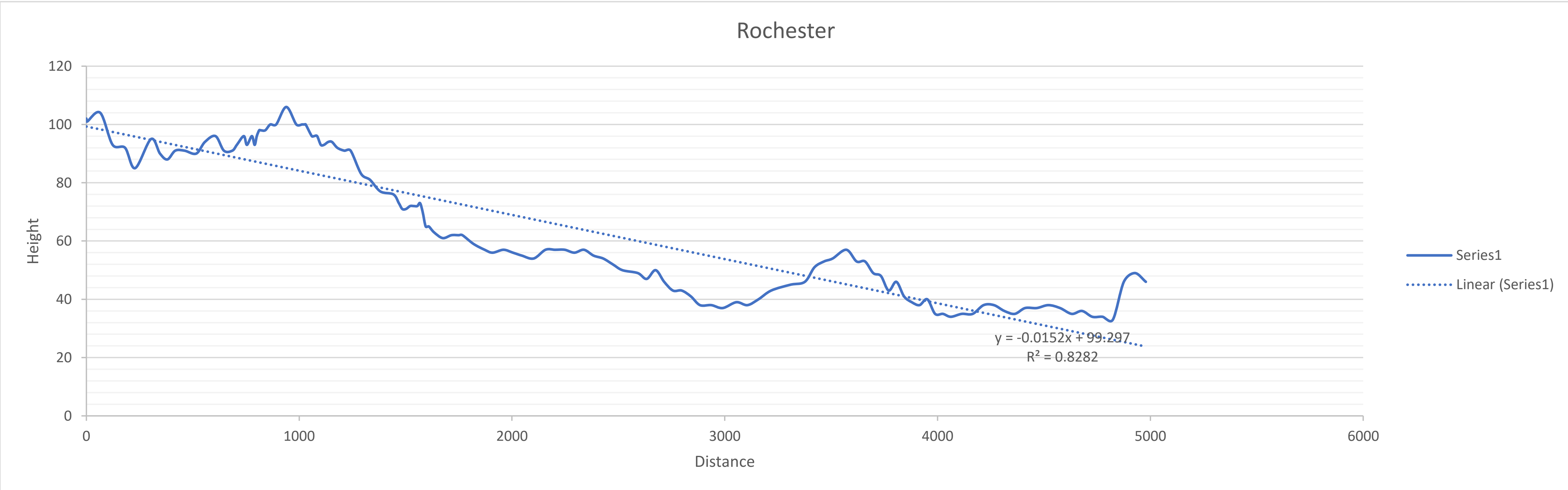

Claremont
Height
Distance
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500
4000
y = -0.0168x + 76.89
R² = 0.5107
Height
Linear (Height)


Liesbeeck
Height
Distance
y = 0.0268x
R² = 0.976
Height
Linear (Height)

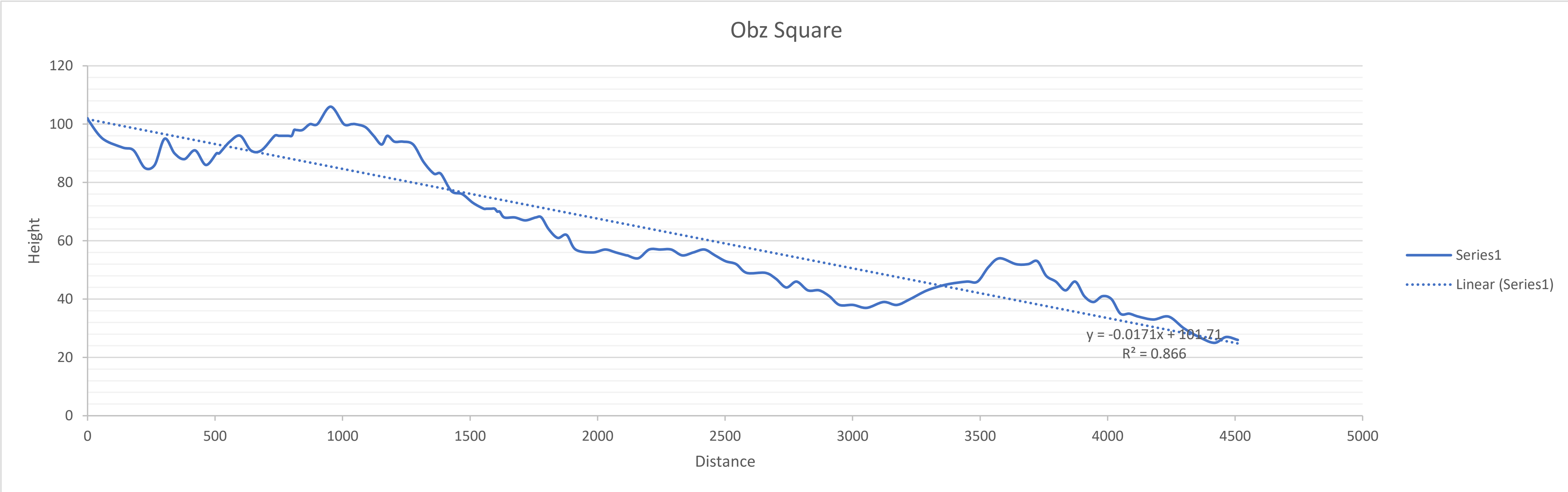

Foresthill Liesbeeck
Height
Distance
y = -0.0151x + 71.819
R² = 0.5908
Height
Linear (Height)

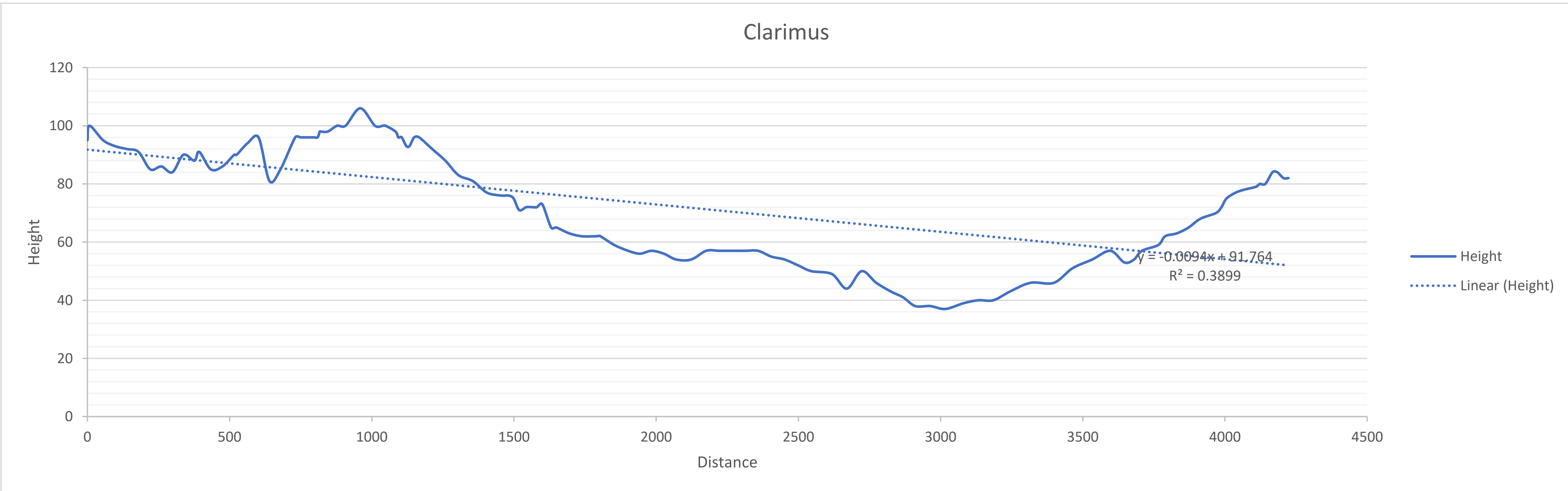


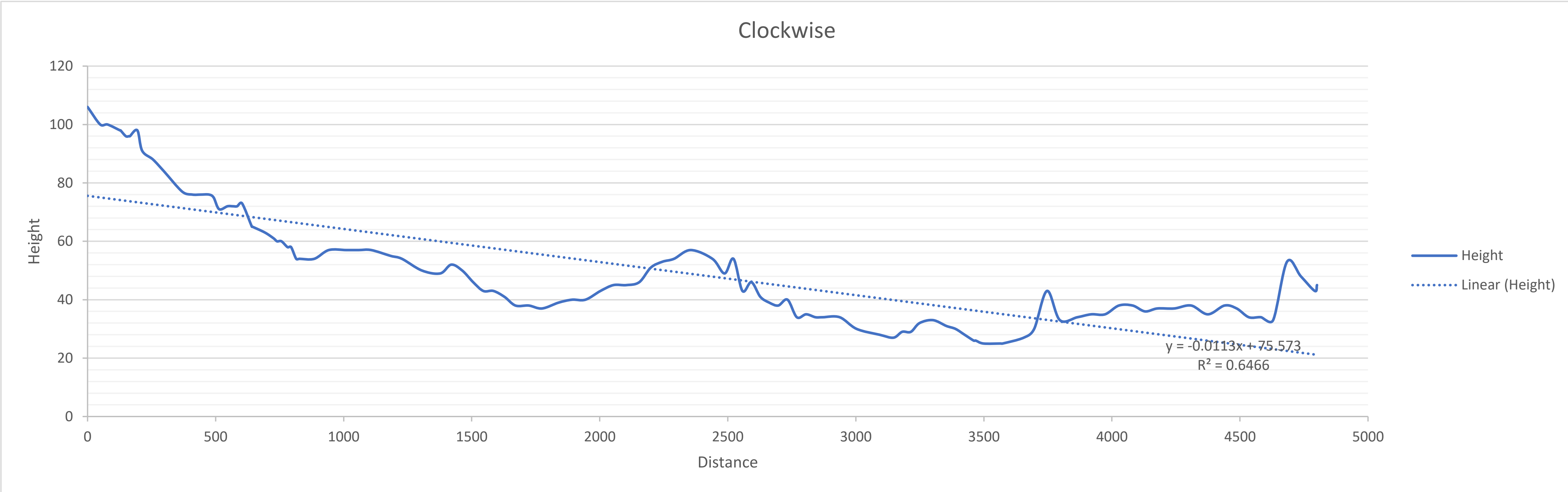
Mowbray
120
100
80
60
40
20
0
Height
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance
y = -0.0245x + 106.56
R² = 0.837
Height
Linear (Height)

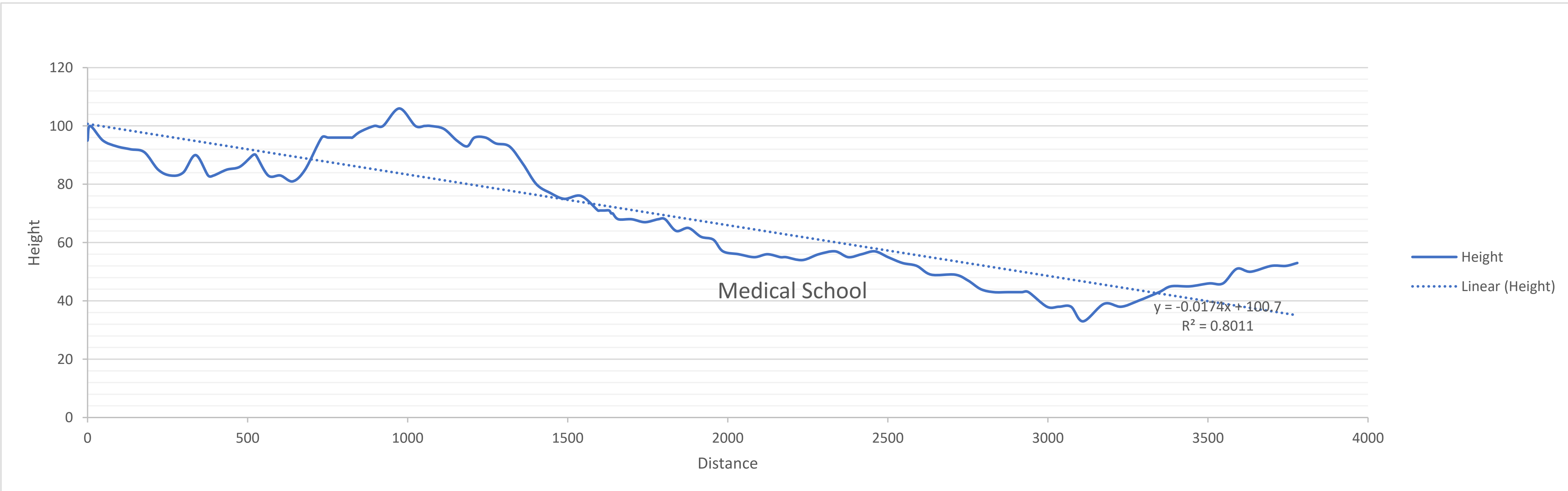


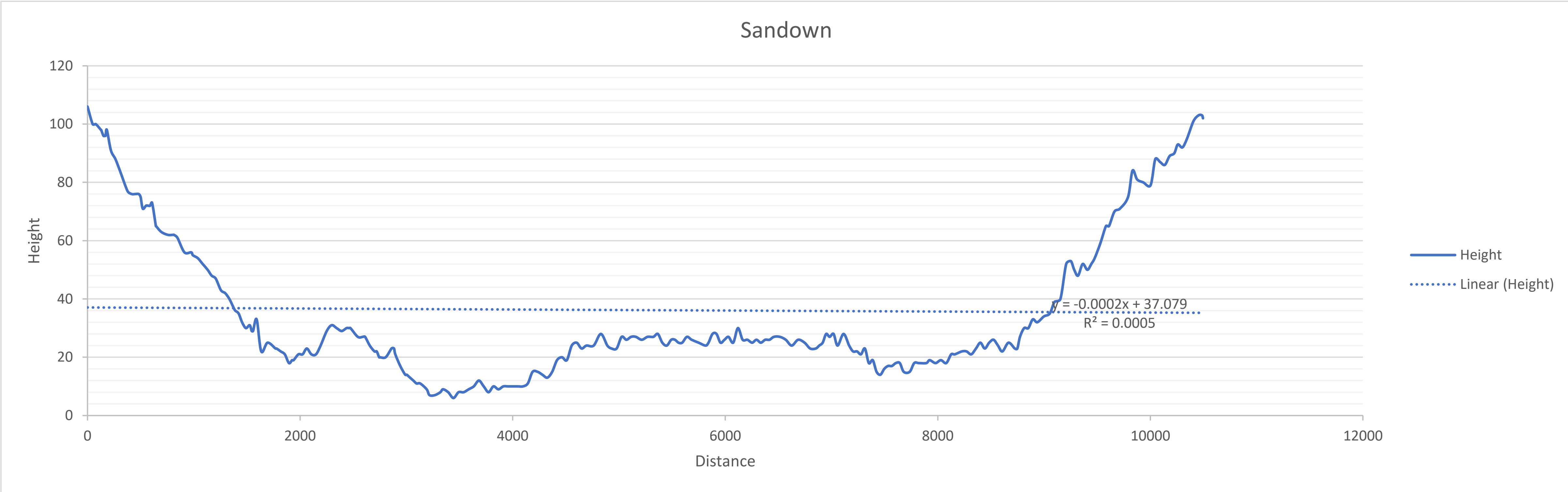
Rochester
120
100
80
60
40
20
0
Height
0
1000
2000
3000
4000
5000
6000
Distance
y = -0.0152x + 99.297
R² = 0.8282
Series1
Linear (Series1)

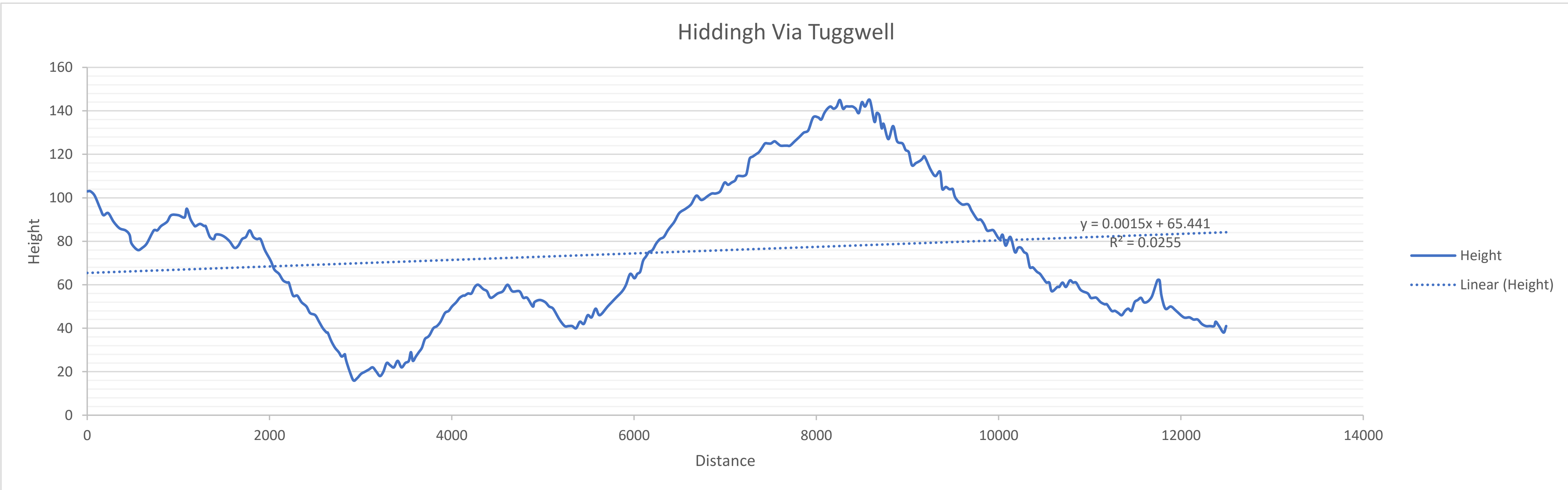

Obz Square
Height
Distance
y = -0.0171x + 101.71
R² = 0.866
Series1
Linear (Series1)
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

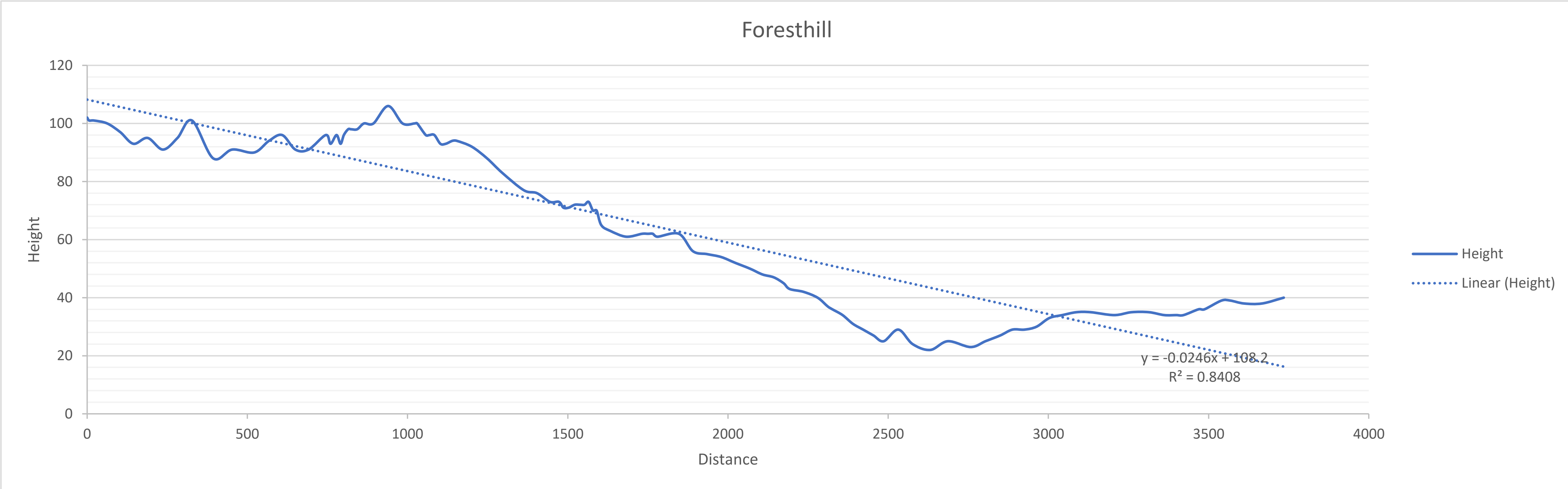

Clarimus
Height
Distance
y = -0.0094x + 91.764
R² = 0.3899
Height
Linear (Height)
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500


Clockwise
Height
Distance
Height
Linear (Height)
y = -0.0113x + 75.573
R² = 0.6466


Medical School
Height
Distance
Height
Linear (Height)
y = -0.0174x + 100.7
R² = 0.8011


Sandown
Height
Distance
120
100
80
60
40
20
0
0
2000
4000
6000
8000
10000
12000
y = -0.0002x + 37.079
R² = 0.0005
Height
Linear (Height)


Hiddingh Via Tuggwell
Height
Distance
160
140
120
100
80
60
40
20
0
0
2000
4000
6000
8000
10000
12000
14000
y = 0.0015x + 65.441
R² = 0.0255
Height
Linear (Height)



Foresthill
Height
Distance
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500
4000
Height
Linear (Height)
y = -0.0246x + 108.2
R² = 0.8408

Appendix E - Concept Design Drawing

STORMWATER

- EXISTING STORMWATER
- EXISTING STORMWATER MANHOLE
- EXISTING STORMWATER CATCHPIT
- PROPOSED STORMWATER
- SW — PROPOSED MANHOLE
- SWCP1 — PROPOSED CATCHPIT
- PROPOSED SUBSOIL DRAIN

FOULSEWER

- EXISTING SEWER PIPE
- EXISTING SEWER MANHOLE
- PROPOSED SEWER PIPE
- FS — PROPOSED SEWER MANHOLE

GENERAL

- DU — DU — PROPOSED DUCTS
- DMH1 — PROPOSED DUCTS MANHOLE

Structure Data: Pr Sewer

STRUCTURE NAME	Y–Coordinate	X–Coordinate	CL	IL
FSCP1	49650.599	3758699.446	80.432	79.567
FSMH1	49624.472	3758696.060	79.284	78.000
SEPARATOR	49657.432	3758690.950	81.631	79.310

Structure Data: Pr Stormwater

STRUCTURE NAME	Y–Coordinate	X–Coordinate	CL	IL
Existing Catchpit	49615.956	3758659.861	76.238	75.244
Kink 1	49641.518	3758666.110	77.268	???
SWCP1	49652.473	3758713.018	81.310	80.347
SWCP2	49649.161	3758689.026	79.739	78.501
SWCP3	49643.712	3758689.778	79.469	78.481
SWCP4	49638.264	3758690.530	79.212	77.794
SWCP5	49632.816	3758691.282	79.014	77.819
SWCP6	49627.615	3758676.805	77.842	76.805
SWMH1	49649.015	3758712.098	81.089	80.134
SWMH2	49645.755	3758688.486	79.589	78.432
SWMH3	49641.758	3758675.652	78.591	77.572
SWMH4	49636.218	3758685.201	78.938	77.680
SWMH5	49619.789	3758676.278	77.522	76.256

IMPORTANT NOTE:
NO SINGLE CONTROL POINT SHOULD BE USED IN ISOLATION. THE STATION USED MUST BE CHECKED AGAINST THE OTHER POINTS TO CONFIRM POSITION AND ELEVATION.

IMPORTANT NOTE:
ALL DIMENSIONS ARE TO READ AND NOT SCALED FROM DRAWING

FOR APPROVAL

REV	DESCRIPTION	DR.	CHKD	APP.	DATE
C	ENVIRONMENTAL AND TOWN PLANNING	MJ	DS	RLM	31 MAY 2019
B	ISSUED FOR COSTING	MJ	DS	RLM	09 NOV 2018
A	ISSUED FOR TENDER	MJ	DS	RLM	04 MAY 2018

	INITIALS	SIGN	DATE
DESIGNED	CvW		31 MAY 2019
DRAWN	MJ		31 MAY 2019
CHECKED	DS		31 MAY 2019
PROJECT ENG.	RLM		31 MAY 2019
APPROVED	RLM		31 MAY 2019

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CONSULTING ENGINEERS
Engineering African Development
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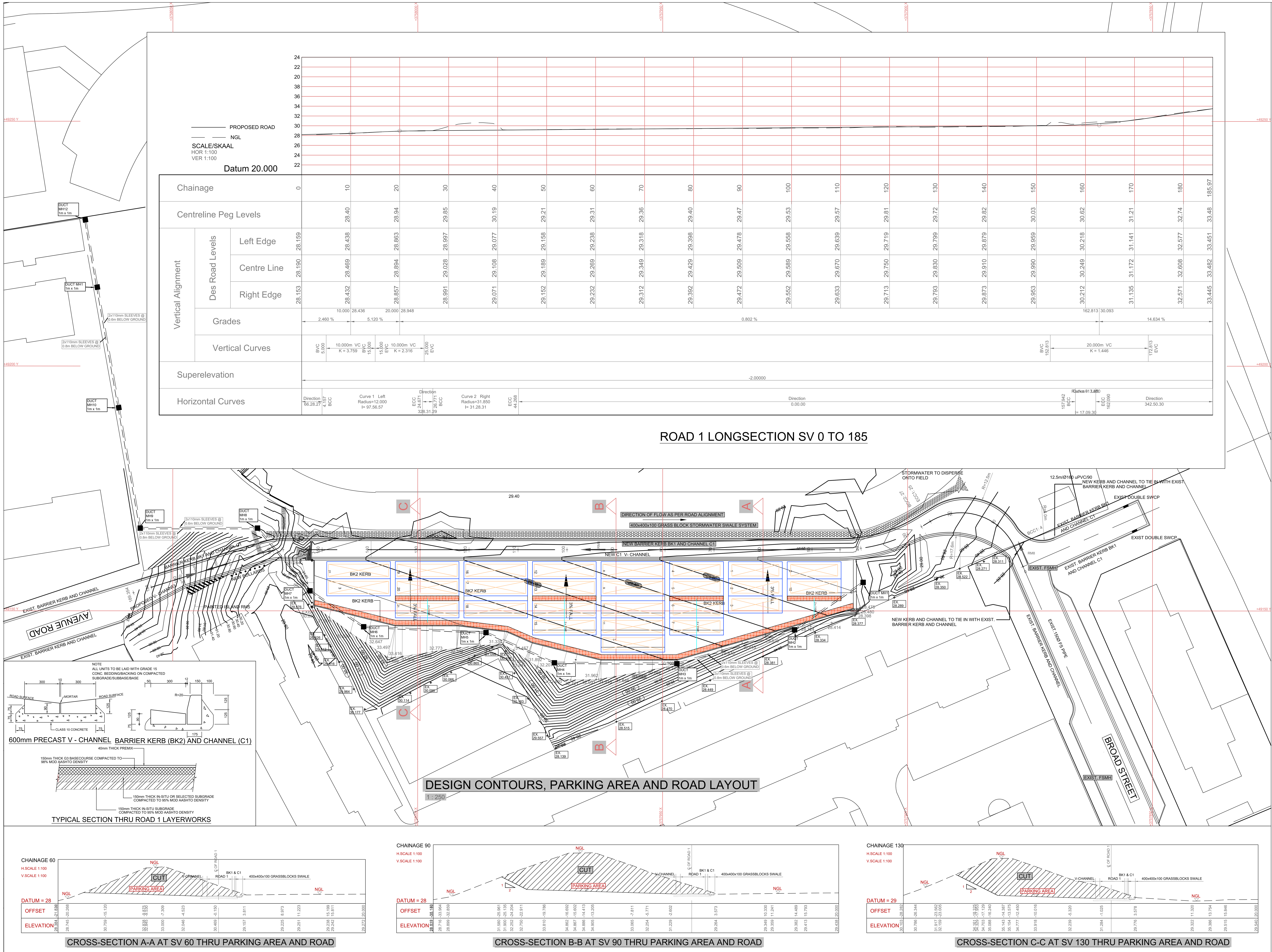
CLIENT
UNIVERSITY OF CAPE TOWN
PROPERTY AND SERVICES

PROJECT
UPPER CAMPUS
BUS TERMINAL

TITLE
NORTH BUS TERMINAL : SERVICES LAYOUT

SCALE : 1:100 | A0

DRAWING No. 15036T–1500 | REV C



ROAD 1 LONGSECTION SV 0 TO 185

Chainage	Centreline Peg Levels	Left Edge	Centre Line	Right Edge
0		28.159	28.190	28.153
10	28.40	28.438	28.469	28.432
20	28.94	28.863	28.894	28.857
30	29.85	28.997	29.028	28.991
40	30.19	29.077	29.108	29.071
50	29.21	29.158	29.189	29.152
60	29.31	29.238	29.269	29.232
70	29.36	29.318	29.349	29.312
80	29.40	29.398	29.429	29.392
90	29.47	29.478	29.509	29.472
100	29.53	29.558	29.589	29.552
110	29.57	29.639	29.670	29.633
120	29.81	29.719	29.750	29.713
130	29.72	29.799	29.830	29.793
140	29.82	29.879	29.910	29.873
150	30.03	29.959	29.990	29.953
160	30.62	30.218	30.249	30.212
170	31.21	31.141	31.172	31.135
180	32.74	32.577	32.608	32.571
185.97	33.48	33.451	33.482	33.445

Grades: 2.460 % (to 10.000 / 28.436); 5.120 % (to 20.000 / 28.948); 0.802 % (to 162.813 / 30.093); 14.634 %

Vertical Curves: BVC 5.000 – 10.000m VC K = 3.759 – BVC 15.000; 15.000 EVC – 10.000m VC K = 2.316 – 25.000 EVC; BVC 152.813 – 20.000m VC K = 1.446 – 172.813 EVC

Superelevation: -2.00000

Horizontal Curves: Curve 1 Left Radius=12.000; Curve 2 Right Radius=31.850; Direction 0.00.00; Direction 342.50.30

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e-mail: consult@bergstan.co.za www.bergstan.co.za

PROJECT/PROJEK
UCT TEMPORARY BUS PARKING
MOWBRAY
CAPE TOWN

TITLE/TITEL
ASTRO PARKING LAYOUT

PRINCIPAL AGENT/HOOFAGENT

DESIGNED/ONTWERP	R.V.W.
DRAWN/GETEKEN	R.V.W.
CHECKED/NAGESIEN	G.K.H
DIRECTOR/DIREKTEUR	G.K.H

SCALE/SKAAL	DATE/DATUM	SIZE/GR
1:250	OCT 2021	A0

DRAWING No. / TEKENING Nr.	REV/WYS
1851 - C - 001	T2

FOR COUNCIL APPROVAL

Appendix F - Charger Datasheets

SIEMENS

SICHARGE UC

Powerful charging solution for your electric fleet

siemens.com/sichargeuc

IEC Standard

The SICHARGE UC family

Powerful and reliable, the SICHARGE UC product family takes care of a diverse mix of electric vehicles with high power demand. It provides you with a technical solution that fits your specific needs and ensures the highest availability of your fleet.

SICHARGE UC with its multiple connection options furnishes you with modular building blocks and freedom to choose between Dispensers and high power automated charging with Pantographs or Hood, thus overcoming space constrains.

Interoperability and future proof up to 1000 V
To ensure flexibility in electrifying your fleet – today & tomorrow

Robust, durable, outdoor designed
To ensure longevity of equipment, easy outdoor usage with IP54 and highest fleet availability

Flexible and space-saving
To easily integrate into existing depot with constraints in HW, SW or layout

Optimized CAPEX and OPEX
To realize the most competitive solution and efficiently manage your daily operation

High power for your electric fleet

Keeping an electric fleet charged and running efficiently requires the distribution of high power in an intelligent way. The SICHARGE UC product family provides the right technical solutions for your business needs. It depends on the routes, charging schedules and location of electric vehicles when and where charging is most reasonable and efficient.

Depot charging

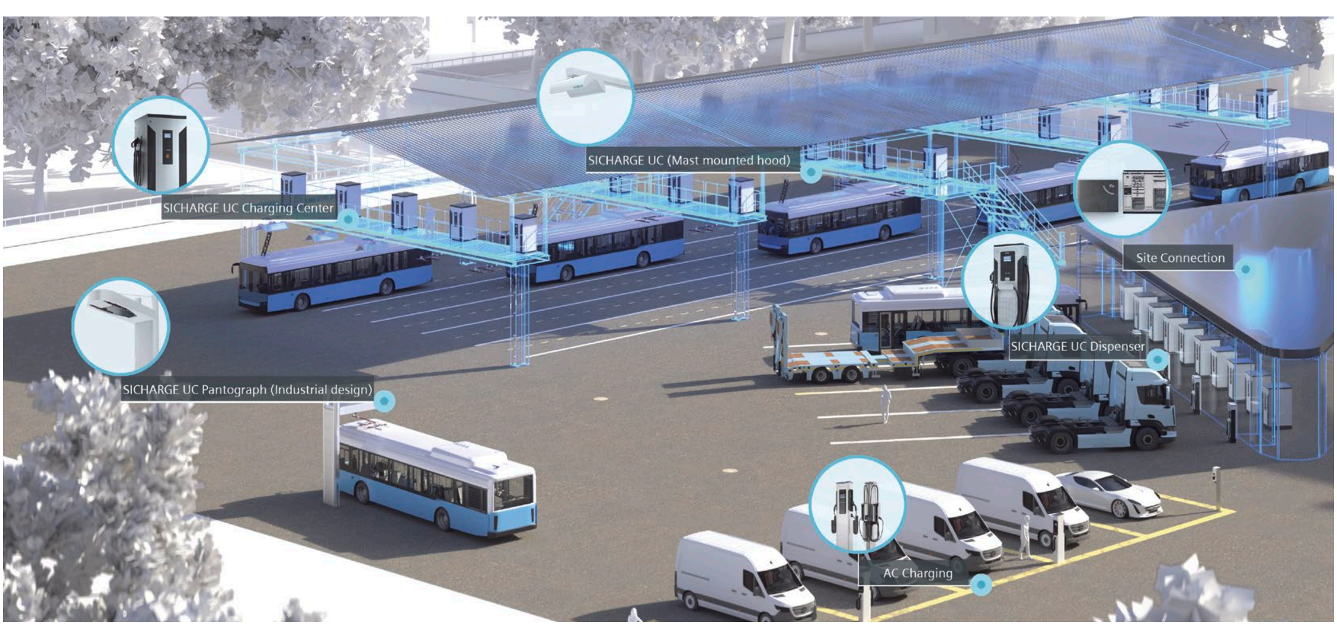
In a central depot, vehicles generally spend some hours during a day or night and can be sequentially charged as per the needs of their schedule.

Charging directly from a SICHARGE UC compact charger or sequentially connected Dispensers is well suited for overnight charging at the depot.

Opportunity charging

High power automated charging with Pantographs or contact Hoods is the optimal solution for ultra fast charging and shorter charging cycles.

This solution can either be implemented for on-route charging or in the depot when tight schedules need to be considered.



Charging setup tailored to your needs

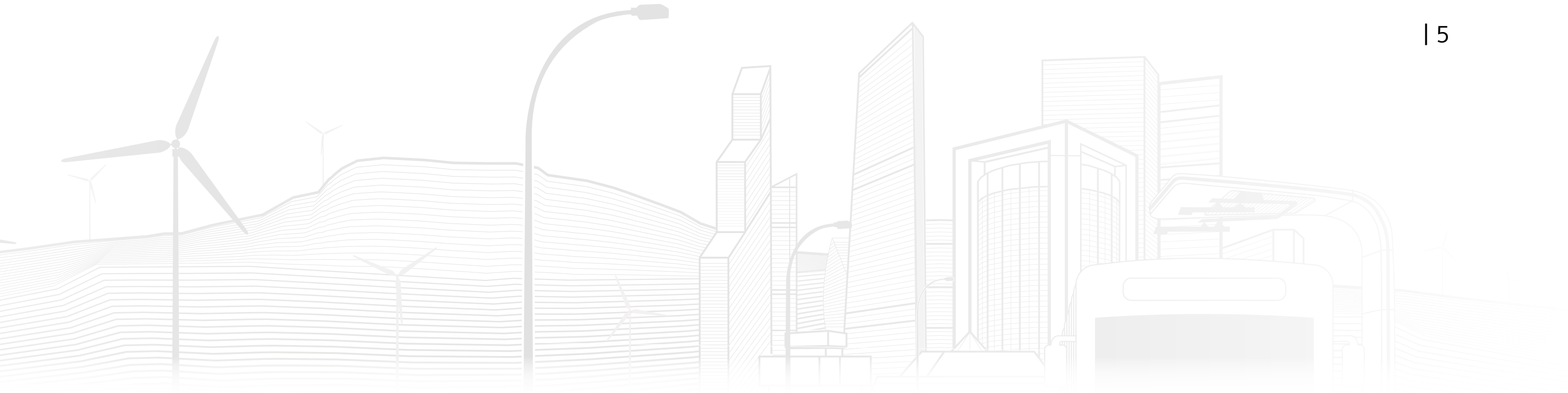
Flexible configuration options

Compact charging

SICHARGE UC 100C or 200C compact charger with integrated cable – simple and direct connection with your eVehicle.

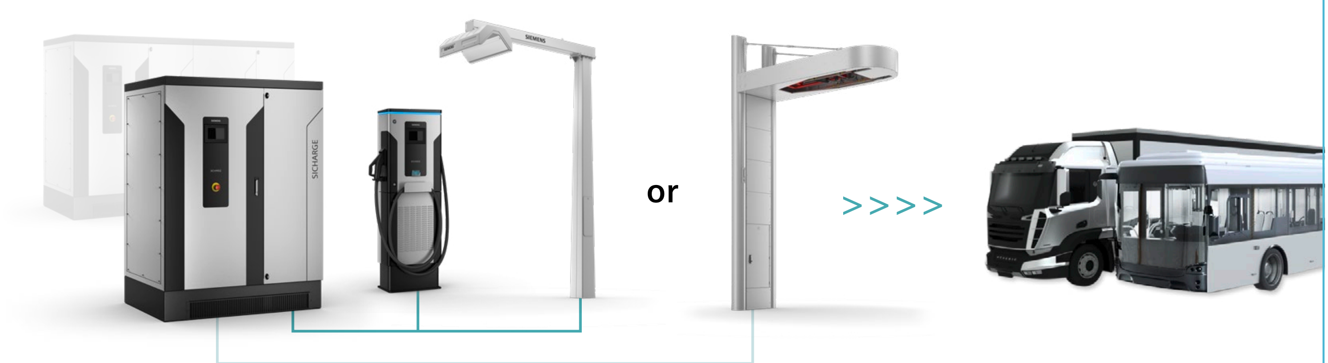
Sequential charging

SICHARGE UC 100 to 400 with up to 5 air-cooled or 3 liquid-cooled Dispensers or automated contact Hoods connected sequentially.



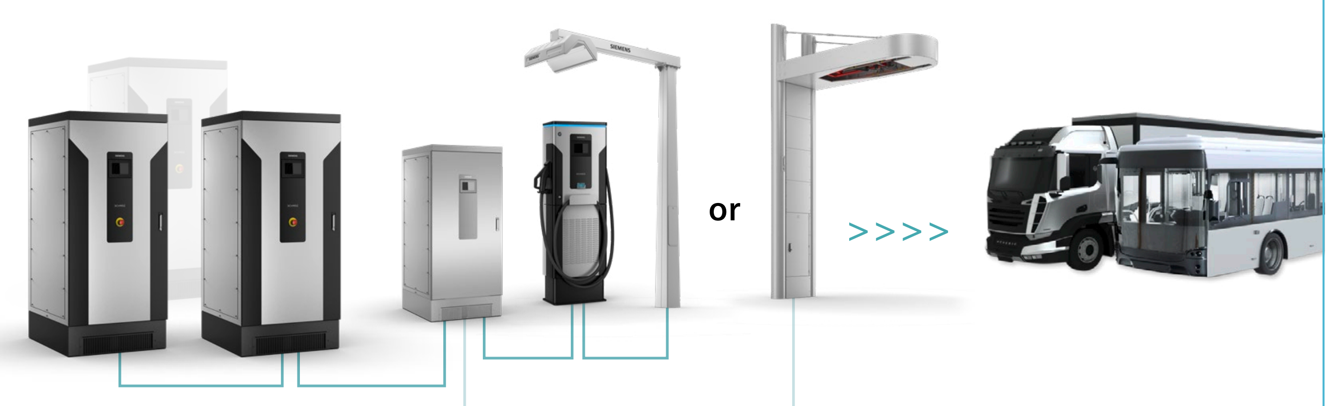
Ultra high power charging

SICHARGE UC up to 800 kW can be connected to liquid-cooled Dispensers or automated contact Hoods or Pantograph sequentially.



Implementation of charging flexibility – project specific

The SICHARGE UC family can adopt to your individual needs through flexible combination in a switching matrix.



State-of-the-art technology

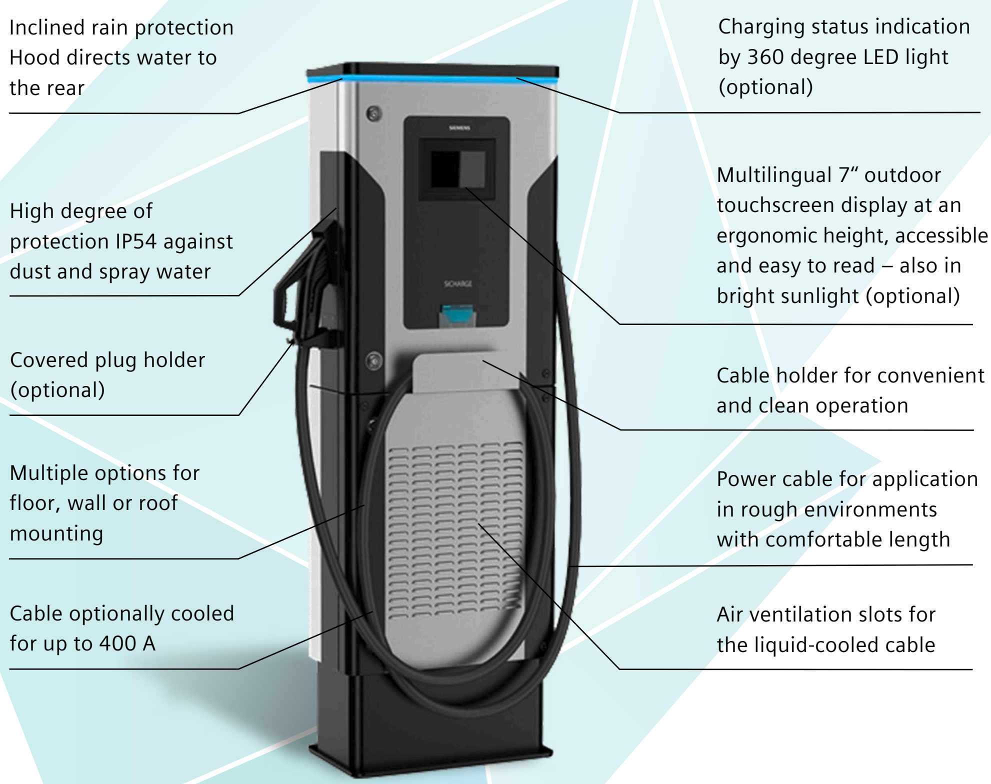
Charging Center

The Charging Center is the core of your system. It contains the charging controller, the DC converters and optionally a direct cable connection to the vehicle. Several other vehicle connections like the cable based Dispenser, inverted Pantograph and Hood can be powered by this unit.

Dispenser

The cable connected Dispenser of the UC family is installed close to the vehicles connection with a small footprint and elegant design.

For investment and space optimization, several Dispensers can be powered in sequence by a single Charging Center.



Inverted Pantograph

MastPanto – industrial design
MastPanto – urban design

The inverted Pantograph is a fully automated option to connect to the fleet e.g. on feeding opportunities along the route.

Industrial design

Urban design

Cantilever arms available in short or long with a large variety of colors to fit individual environment of the city

WLAN antenna for the secured and reliable Wi-Fi communication to charging infrastructure

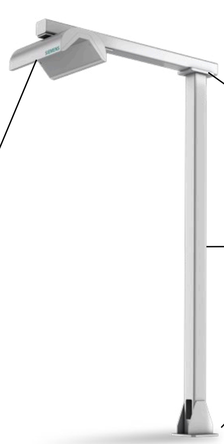
LED signal lamp to indicate the status of charging

Inverted Pantograph

Easy maintenance access through the door, 230 V sockets inside

Robust charger mast

Baseplate for safe attachment to the foundation



Connection Hood with insulated 4-pole contact

Cantilever arm

Lightweight mast and simple architecture easy to set up

Baseplate for safe attachment to the foundation

Mast mounted Hood

For electric vehicles with integrated Pantograph, the Hood is the connecting counterpart. The Hood is available in two variants: mounted on a mast or directly under the ceiling.

Technical data

	SICHARGE UC Compact charger & Charging center	SICHARGE UC Charging center	SICHARGE UC High power charger

SICHARGE UC	100 C / 100	200 C / 200	400	600	800
Vehicle interface					
Integrated cable	CCS	CCS	-	-	-
Air-cooled CCS cable Dispenser	×	×	-	-	-
Liquid-cooled CCS cable Dispenser	-	-	×	-	-
Mast mounted Hood	×	×	×	×	×
Mast mounted (inverted) Pantograph	-	×	×	×	×
Nominal input					
Voltage, V AC	400 (3ph + PE) ± 10 %				
Current at nominal voltage per phase, A	152	228	456	683	911
Frequency, Hz	50*				
Power factor (cos phi)	> 0.98				
DC output**					
Peak power, kW (@1000 V DC)	125	200	400	600	800
Rated power, kW	100	150	300	450	600
Current (max.), A	125	200	400	600	800
Voltage (range), V DC	10 ... 1000				
Efficiency factor η (at load 100%), %	≥ 96				
Environmental conditions					
Operating temperature and humidity	-25 ...+45 °C (can be extended upon request) and up to 95% relative humidity (noncondensing)				
Max. operating altitude, m	2000 (without derating)				
Mechanical specifications					
Operational environment	Indoor and outdoor				
Protection enclosure	IP54, IK10 for housing, IK 09 for HMI				
Casing material	Galvanized steel, painted, C3				
Color	Main housing: RAL 9006 – White aluminium; roof and base: RAL 9017 – Traffic black matt				
Overall dimensions W x D x H, mm	746 x 898 x 1800	929 x 1109 x 2000	1526 x 1109 x 2000	3052 x 1109 x 2000	
Approx.weight, kg	1000	1400	2780	4120	5560
General specifications					
Charge control unit	Siemens controller				
Local user interface	7" touchscreen HMI (optional)				
User authentication	RFID (optional)				
Network connection	Ethernet interface / 3G / 4G				
Electric safety device	RCD B-type (optional)				
Communications protocol	OCPP 1.6 (J-SON)				
Cable lengths	3.5 / 6 / 10 m				
Charging standards	EN 61851-1/23/24, ISO 15118 (DIN 70121)***				
EMC standards	EN 55016-2-1 & -3; EN 61000-4-2 & -3 & -4 & -5 & -6				
CE-Certification	Yes				

*60 Hz upon request

**Details available in the technical manual

***Complies with ISO15118-1 standard use-cases, further use-cases being implemented

	SICHARGE UC Dispenser		**SICHARGE UC Mast mounted Hood**	**SICHARGE UC Inverted Pantograph**
	Air-cooled	Liquid-cooled		

Connection options	**Dispenser**		**Mast mounted Hood**	**Inverted Pantograph**		
Design variants	**Air-cooled cables**	**Liquid-cooled cables**	**ID Industrial design**	**UD Urban design** (optional*)	**ID Industrial design**	**ID-E Industrial design-extended**
DC output**						
Connection standard	CCS type 2		CCS	OPPCharge		
Peak power, kW	125 / 200	400	800	800		
Rated power, kW	100 / 150	300	600	600		
Current, A	125 / 200	400	500	800		
Voltage (range), V DC	10...1000					
Environmental conditions						
Operating temperature and humidity	-25 ...+45 °C (can be extended upon request) and up to 95% relative humidity (noncondensing)					
Max.operating altitude, m	2000 (without derating)					
Mechanical specifications						
Protection	IP54, IK10 for housing, IK 09 for HMI					
Height, installed, mm	2000 (915 for wall mounting)		5000	5805	6573	6573
Road clearance, mm	n/a		4635	4550 to 4650		
Cantilever length, mm			3500	3955	4200	5200
Approx. distance mast to curb, mm			1900	1400	1400	2400
Footprint on sidewalk, mm	600 x 300		350 × 300	940 × 315	1300 × 330	1300 × 330
Operating range Pantograph, mm	n/a		n/a	900		
Approx. weight, kg	95 (60 for wall mounting)	180	900	1975	1870	2300
Color	Main housing: RAL 9006 – White aluminium; roof and base: RAL 9017 – Traffic black matt		RAL 9006 – White aluminium			
Material	Galvanized powder coated steel		Galvanized steel, painted, min. C3	Galvanized steel with fiber glass panel	Galvanized steel, painted, min. C3	
General specifications						
Communication standard	PLC		PLC	WiFi IEEE 802.11a		
Number of possible connectors (sequential charging)	up to 5		2***	1		
User authentication	RFID (optional)		n/a	RFID (optional)		
Cable lengths, m	3.5 / 6 / 10	3.5 / 5	n/a	n/a		
CE-Certification	Yes					
Network connection	Ethernet interface / 3G / 4G					
Local user interface	7" touchscreen HMI (optional)		n/a	n/a		
Charging status indication	LED (optional)		LED	n/a		

* Upon a project-specific request
** Details available in the technical manual
*** eVehicle under the Mast Hood will be given priority in charging sequence

More than charging

Experience peace of mind

We offer you world-class services and support throughout the entire lifecycle of your charging equipment, thus assuring the maximum uptime and highest availability of your chargers.

Service packages

Our cloud-based service packages Care and Care Plus look after your chargers using the dedicated Siemens service backend.

Care

The basic Care package is included during the warranty period and can be extended by subscription.

It ensures that firmware updates keep your chargers up to date as eMobility continues to evolve. Remote analyses and diagnostics are performed by our support center on demand.

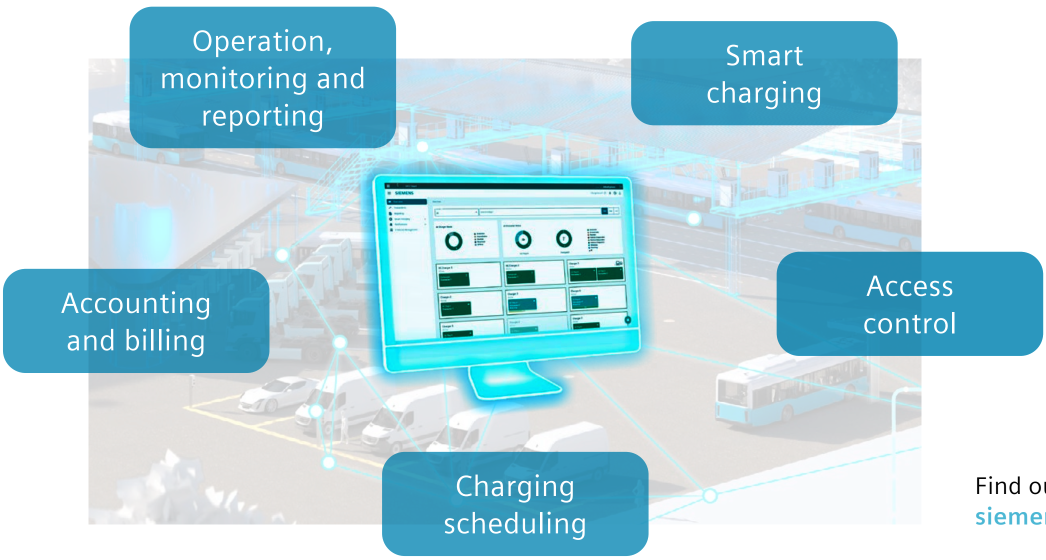
Care Plus

Enjoy all Care digital services and even more with our Care Plus package. Your charger will be proactively monitored and analyzed by our operation center. Firmware updates will be delivered with priority.

Managing charging of your fleet

Benefit from Siemens digital solutions

Together with the charging equipment, our best-in-class software services ensure smooth, reliable and efficient operation of your electric fleet.



Find out more at
siemens.com/emobility

From planning to operation

Superior support throughout the lifecycle

Intelligent planning: we support your depot electrification starting from the expert consultancy and depot planning including the charging simulation.

Smart infrastructure: benefit from our comprehensive charging portfolio which includes DC and AC equipment as well as advanced solutions for the power connection of your site.

Managing the operations: Siemens software suite offers everything you need to manage charging of your electric fleet intelligently and efficiently.

Rely on us – we care: during the whole lifecycle our cloud-based service packages Care and Care Plus look after your chargers to ensure highest availability of your fleet.

Siemens AG
Smart Infrastructure
Distribution Systems

Mozartstrasse 31c
91052 Erlangen, Germany

Article No. SIDS-B10059-00-7600

Never stop moving!

Terra 360. The EV charger designed for users on the move, busy urban locations and fleets of commercial vehicles.

- The world's fastest high power charger, delivering up to 360 kW
- Charge up to four vehicles simultaneously
- Innovative design suitable for all parking configurations

At ABB, we have 130 years of heritage in accessible technology leadership and a world-leading AC and DC charging portfolio – for safe, smart and sustainable mobility.

That's why some of the world's biggest brands trust us to provide market-leading e-mobility solutions from home to highway to workplace.

Terra 360

Designed around the needs of urban spaces and today's EV driver

Municipalities are banning internal combustion vehicles from the city centers

Delivery and taxi companies are electrifying their fleets

Gas & oil companies are embracing electric car charging, electricity is a new type of fuel

Distributed fast charging in residential areas is an alternative to traditional refueling stations

500 different EV models available globally by 2022 with the sale of EVs estimated to reach close to 10 million by 2025

Cities are investing into high power charging infrastructures for private and public transports

Retail chains are investing in fast charging offering customers a full charge in exchange of an extended visit to the store

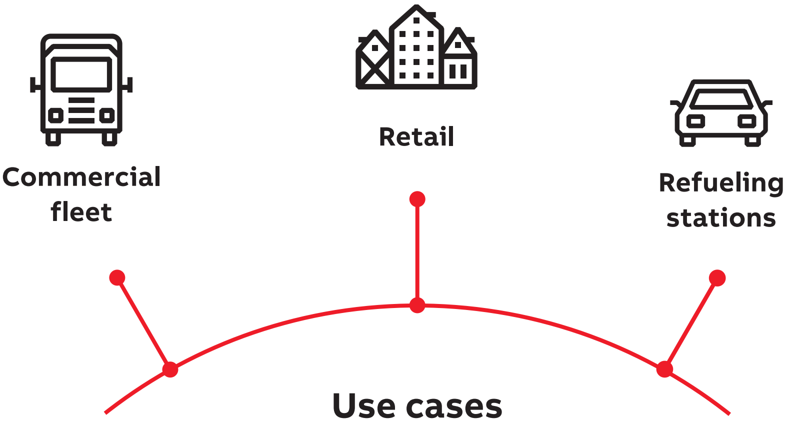
Terra 360
The high-power charger for everyone

The Terra 360 is the fastest all-in-one charger on the market. Designed around the needs of today's EV driver, the Terra 360 is powerful, flexible, user-friendly and designed for accessibility.

Key features
- "All-in-one" integrated design
- Up to 360 kW of charging power
- Modular and scalable in 30 kW steps
- Serving multiple EVs at the same time
- Dynamic power allocation across the outlets
- Supporting the major charging standards
- CCS charging up to 500A (liquid cooled option available in 2022)
- The only charger that can serve a high performance car, such as the Porsce Taycan, at full power (270 kW) and charger a second vehicle (90 kW)
- Serving up to four vehicles at the same time (available from 2022)
- Charging batteries up to 920 Vdc
- Integrated cable management system
- Five meters of cable reach on all sides of the charger
- 15" touchscreen user interface
- Optional 27" advertisement screens
- Optional credit card payment terminals
- Native support to OCPP 1.6 JSON
- Easy and fast installation and commissioning
- Online and local service and configuration tools
- Native integration to ABB site and fleet power management solutions

A smart and sustainable investment

ABB's Terra 360 is the world's most powerful and compact all-in-one high power charging solution, helping charging network operators deploy fast-charging stations and accelerate the transition to future mobility.



Commercial fleet	Delivery fleet depots, Taxi, EV fleet depots
Retail	Modern urban charging stations, convenience stores, supermarkets, shopping centers, parking structures, car dealerships, racetracks, car dealerships
Refueling stations	Highway refueling stations, high traffic roads

Terra 360 benefits

Best in class charging performance

- 100 km of range in less than 3 minutes
- Dynamic power allocation
- Sharing power to serve up 4 vehicles
- Up to 500A on every outlet

Designed for flexibility

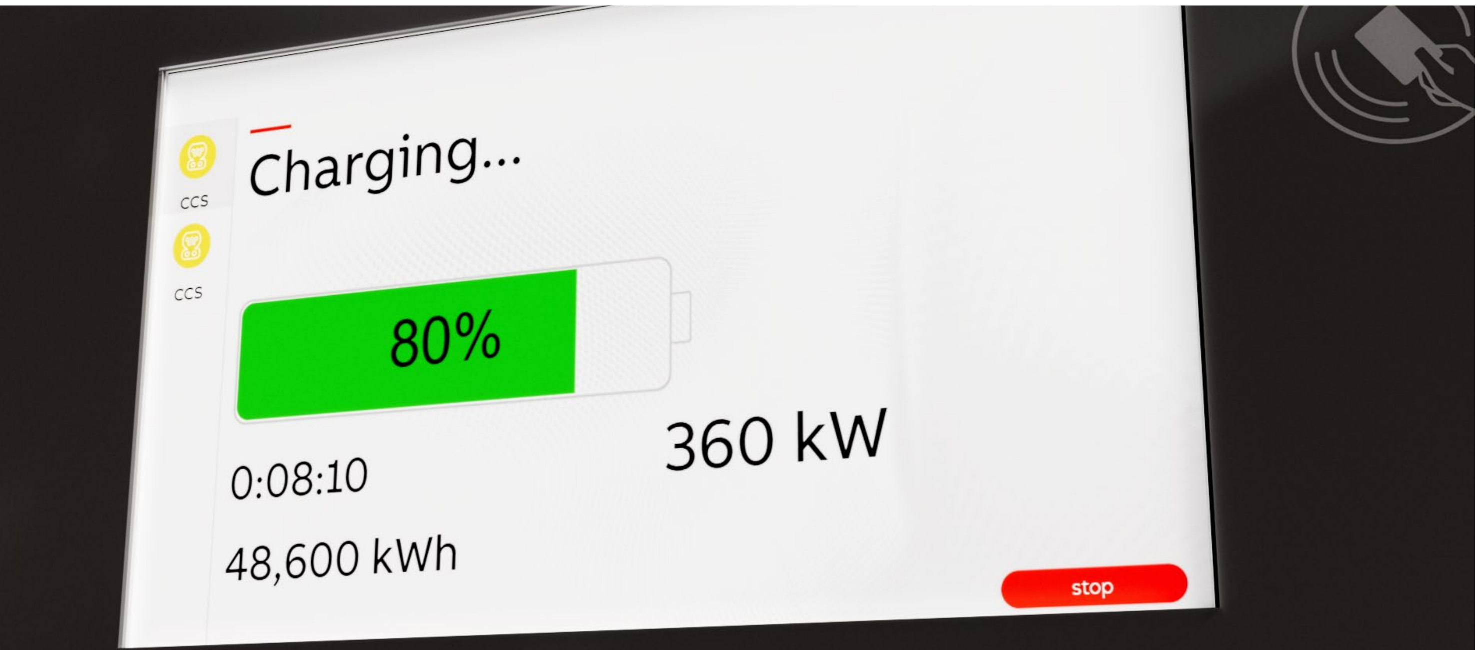
- Various parking configurations possible
- Wide range of customization options
- Power modularity from 90 kW up to 360 kW
- Supporting all charging standards

Accessible to everyone

- Start charging in seconds with Plug&Charge functionality
- Serving all EV models due to long cable reach
- Cables always ready with integrated retraction system
- Designed to be wheelchair user friendly

User centric design

- Simple and intuitive user interface
- User guided by the innovative LED lighting system
- Entertainment and information with the optional advertisement screen
- Easy branding and colour customization

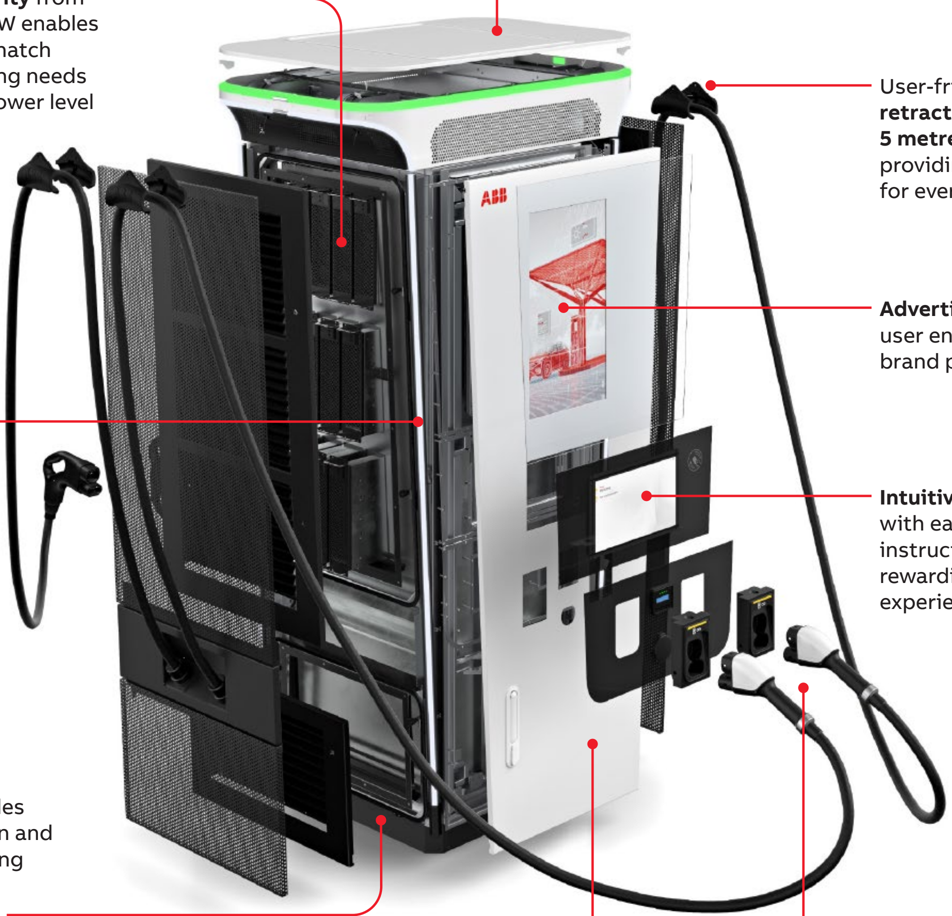


The Terra 360 all-in-one high-power charger

At a glance

Connected to all the major back-ends via OCPP

Power modularity from 90 kW to 360 kW enables customers to match specific charging needs and increase power level when required



User-friendly **cable retraction system** and **5 metres long cable reach** providing accessibility for everyone

Advertisment screen for user engagement and brand promotion

Innovative lighting system shows the charger availability and the State of Charge (SOC) of the connected EVs

Intuitive user interface with easy-to-follow instructions ensures rewarding customer experience

Small footprint provides flexibility in installation and enables multiple parking scenarios (frontal and drive-though parking)

Charger designed to meet everyone's charger needs, **accessible to everyone** (including wheelchair users)

Connectors available in multiple standards and delivering up to 500A (CCS) with air or liquid cooled technology

CHARGING POWER

CCS charging up to 360 kW
CHAdeMO charging up to 150 kW
AC Type-2 up to 22 kW

POWER CONFIGURATIONS

360 / 240 / 180 / 120 kW
(Upgradable with extra modules)

DIMENSIONS

Height 2200 mm
Width 720 mm
Depth 710 mm

Technical specification

Charge post	
Charging type	Fast / high power charging
Localization	CE UL (2022)
Outlet options	
Outlet 1	1. CCS 500A 2. CCS 500A liquid cooled (2022)
Outlet 2	1. CCS 500A 2. CCS 500A liquid cooled (2022)
Outlet 3 (Optional available from 2022)	1. CCS 500A 2. CHAdeMO 200A
Outlet 4 (Optional available from 2022)	1. CCS 500A 2. CHAdeMO 200A 3. AC Type-2 22 kW
Input AC power rating	560 A, 385 kVA @ 50 Hz
Input voltage range	400 VAC +/- 10% (50 Hz or 60 Hz)
Max DC output power rating	360 kW
Max AC output power rating (optional)	22 kW
DC output voltage	150-920 Vdc
Number of EV served	Base model up to two, optionally up to four (2022)
Cable length	5.5 meters
CCS cables maximum current	500 A (air cooled, liquid cooled option available from 2022)
CHAdeMO cables maximum current	200A or 125A (available from 2022)
Network type	TN-S, TN-C, TN-C-S, TT (with upstream RCD)
Connector types	3P + N + PE
Protection	Overcurrent, overvoltage, undervoltage, ground fault including DC leakage protection, integrated surge protection
Overvoltage category	Type II
Power factor (full load)	> 0.96
THDi	< 4.5%
Efficiency	> 95% (peak)
Standby power	80 W
Short circuit current	>60 kA
Pre-charge current	< 1 A
Inrush current	< 100 A
Leakage current	30 mA
Energy metering	MID and Eichrecht compliant meters available as option from 2022
Cellular communication	GSM / 4G / LTE
Modem	Embedded cellular modem. Second modem available as option

User interface	
Connectivity	Internet access via 4G / 3G / Ethernet (RJ45)
User authentication	App, ISO 15118 Plug'n'Charge, RFID, PIN code
User interface	15" LCD high-contrast touchscreen
Number of user interfaces	Front (standard). Rear (optional)
Communication protocols	OCPP 1.5, OCPP 1.6 JSON
RFID Reader	ISO 14443 A + B to part 4 and ISO/IEC 15693, Mifare, NFC, Calypso, Ultralight, PayPass, HID; and more
Emergency button	Yes, option available
Configuration	
Software update	Over-the-air updates via ABB web portal
Control and configuration	ABB web portal, on-board Service Portal, OCPP 1.6
Multilanguage system	English, Italian, Spanish, Germany and more than 50 languages available and new languages configurable via ABB Web Tool
General characteristics	
IP and IK rating	IP-54 and IK-10 (cabinet) / IK-8 (touchscreen)
Enclosure type	Stainless steel 430 and Aluminium
Operational altitude	Up to 2000 m
Operating temperature range	-35 C to + 55 C (power de-rating applies)
Storage temperature range	-40 °C to +70 °C
Humidity	20-95 % Rh non-condensing
Mounting	Free-standing cabinet
Dimensions (H x W x D)	2200 x 720 x 710 mm
Weight	700 kg
Certification and standards	
Charging system	IEC 61851-1 ed 3, IEC 61851-21-2 ed 1, IEC 61851-23 ed 1, IEC 61851-24 ed 1, IEC 62196-2, IEC 62196-3, IEC 61000
Communication to the EV	DIN 70121, CHAdeMO 1.2
Warranty	Base warranty 24 months after Site Acceptance Test or 30 months after factory delivery. Warranty extensions available

—

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https://emobility.abb.com/

9AKK107992A8963

In diversity there is beauty and there is strength.

MAYA ANGELOU

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