City of Cape Town Electric Vehicle Tariff

Briefing Note

Final Report

10 July 2018

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List of Abbreviations & Glossary of Terms

AMI: Advanced Metering Infrastructure. Metering that can accommodate TVP.

BEV: Battery Electric Vehicle

CPP: Critical Peak Pricing

DCFC: Direct Current Fast Charging

DR: Demand Response

DSM: Demand Side Management

EE: Energy Efficiency

EV: Electric Vehicle

EVSE: Electric Vehicle Supply Equipment

PTR: Peak-time rebate

TOU: Time of Use (Tariffs)

TVP: Variable prices based on when energy is consumed. Includes time-of-use pricing (TOU), real-time pricing (RTP), dynamic pricing and critical peak pricing (CPP)

V1G: Controlled or managed charging of EVs

V2B: Vehicle-to-building

V2G: Vehicle-to-grid two-way power flow

V2H: Vehicle-to-house

1 Introduction

This briefing note, funded by the **Friedrich Naumann Foundation for Freedom** (FNF), represents an initial investigation into a potential electricity tariff structure for electric vehicles (EVs) for the City of Cape Town. It draws on international experience and local knowledge, concerns and expectations based on a review of literature and targeted interviews. This note provides recommendations for taking the discussion further but does not propose a specific tariff structure. Further development of the City's EV strategy (in the form of the EV Framework) is needed to clarify the City's objectives that will inform the most appropriate EV tariff.

1.1 Context

EVs are experiencing strong growth. In 2017 over two million EVs driving worldwide with growth particularly in China, the USA and Europe. High penetration rates are forecasted in the near future (250 million EV units in 2040 (OPEC); annual sales of 10 million units by 2025 (Fitch); 40-70 million by 2025, 200 million by 2030 (IEA). Bloomberg New Energy Finance predicts that before 2040 sales of EVs will overtake those of combustion engine vehicles (Fishbone, et al., 2017).

Multiple countries are banning ICE vehicles (Norway by 2025; Germany by 2030; Scotland by 2032, England and France by 2040) **and promoting EVs.** EVs will have to make up at least 12% of each automaker's output in China by 2020 and India aims to have new car sales to be electric by 2030.

EV technology is rapidly evolving. EVs employ superior technology and deliver higher system efficiencies (EVs are up to 4 times more energy efficient than diesel vehicles and 5 times more efficient than petrol vehicles). EVs, and particularly battery range, are constantly improving (faster charge, longer driving range up to 700 km already), mitigating range anxiety.

EVs are increasingly affordable. Transitioning to EVs increasingly makes financial sense, due to the lower Levelised Cost of Transport (LCOT) of EVs over ICE vehicles: maintenance of EVs is minimal and low cost and running costs per km are also much lower on EVs than ICE vehicles. The capital cost of EVs is expected to match ICE vehicles around 2025 (price parity).

EVs are more sustainable. EVs have no tailpipes and produce zero local emissions. Significant reductions in local air pollutants such as NO_x, SO_x and particulate matter will lead to substantial health and socio-economic benefits in cities. EVs powered by the South African grid also emit marginally fewer greenhouse gases than ICE vehicles[1]. As the grid decarbonises and more EV owners invest in small scale embedded generation (SSEG) the GHG benefits will be significant.

EVs enable a broader transition. Mobility is evolving worldwide towards more sustainable, smart and service-orientated systems. EVs, and electrification more broadly, are at the centre of the evolution of public transport, private transport services (Uber, car sharing) and the wider transition towards mobility as a service (MaaS). EVs are also at the core of the move towards autonomous vehicles and 'smart' cities, aiming to integrate all forms of transportation through utilising renewable energy and SSEG, MaaS, improved real-time communication interacting with various interfaces and applications.

EVs contribute to a better business and tourism industry and quality of life in cities. Greenway and CleanTechnica argue that cities can compete by offering a cleaner, greener and quieter environment, a higher quality of life, where families want to walk around and play outside, tourists want to visit, and businesses want to have offices because the community is attractive to their future employees. Zero emission electric mobility is an essential part of this cleaner future (Fishbone, et al., 2017).

[1] The discretionary choice of whether to drive a big car or a small car makes a big difference to energy economy and small conventional cars currently give rise to lower GHG emissions than battery electric vehicles in the South African context if Coal-To-Liquid (CTL) refining emissions are not considered. If CTL is included at its national production share, battery electric vehicles significantly outperform gasoline fuelled conventional vehicles on a GHG emissions basis but small diesel fuelled IC engine cars are comparable because the CTL refinery produces proportionally less diesel (SEA, 2016).

Cities are taking action. Cities and local governments around the world continue to develop clean vehicle policies to reduce greenhouse gases, improve air quality, and increase sustainability. Paris, London, Oslo, and Beijing, among others, have announced restrictions on the most polluting vehicles in order to improve air quality. Increasingly, cities are promoting electric vehicles specifically as a solution to environmental issues (Hall, et al., 2017).

EVs have only recently become a sufficiently significant type of electricity load to warrant special tariffs, and so there is not yet an established practice for EV rate design, especially for public fast charging (Nelder, 2017). However, in light of expected growth in EV ownership, unique charging attributes of EVs, and resulting effects on electricity demand, the City needs to consider designing specific electricity rates for EVs.

1.2 Objectives

The City will develop an EV Framework to assist in promoting and managing the growth of EVs in the City. Feeding into this process an investigation was required to understand the role the municipality could play and the opportunities and impact EVs could have on the City. A first phase of this investigation, culminating in a briefing document, was to assess the potential tariff structure options for:

- behind the meter, to eV owner customers; and
- wholesale eV tariff to owners of the charging infrastructure.

The overall objective of the briefing note is to **shed light on the potential impacts of different EV tariff structures, set by the City, on the economic viability of EVs, charging behaviour and grid storage benefits.**

The aim of the EV tariff being considered is to:

- provide electricity at a rate that will make electric vehicles more economically viable when compared to ICE vehicles;
- encourage electric vehicle owners to charge their vehicles during off-peak hours in a manner that is cost efficient for electricity utility services and does not result in additional investment in utility infrastructure to handle the increased electrical demand; and
- potentially utilize the battery storage option to increase flexibility in the load.

1.3 Approach

The development of this briefing note is based on a review of international EV structures (with a focus on municipality-scale programmes behind the meter and wholesale tariff structures, in the absence of real time pricing); a review of charging options (technology and ownership models and their impact on viable tariff options); a review of existing regulations and structures (local and international and their impact on viable tariff options); an assessment the potential relationship between the EV tariff and Small-Scale Embedded Generation (SSEG) and a reflection on the findings in the South African context.

An additional assessment of economic viability was conducted to assess the impact of different EV tariffs on the cost effectiveness of EVs relative to ICE vehicles.

The interview process included engagement with the City of Cape Town's Electricity Department and the EV Tariffs and Procedures Working Group. A presentation of initial findings to these stakeholders formed an important part of the reflection of the findings in the local context and enabled City expertise to feed into the recommendations. A list of interviewees is included in *Annex A*.

2 Framework

A framework was developed to communicate, conceptually and graphically, how the different tariff options and models available could lead to different effects and impacts with varying contributions to meeting the City's EV tariff objectives. The framework is also designed to assist in understanding how the key issues identified (next section) fit into the overall picture. The City will need to consider different options recognising the relative pros and cons with respect to meeting its multiple objectives. The "contingent" recommendations (*Section 5.1)* stem from having multiple objectives and highlight the importance of engaging with stakeholders to inform the prioritization of objectives.

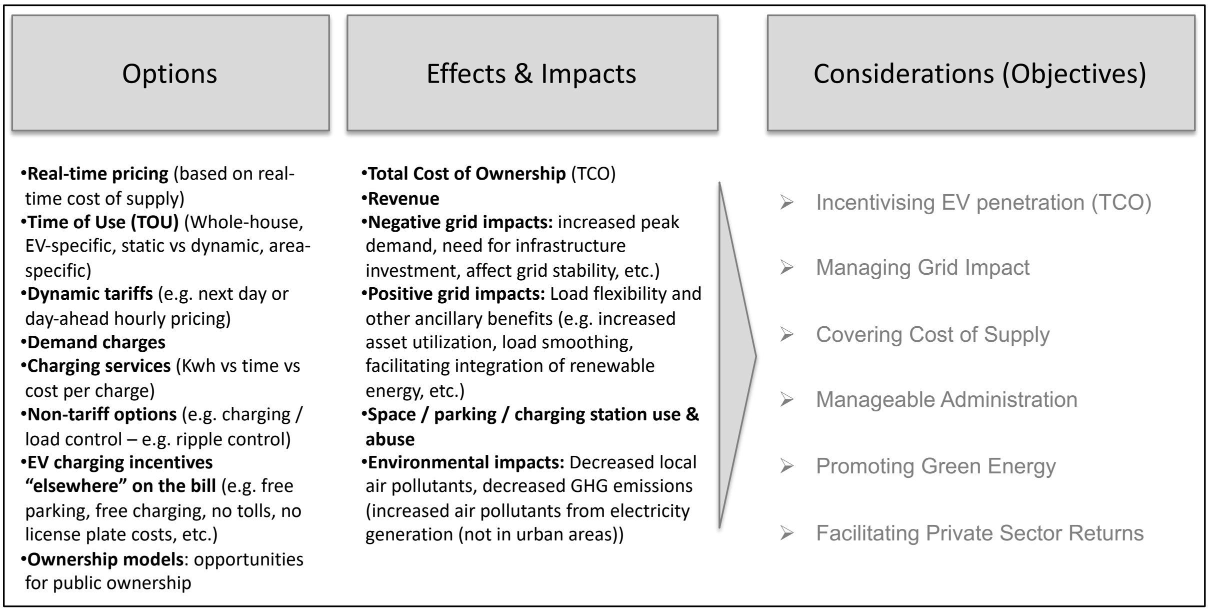

Figure 2-1: EV tariff assessment framework[2]

Given the objectives highlighted above, the City should use the following "success criteria" to guide the development of an EV tariff (adapted from a recommendation for New York (NYSERDA, 2015)):

- Facilitate the adoption of EVs in the City;
- Minimize the costs and network impacts associated with EV integration;
- Maximize the environmental benefits (through integration with SSEG and other green energy programmes);
- Maximize grid benefits associated with EV integration (smartification, load smoothing, enablement of renewable energy integration);
- Be simple to administer;
- Be flexible in the context of emerging technologies and pilots underway;
- Provide customers with easy to understand electricity pricing options allow with an indication of Total Cost of Ownership (TCO) implications;
- Provide customers with options;
- Create an enabling environment for private sector investors; and
- Enable other transport objectives (through a tariff that promotes Mobility as a Service and other transport models that reduce congestion and improve access particularly for the poor).

2.1 Mapping stakeholder interests and concerns

The choice of EV tariff programme should consider what different stakeholders want the tariff to achieve / deliver and the concerns stakeholders have around the transition to greater EV penetration in the City.

Stakeholder	Interests / Concerns
City of Cape Town: Sustainable Energy Markets	• Stimulating EV penetration • Simple administration requirements • Grid smartification • Incentivizing the use of green energy (purchased or self-generated)

[2] Based on (C.M. Flath, 2014), (NYSERDA, 2015), (Forum of Regulators, 2017) (Ensslen, et al., 2018)

Stakeholder	Interests / Concerns
	• Managing access (e.g. avoiding charging bays being occupied and not used for charging)
City of Cape Town: Electricity Department - Finance	• Covering costs of supply & generating revenue • Promoting charging on the City's network (rather than the Eskom network) • Avoiding subsidization of the rich • Avoiding bad debts and negative cash flow impacts (a risk when pre-paid meters can't be used)
City of Cape Town: Electricity Department - Network	• Avoiding negative grid impacts (clustering & uniform charging during peak periods) • Grid smartification • Controlling Maximum Demand
Western Province Government	• Incentivizing the use of green energy (not at a premium)
Original Equipment Manufacturers (OEMs)	• Lowest cost for consumers • Managing warranty issues and customer experience
Eskom	• Increased electricity sales • Grid stability • Controlling Maximum Demand • Would prefer pre-paid solution • Worried about risk to first movers
EV charging providers	• Highest possible margin (freedom to set the charges) - ROI • Stable costs • Policy certainty ("no surprises") • Avoidance of overtrading
EV owners (private)	• Lowest cost • Adequate and convenient charging options (mitigation of range anxiety)
EV fleet owners (MaaS)	• Lowest cost - ROI • Freedom to build own charging network

3 Key issues

There are clear trends of longer range vehicles, requiring larger capacity batteries, and customer behaviour that suggests a trend towards faster charging times and clustering of chargers in some areas on the network (Vector, n.d.). These trends necessitate the need for a strategy on EV charging for the City of Cape Town that is future-proof. The following represents a summary of the "Big Issues" that should be considered in the setting of an EV tariff as part of this strategy (Roadmap).

3.1 Tariffs

A special EV tariff with lower prices during off-peak times can incentivize EV charging off-peak. Although electricity tariffs provide indirect control of EV charging, detailed analyses of such schemes are limited (Forum of Regulators, 2017).

The consideration of a specific tariff needs to take the following into account:

- Covering cost of supply (both of the electricity and the space / property in the case of public charging);
- Avoiding a situation where the tariff effectively subsidizes the rich (and preferably benefits the poor);
- Potentially contributing to increased revenues for the City;
- Setting the rate at a point that will make EVs more cost effective (contributing to greater penetration);
- Offering a margin that will enable a return on private investment; and
- Creating a structure that incentivizes charging behavior that minimizes negative grid impacts

A variety of options are available.

Time of Use (TOU) tariffs

TOU rate plans for customers schedule electricity rates according to the time of day (typically peak, standard and off-peak), type of day (weekday or weekend), or season. This rate structure, which reflects the cost to produce and deliver electricity at various times, makes electricity more expensive at peak hours when the grid has high demand and offers cheaper electricity at off-peak hours. In addition to residential TOU rates, a few utilities now offer EV-specific TOU rates. Such rates can be used both to incentivize EV purchase through low off-peak rates and to help manage charging behaviour (Khan, 2018). While experience with shaping the demand of EV owners with TOU rates is still limited, data from Portland and California indicate that TOU rates do encourage a shift of demand to off-peak periods as shown below in Figure 3-1 for Pacific Gas and Electric (California). The special EV rate incentivizes off-peak charging more than the TOU rate through a larger differential between peak and off-peak rates.

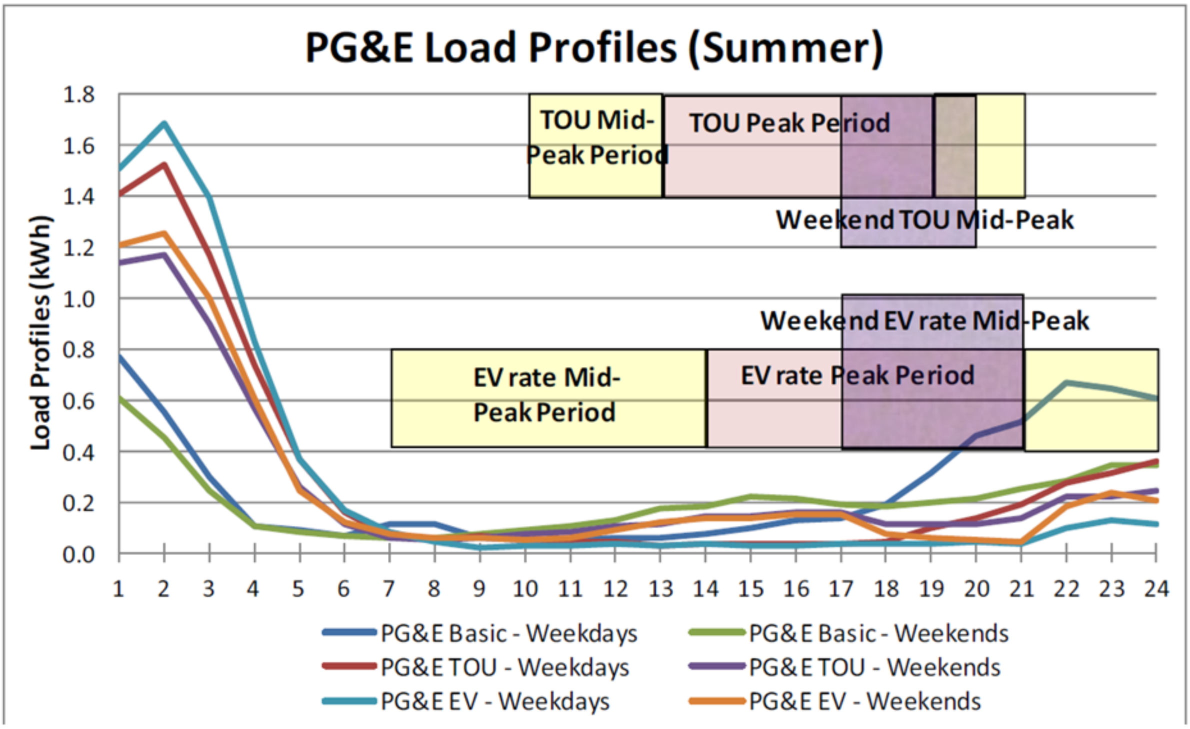

Figure 3-1: Pacific Gas & Electric (California) average hourly EV charging load curves for basic, TOU and Special EV Tariffs on weekdays and weekends (Biviji, et al., 2014)[3]

Results for Portland (PGE) supported the above. Additional results of interest were that Mondays generally had the lowest demand indicating that off peak rates on weekends were being used and seasonal variation with more consumption in the winter months when average rates are generally lower.

Norway has minute-based pricing in play. If households have a smart meter (this is already the case for most households), power retailers in the **Nordic** markets can offer the option of a contract where customers are charged at variable rates (IEA , 2018). This means that the electricity rate can vary by hour, limiting opportunities for demand response. In the case of **Finland**, only 7% of the consumers have opted for hourly electricity pricing to date (IEA , 2018).

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[3] Caveats to this work are that the sample self-selected the tariff and customers that voluntarily select TOU tariffs may be more flexible and the relatively small sample group (27 – basic, 118 – TOU, 71 – special EV rate).

Beijing electricity customers pay TOU rates with seasonal adjustments. **Shenzhen** EV drivers can sign up for reduced electricity rates, including off- peak prices of 0.3 yuan (USD 0.05) per kWh (Forum of Regulators, 2017).

The **UK** government only introduced TOU in early 2017 (Ward, 2017) and studies on the impacts are in their infancy (OFGEM, 2017). One study found that consumers prefer static TOU (35% uptake to dynamic TOU charges (18% uptake) (The Brattle Group, 2017). Opt-out as a default was found to be one of the most important drivers of TOU uptake: 83% average enrolment with opt-out versus 26% with opt-in. A financial incentive also contributed to higher uptake and bill protection[4] was found to have some impact on uptake (in **Australia** this was shown to only have a moderate benefit) (The Brattle Group, 2017). Researchers in **Germany** highlighted the risk that the sole use of time-based electricity prices can lead to load spikes and suggest a spatial dimension to tariff setting (tailoring) (C.M. Flath, 2014).

More than 200 utilities in the United States reportedly offer residential TOU rates. Of 52 utilities surveyed by the American Council for an Energy Efficient Economy (ACEEE), 39 offer residential TOU rates on a voluntary basis but less than 3% of customers have taken them up. There is wide variation in the structure but in the case of utilities offering EV specific TOU rates, super off peak rates are generally lower than residential rates and can be as little as 5-10% of peak hour rates (Khan, 2018). *Table 3-1* below compares residential TOU tariffs to special EV tariffs for selected large utilities to the TOU energy charge that Eskom charges the City of Cape Town and that the City of Cape Town charges its Low Voltage large customers. All the rates have been normalised relative to the lowest off-peak rate in that tariff structure to illustrate the scope of the incentive. Peak rate will therefore be the ratio of peak rate charge to the lowest charge (This is called 'off-peak' by Eskom but 'super off-peak' by others)

Table 3-1: Normalised Residential and Special EV TOU Rates for Selected US Utilities Compared to Relevant Eskom and City of Cape Town TOU Rates

Utility	Rate Type	Peak Rate	Off-Peak (Eskom 'Standard') Rate	Super off-peak (Eskom 'Off-Peak') Rate
Pacific Gas & Electric	Res. TOU	3.0	2.0	1.4
	EV TOU (Summer)	3.8	2.1	1.0
	EV TOU (Winter)	2.6	1.6	1.0
Southern California Edison TOU-D-A	Res. TOU	3.5	2.2	1.0
	EV TOU	2.6		1.1
San Diego Gas & Electric	Res. TOU	2.4	2.1	1.9
	EV TOU	2.6	1.3	1.0
Georgia Power Company	Res. TOU	10.0	1.0	
	EV TOU	20.0	7.0	1.0
DTE Energy	Res. TOU	3.3	1.0	
	EV TOU	4.0	1.0	
Eskom (Average)	*Megaflex LA*	*3.0*	*1.5*	*1.0*
Eskom (June - Aug)	*Megaflex LA*	*5.3*	*1.7*	*1.0*
City of Cape Town (Average)	*LV Large User*	*2.6*	*1.4*	*1.0*
City of Cape Town (Jun - Aug)	*LV Large User*	*4.5*	*1.6*	*1.0*

[4] where participants are informed that they will get reimbursed during the first six months should their bill be higher than under a flat rate tariff

1 *Rates for US Utilities are for summer except where otherwise indicated. Given that gas is used for heating through much of the United States, air-conditioning load in summer presents more of a load management challenge.*
2 Sources: (Khan, 2018)*,* (Pacific Gas and Electric Company, 2017)*,* (Eskom, 2018) (City of Cape Town, 2018)

As can be seen, on average, the price signals from Eskom and the City of Cape Town are in general similar to those offered by major US utilities although those for the short winter period are very pronounced.

The City offers TOU rates to commercial and industrial customers. The existing structure can therefore be used to partially mitigate grid risks associated with clustering and peak loads. However TOU for public chargers needs to be set so that grid risk is mitigated regardless of the price that the resell price the customer pays. Very strong price signals and direct charging controls may also be needed.

On the downside, TOU pricing reduces the potential for resellers to benefit from arbitrage (buying at bulk supply costs and selling at a flat rate preferably at off-peak periods). However if resellers are not bound by the Electricity Regulation Act (2006) then they could charge what the market would be willing to pay and the loss of arbitrage opportunities would not apply.

In the domestic context there is the potential to move the whole house onto TOU or have TOU for EV changing only if a separate AMI meter is installed. EV owners would then need to be required or adequately incentivized to move onto TOU for EV charging. *Section 3.6* details some of the challenges related to the technology needed to achieve this.

Nelson Mandela Bay Municipality pioneered TOU but faced challenges in the EV context because electricity is not classified as a transport fuel. The municipality also does not have an understanding of the extent to which EV owners are reacting to the TOU tariffs.

Demand charges

Demand charges are used to recover the on-fuel costs of providing electricity to large commercial and industrial customers and are designed to incentivize them to have consistent load and avoid fluctuations (Khan, 2018). EVs particularly when fast charged, are large sustained loads with potentially low diversity and can thus add significantly to local demand. Demand charges could therefore adversely affect EV adoption. For example, businesses may discourage workplace EV charging to avoid demand charges from simultaneous charging, which in turn will discourage EV ownership among people without convenient residential or public charging options (Khan, 2018).

- The City indicated that it would not likely include a demand charge in a residential EV tariff structure but public charging stations with supplies exceeding 500 kVA would be subject to demand charges under the current tariffs.
- ESKOM is still in the process of researching a residential EV tariff structure and indications are this would be a TOU tariff and there is no indication at this time that this would include a demand charge.

Dynamic charges

Dynamic rates track electricity production and distribution changes from hour to hour. Dynamic rates can shorten the highest-rate period to a few hours, improving customer response (Lazar and Gonzalez 2015). Dynamic rates can provide windows of low-cost EV charging in periods that would be peak hours under a TOU rate structure. These windows could create low-cost charging opportunities for Level 3 fast charging, which provides 60–80 miles of range in 20 minutes. However, while fast chargers are increasingly common, most charging uses Level 1 or 2 chargers and requires a longer charge period. Hence shifting peaks under dynamic rates could be challenging for most EV owners, as they would have to adjust charging time on a day-to-day basis; because most EV drivers plug in out of necessity, they may not have this flexibility (Khan, 2018).

Dynamic rate structures have not been widely adopted and experience with such dynamic pricing arrangements for electric vehicle charging is still limited, and ongoing changes in technology, including the systems used to control charging, contribute to uncertainties about how dynamic pricing will affect charging behaviour (Forum of Regulators, 2017) (Khan, 2018).

Liberalization of the electricity sector in Europe (deregulation) is leading to the development of dynamic pricing (driven by greater competition). **European Union** incentives driving variable retail prices are expected to come into force by 2020 (Kari, 2017). In spite of this, recent trends are toward capacity-based, fixed network charges in several places in Europe (Kolokathis & and Hogan, 2018).

Flexible prices are being rolled out in the **UK** (Kari, 2017) but not specifically targeting EVs.

Day-ahead provides dynamic hourly rates for EV charging on a day-ahead basis. This is being tested in **San Diego** (Forum of Regulators, 2017)

Pilot projects for dynamic pricing have demonstrated that the benefits of smart prices increase when accompanied by smart technology, and vice versa. Consumers also sustain new behaviours longer when automated controls are available, through either individual adopters or demand aggregators (Kolokathis & and Hogan, 2018)

An interviewee suggested that dynamic prices would be an important tool in helping to manage the grid impacts in Cape Town. For example, something similar to the surge charge used by Uber during peak periods could be developed. Opinion varied in terms of whether the regulations allow for dynamic charges. The regulator NERSA reportedly declined to approve an Eskom pilot of dynamic rates in a so-called “critical peak” tariff pilot.

Cross subsidization and non-tariff options

Options exist to generate revenue other than through the sale of electricity and use that revenue to offset any losses through the EV tariff (in cases where the objective of promoting EV penetration is particularly important). Many countries have in place EV charging incentives “elsewhere” on the bill (The Regulatory Assistance Project, 2013). This has been particularly prevalent in Europe where parking fees, congestions charges and tolls are high or where congestion is at a level where preferential access is highly valued. These benefits are less valuable in the context of the City of Cape Town but should still be considered.

Examples include **Norway** where free parking is available for EVs, in Norway and France where free, fast charging, locations are offered (Forum of Regulators, 2017). In the cities of **Paris, Oslo, Stockholm and Bergen** free fast charging locations are available (Forum of Regulators, 2017) (Hall, et al., 2017).

China has also introduced a preferential vehicle licensing system in several cities. Licence plates are given out either by auction, lottery or after payment of a high fee in an effort to halt car congestion, but EV buyers get license plates free and without a wait in at least six Chinese cities. These centres account for 70% of domestic EV purchases (Clover, 2017)

Germany has not focused on tariffs as a measure to influence penetration but has rather provided special privileges in traffic and public places (e.g. free parking, special lanes privileges, access to special zones etc.) (German Trade & Invest, 2016).

In certain parts of the United States three levels of incentives are available for the purchase of electric vehicles at the federal, state and utility level. PG&E are running a time limited program till 31 May 2018 that offers a $10,000 discount on a BMW i3 to their customers. Owners might simultaneously benefit from BMW’s ‘ChargeNow’ program which offers 24 months of free charging at participating Evgo stations (Pacific Gas and Electric Company, 2018). More modestly, the three largest Californian utilities PG&E, SCE and SDG&E return the credits they earn from power supplied to charge EVs from the state’s Low Carbon Fuel Standard program in the form of $200 - $500 credits to EV owners (Khan, 2018).

Bundling services represents an opportunity to subsidize across services but also, through innovative payment platforms, to deliver benefits such as fraud detection and improved payment rates (as (Jouanna, 2018)

There are many other options available to incentivize EV penetration but these would need to be driven at the national level. Examples include no purchase / import taxes, VAT exemptions, low annual road tax, reduced company car tax, exemption from registration taxes, feebates, "Super bonus" for scrapping old diesel, tax credits for automakers, and many others (Hall, et al., 2017).

Tariff differentiation per user

Tailoring the tariff to different users recognises different charging requirements and different incentives. There are likely to be three main groups of users:

- Normal residential users (mostly charging at night)
- Commercial users (including public and office charging stations)
- EV fleets (including private and public passenger as well as commercial and industrial fleets)

Mobility as a Service (MaaS) companies may warrant a specific tariff. MaaS fleets will charge during the day, often at peak periods. Cars will be charged multiple times per day needing a fast charge "top up." The cost of electricity will be an important value driver for these forms and they will be incentivized to adopt a particular tariff structure or engage in a particular contractual arrangement with the City if it leads to the lowest possible, stable, electricity costs. Finally, MaaS delivers a social benefit ("responsible miles") by getting cars off the road and may therefore warrant a special rate (i.e. a rate that not only incentivizes EV penetration but also technologies and systems that contribute to the broader transport objectives of the City)

The City will also need to consider whether it adopts a different tariff structure for direct customers and electricity resellers (e.g. public charging operators).

Impacts on the city

Any revenue benefits in the short term are likely to be limited due to slow projected uptake and the fact that EVs, typically consume less than a quarter of the energy of an ICE vehicle. On an individual level however consumption can be significant for EV owners with longer commutes. Fuel economy is quite dependent on vehicle size and driving style for both EVs and ICE vehicles but a value of around 0.2 kWh/km is representative of current EV fuel economy. For a 50 km daily travel distance and an 85% charger efficiency, daily demand would therefore be around 11.8 kWh or approaching 300 kWh per month. This is a substantial additional consumption for most customers and suggests that long term revenue impacts could be significant.

Eskom modelled the potential impacts of EVs on their revenue. They projected that 5% of the vehicle parc in 2047 will be electric, requiring an estimated 1 440 GWh of electricity per year or 400 MW per day. This represents about 1% of South Africa's current installed capacity. If all of the vehicles in the country were electric this would require about 20% of the country's installed capacity (Jacobs, 2018).

According to researchers, an anticipated shift to 40% electric cars on German roads by 2035 could see German utility companies gain between 500 and 700 million euros a year in additional earnings before interest and taxes (EBIT), if they exploit cross-selling opportunities with start-ups in the chargepoint sector (Reuters, 2018).

The City needs to mitigate the risk of "avalanche effects" - sudden increases of load induced by the optimal price-sensitive behaviour concerning demand allocation in time periods in which low electricity prices are offered to consumers (Ensslen, et al., 2018). Iteratively setting the rate will help to mitigate this as the City can evaluate the effectiveness of the rate in influencing behaviour and can iteratively pitch the rate at a level that helps to mitigate avalanche effects. Additionally, back-end systems have the smarts to identify battery charge state and can this information can be used to control charging of vehicles, depending on their state, to avoid peak charging while still delivering the required service.

3.1.1 Tariff rate

In the absence of other measures incentivizing the purchasing and use of EVs in the country, setting favourable tariffs represents an important lever by which government can influence EV penetration.

Some stakeholders suggested that free charging is needed in the short term (next 5 years), although some commentators have noted that the early introduction of fair prices for the use of chargers is important. They suggest that free charging sends incorrect price signals about the cost of charging/using electric vehicles and creates an outcry and drop in usage later when the free/subsidized charging ends. This undercuts the ability of commercial operators to create a sustainable business in the community (Fishbone, et al., 2017)

Scotland's national public electric vehicle charging network, ChargePlace Scotland, is also largely free to users, beyond a £20 annual fee. It is otherwise subsidized by the Scottish government (Fishbone, et al., 2017).

All public charging points in South Africa currently offer free charging based on the partnership requirements set by the OEMs (that will likely change once penetration increases).

Private sector players wanting to play in the public charging space differed in terms of their view on the rate. One group suggested, based on selling charging as a service rather than selling KWh, that sellers charge the maximum rate that the market will accept. An argument was made that for some time to come consumers would compare the cost to "fill up" relative to the cost to fill up an ICE vehicle rather than consider the cost per KWh. Given the higher efficiency of EVs, charging at the peak winter City of Cape Town commercial TOU rate of R3.87/kWh (VAT inclusive), which is over 2.5 times the price of petrol per unit energy, would still be around 25% cheaper than refuelling an ICE car.

One investor suggested that a blended price of electricity plus a 50% margin would deliver an acceptable ROI on a going concern basis (established business). At a minimum 30% would be required especially if the technology costs come down.

OEMs have found that current EV owners are happy to pay the existing tariffs and are of the opinion that the largely environmentally conscious consumers would be willing to pay a premium for green energy.

The California Public Utility Commission (CPUC) provide a useful set of principles to consider when applying an EV tariff rate. These are shown in *Table 3-2.*

Table 3-2: Rate Design Principles

Cost of Service	• Rates Should be based on marginal cost; • Rates should be based on cost-causation principles • Rates should generally avoid cross-subsidies, unless the cross subsidies appropriately support explicitly City policy goals; • Incentives should be explicit and transparent; • Rates should encourage economically efficient decision-making;
Affordable Electricity	• Low income and medical baseline customers should have access to enough electricity to ensure basic needs are met at an affordable cost;
Conservation	• Rates should encourage conservation and energy efficiency; • Rates should encourage the reduction of coincident and non-coincident peak demand;
Customer Acceptance	• Rates should be stable and understandable and provide customer choice; and • Transitions to new rate structures should emphasize customer education and outreach that enhances understanding and acceptance of new rates, and minimizes and appropriately considers the bill impacts associated with such transitions.

(Garrett, 2017)

3.1.1.1 Assessing the potential impact of an EV tariff on economic viability

This paper considered the impact of different EV tariffs in terms of the impact on the Total Cost of Ownership (TCO) of an EV relative to ICE vehicles. Recognising that decisions to purchase vehicles include multiple attributes (including status and convenience), cost represents an important criteria. In this context, understanding the impact of different tariff rates and structures on the economic viability of an EV is important in understanding the potential role of the EV tariff in meeting the City's objective of driving penetration.

A levelised cost of transport (LCOT) model was developed to establish the cost of supplying the public (bus) and private (passenger car) transport service over the life of the vehicle and is expressed in units of Rands per passenger.km (R/pkm). The details of the methodology and assumptions are provided in *Annex B.* The purpose of the model is to find the tipping points in levelised cost where EVs start to become cheaper to own than conventional ICE technologies. In this type of analysis, rather than trying to predict the future cost of owning an EV, sensitivity analysis is used to vary the electricity price and the capital costs of EVs relative to ICEs to determine under what circumstances tariffs might incentivise EV ownership by making them cheaper to own. In this analysis, the total social cost of the vehicle is assessed across all its owners, not just the first owner, over a technical life of 12 years for a passenger car. Caution should be taken to avoid debates regarding the many such assumptions in the analysis particularly since the outcome is not highly sensitive to most of them. Instead the results should be used to highlight under which approximate price regimes EVs begin to look economically competitive.

Taking the lowest possible tariff as an example, it was found that if EV owners charge exclusively at the current City of Cape Town summer/winter average off-peak rate of around 80c/kWh for low voltage large users (Average Eskom Megaflex + 24c/kWh), then the levelised cost of ownership breaks even with entry level cars at a capex premium of only 72% compared to the current 166%. Looked at another way, the average price of the current two available EV models (R553,300) is relatively high at around the 70th percentile of model prices (unweighted) and if the prices of available EVs dropped to the 50th percentile they would breakeven with the entry-level ICE market (set at the 20^{th} percentile of prices) in levelised cost terms, if they could charge at 80c/kWh. If we assume the mid-range market is represented by the mid-point of 20^{th} and 80^{th} percentile of prices (R454,931), then at a charging energy cost of 80c/kWh, owning an electric car would already be around 10% cheaper.

A higher rate was derived as shown in Table below by assuming that TOU tariffs prevail and that the EV owner splits charging between the three rates but favouring off-peak charging at home as follows:

Table 3-3: Derivation of an Assumed Bundled Charging Rate Assuming high rates of Public and Work Charging on Current Low Voltage Large User TOU Rates

TOU Period	Summer (Sep - May) [R/kWh]	Winter (June - Aug) [R/kWh]	Average [R/kWh]	Share of Charging	Rate [R/kWh]
Peak	1.46	3.92	2.08	25%	3.12*
Standard	1.10	1.38	1.17	40%	1.17
Off-peak	0.80	0.88	0.82	35%	0.82
** Peak + 50% mark-up*				Effective Bundled Rate	1.53

Coincidentally the effective bundled rate is similar to the 2017/18 Block 1 energy charge for Home Users. The highest rate for the sensitivity analysis was assumed to be the flat rate energy charge for greater than 600 kWh consumption which for 2017/18 was R2.34/kWh inclusive of VAT. The results for passenger cars shown below indicate that tariff setting can indeed have a significant effect on the economic proposition of electric vehicles particularly in stimulating uptake in the phase where prices are still dropping due to declining battery costs and improved economies of scale.

Table 3-4 Summary of Sensitivity Analysis of Charging Tariff on Economic Viability (levelised cost in R/km) of Electric Passenger Cars in the South African Market

Average Charging Tariff [R/kWh]	Comparison to Mid-Range ICE	Comparison to Entry Level ICE*
0.82	10% cheaper to own at current vehicle costs	Breaks even at 72% EV premium
1.53	8% cheaper to own at current vehicle costs	Breaks even at 63% EV premium
2.34	5% cheaper to own at current vehicle costs	Breaks even at 52% EV premium

** Current Premium of average of Nissan Leaf and BMW i3 relative to upper end of entry level segment is 166%*

Impacts when only Public Fast Charging is subject to an EV electricity tariff

Experience in Europe has shown that around 80% of EV owners charge their vehicles overnight at home using AC power. If they have home charging and workplace charging, 96–97% of charging is done at home or work (Fishbone, et al., 2017).

If a similar situation is assumed in South Africa[5], then an EV tariff for public charging stations would not have a significant impact on TCO and therefore on price-related considerations for buying an EV. There would be benefit in terms of managing grid impacts and sending a signal / messaging but the main driver of EV penetration would be the role of public charging stations in mitigating range anxiety (i.e. the tariff is not the key variable).

3.2 Public charging stations

The availability of public charging infrastructure supports the increased uptake of EVs as it enables the possibility to complete journeys beyond the battery range and reduces range anxiety. Offering public fast-chargers in proximity to residential neighbourhoods could also discourage customers from installing the more expensive fast and rapid chargers at home and therefore reduce low-voltage network impacts (Vector, n.d.). Countries with dense public charging infrastructure have higher EV market shares (Forum of Regulators, 2017).

Amsterdam has put in place a demand-led public charging expansion plan. Under this plan, EV owners put in an online request for a new public charging location. The request is evaluated based on the walking distance to the nearest existing station, the occupancy rate of the nearest stations and previous requests for the location under consideration (Vertelman, 2016).

The Rocky Mountain Institute argues that public fast charging should be seen as a societal objective. They suggest developing a target up from what would be attractive for EV drivers rather than what would work for utilities (or municipalities in City’s context) (Nelder, 2017).

City and Utility ownership models

The City can pay for new EV infrastructure out of its own budget and thereby own the infrastructure and the land it sits on. It can manage the infrastructure itself or develop an arrangement to entrust a Charging Point Operator (CPO) with all that responsibility. However, the city doesn’t need to go “all in.” It can also contribute some, but not all, of the cost of the infrastructure and be a partial owner (Fishbone, et al., 2017). The City can also provide the land for EV charging infrastructure for free or it can lease the land. Alternatively the City could also operate the charging infrastructure itself, though this is uncommon (Fishbone, et al., 2017).

Various authors suggest that owning charging infrastructure (or other components of the EV value chain) represent an opportunity for utilities / municipalities to increase revenues. There are limited examples however of cities becoming owners of public charging infrastructure at scale. In **Oslo**, the municipality has built two large parking garages dedicated to electric cars (IEA 2017, 2017). In

[5] Further work is needed to explore and understand the driving and charging behaviour of South Africans

Vancouver the city owned 75 of the 200 public charging stations as of 2017, the use of these has been free aside from standard rates (City of Vancouver, 2017). This arises from its EV Ecosystem Strategy that aims to direct its, "capacity for patient (long-term) capital" to "act as an early supporter of the EV charging market increase the number of customers at public charging stations – and particularly fast charging stations – that will reduce the future business risk in public charging investments" (City of Vancouver, 2016). With usage of these stations doubling in a two year period and data showing inefficient use with resulting congestion, the city is moving to a payment model and a policy of ultimately transitioning away from providing and operating charging infrastructure when the market is large enough to provide attractive ROI for the private sector (City of Vancouver, 2016).

California decided to allow utility investment in EV charging infrastructure in 2014 after an extended public process. The basis of the decision was that utilities could play a key role in the development and roll-out of EVSE. The California Utilities Commission (CPUC) however plans to decide the role of utilities in EVSE on a case by case basis, trading off the benefits against competitive impacts (Khan, 2018). Vermont's Drive Electric Vermont (DEV) Program has encouraged utility support for ESVE to drive the expansion of infrastructure and incentivize EV uptake. The state's Public Service Board (PSB) reviews and approves fees/tariffs charged at utility owned public charging locations (Khan, 2018) (Wagner, et al., 2016)

Investing in the charging infrastructure could potentially enable an arbitrage model for the city given that it is on a Time of Use tariff (Megaflex). If the city leverages the batteries of its EV fleet it could, in theory, further benefit from arbitrage opportunities (at a point where dual flow or V2G becomes more of a reality). The interviews however highlighted that currently automotive batteries are highly optimised and so the cost incurred by reduced life due to cycling is far higher than a battery designed for power system storage and could be as high as R5-6 / kWh. This was cited as the reason why BMW does not currently enable V2G.

Lessons from international experience suggest that public private partnerships (PPPs) have been successful in deployment of infrastructure, supplementing the consumer awareness efforts as well as providing independent incentives to the consumers (Forum of Regulators, 2017). Entities within the emerging local charging industry are in dialogue with at least two metropolitan municipalities with the aim of entering into PPPs where the city provides capital and the private partner supplies the equipment and operates the site under a management contract, sharing profits. Locally based players have indicated an appetite for equity in these partnerships ranging from considering the option to half of the capital costs. Recent developments in the corporate space suggest the possibility that foreign based companies interested in the market may be prepared to capitalise at scale in return for advertising rights on the site.

It is however important that any ownership position is not seen to be disadvantaging the competitive environment. This is not only because of legal considerations but also because it might be argued that utility linked monopolies can inhibit the uptake of new charging technology and dis-incentivize EV uptake. Furthermore when a public entity or utility such as PG&E in California, capitalises charging stations they draw on the revenues from all their customers, not just EV owners which is not equitable (Gear, 2015). Discussions with The city's Electricity Services Department indicated a range of views including the following:

There is an opportunity for the city to expand its electricity services and offset its costs
It's not appropriate for the city to compete in a space better suited to the private sector and leasing land, regulating and setting tariffs should be the limit of involvement.

An important consideration brought up in the interviews is that while the nascent market may not offer attractive ROI in the short term, the early sites are likely to be the best locations for profits in the long term. In the case where the city rather opts for direct involvement in public charging through leasing of attractively located public land, these agreements therefore need to be flexible to respond to a changing commercial environment. The local charging industry representatives interviewed spoke out strongly against regulated beyond the meter tariffs for public charging on the basis that they are not technically resellers of electricity. Furthermore, they want the opportunity to set prices in response to demand in a free market to maximise their return on assets. The aspect of electricity reselling is a key legal issue and is discussed in more detail below.

An example of a successful PPP is **Source London** started by Transport For London (the integrated transport authority for London) and is now managed by a private operator, which currently provides more than 850 charge points across London and plans to install another 4 500 by 2018 (IEA 2017, 2017). **Stockholm** adopted a business model that sees private companies offered free access right agreements for parking places in exchange for installing charging points on or near their premises. Access right agreements are granted for five years. Following this, they can be extended annually if both parties agree. (Fishbone, et al., 2017).

Electricity reselling

The Draft Green Transport Strategy notes that the resale of electricity in the SA electricity supply industry (ESI) is a growing business. The Electricity Regulation Act, 2006 makes provision for the licensing of generation, transmission, distribution, export or import and trading activities with regard to electricity by the Energy Regulator. Electricity resale falls under trading activities, which need to be licenced (e.g. municipalities) or registered (e.g. high density housing complexes, shopping malls or commercial property). Several requirements apply, including; with regard to mark -up on cost. (Department of Transport, 2017). A notable application of this is the case of malls that resell electricity to tenants, that the reseller cannot charge more than the customer would pay directly to the City

There are different interpretations of the Electricity Regulation Act (2006). Some charging infrastructure / public charging providers are of the opinion that public EV charging represents the sale of a service rather than the sale of electricity and is therefore not subject to the regulations (i.e. the charging service provider is free to charge whatever rate the market is willing to pay).
The situation is similar in **India** where provision of public EV charging service to the users amounts to distribution/supply of electricity. In **France**, the Commission de régulation de l'énergie (French Regulatory Commission of Energy) issued direction for the utilities to facilitate development of EV charging businesses and recommended that energy code can specify that recharging is not considered as electricity supply (Forum of Regulators, 2017).

3.3 Managing grid impacts

Eskom suggests the impact of EVs on the grid will not be significant but notes the need to manage at-work daytime charging points and charging of public transport fleets in particular (Jacobs, 2018). Other stakeholders have supported this saying that only when EV penetration is significant will there be negative impacts on the grid. The Forum of Regulators suggests that loading of around 20% from fast chargers should be the threshold for network expansion. This is based on experience in **Norway** (Forum of Regulators, 2017). However, the City remains concerned that, in certain areas, any additional pressure could pose a risk to grid integrity.

A growing amount of empirical data has shown that the grid impacts of EV charging are best managed when utilities have the ability to create incentives for PEV owners to charge their vehicles during off-peak hours (NYSERDA, 2015).

European regulators have taken significant steps in recent years to deregulate the electric sector by unbundling generation and transmission, and creating trans-national electricity markets (The Regulatory Assistance Project, 2013). The South African electricity sector remains highly regulated which may limit opportunities to mitigate negative grid impacts to the same extent.

Setting rates that manage grid impacts and charging access

Smartification is necessary to enable variable tariffs that ramp up when the grid is constrained or when car owners occupy charging spaces for too long. A dual approach, as an option for managing access to charging infrastructure, involves a KWh charge followed by a time charge that can ramp up.

Charging/ load control

Managing charging, through ripple controls for example, provide a guarantee that the network capacity will not be breached. Charging loads could be controlled directly by grid operators, discoms or aggregators of charging infrastructure within the defined parameters set by the user. This would give the flexibility to avoid overloading the distribution network and optimize all assets on the grid. Charging control could be combined with a dynamic pricing regime however, it would be infrastructure intensive and require Advanced Metering Infrastructure (AMI) to measure hourly or sub-hourly demand to enable billing for dynamic pricing. It would also require a high degree of communication between the network operators, aggregators, distribution licensees, and the users (Forum of Regulators, 2017).

Supply and demand in **South Africa** is currently managed through grid frequency which could be used to initiate responses and associated communication. uYilo is currently undertaking work to understand how this would work in the local context.

EV fleet owners and managers have some control over charging. With the right incentives or agreements in place they could be incentivized / required to adopt a particular charging behaviour (e.g. send vehicles to a part of the grid that is not constrained).

The City is unlikely to be able leverage partnerships with OEMs to help manage grid impacts and revenue issues (this is not a core focus of theirs).

In the **UK** project 'Electric Avenue' for example, the aggregate EV demand can be shifted so that the peak occurs after midnight via managed charging (Vector, n.d.). The IEA's "Digitalization and Energy" study quantified the benefits of managed charging on a **global** level. The study finds that in a medium growth EV scenario where 150 million EVs are deployed by 2040, 140 GW of capacity is needed to meet standard EV charging needs. However, if managed charging is implemented, capacity requirements are reduced by nearly half (65 GW) (IEA, 2017).

Accommodating change

The City can be flexible in design and can adjust the tariff and tariff structure over time. The design of the SSEG tariff represents a precedent with the current structure being the third iteration.
The lead time for setting or adjusting a tariff is about 15 to 16 months. There is effectively one chance per year to make changes.

Putting in place standards and protocols

Managing harmonics and other grid impacts requires that standards be in place for charging grid infrastructure.

3.4 Green energy

The Western Cape Government has expressed interest in linking EVs and green energy: leveraging EV rollout and charging to increase renewable energy in the mix. This would also have important awareness raising and messaging benefits linked to the Province and City's climate change and green objectives.
The mechanisms for linking EVs and renewable energy (through the Small Scale Embedded Generation programme, for example) need to be explored. The City is considering a green energy requirement for public charging stations greater than a set threshold (based on KVA maximum demand). Options then include:

- Setting a requirement for charging stations of greater than the threshold to have a certain component of their power for recharging being renewable. This could potentially be included in the development planning approval process. They could meet this requirement through:
    - SSEG if they have available space for installing solar PV; or
    - Purchasing green energy through a contractual arrangement such as purchasing a Renewable Energy Certificate (REC) or through wheeling (where power is purchased directly from a renewable energy Independent Power Producer (IPP) and wheeled through the grid; and

- Creating a mechanism linked to the City's (future) purchase from IPPs from within and external to the Municipal grid (subject to changes in the regulatory environment to allow for this[6]).

Alternatively the City could do nothing with the expectation that the grid is becoming greener and the increasingly attractive economics of renewable energy will lead to EV charging suppliers investing in renewable energy anyway.

The City has set guidelines and associated tariffs for small scale embedded energy generators with a generation capacity of less than 1MVA. One consideration has been around whether the potential EV tariff could be the same as the SSEG tariff structure. The benefits of this are that the system would be administratively easier to manage. The downside is that the EV tariff would not reflect cost of supply or be optimally designed to influence behaviour (EV uptake and charging behaviour).

This stems from the fact that the cost of supply and the cost of investing in the technologies differ. SSEG reduces demand and therefore revenue for the City. SSEG is contributing to the need for fixed charges that cover the system (grid) costs to deliver electricity. EVs on the other hand would increase demand for electricity. Secondly, the rate at which consumers are incentivized to invest in PV panels on their roof relates to costs of energy use in buildings and for EV owners this relates to the cost of transport. In both cases the costs of the new technologies and of the reference case (alternative) differs.

Anecdotally, the OEMs suggest that drivers of passenger EV cars would be willing to pay a premium for green energy when charging their vehicles.

The City of **Oslo** offers free charging with renewable energy at all Level 2 charge points (Hall, et al., 2017). Good Energy, a company in the UK, offers an EV tariff comes with 100% renewable energy (Good Energy, 2018). The non-profit green energy aggregator MrCleanEnergy offers PG&E customers 3 different tiers of green energy in a tailored EV tariff structure at a significant discount to PG&E's EV tariff as shown below. Interestingly this includes domestic solar energy which is sold at a flat rate which is higher off-peak but lower during peak.

Table 3-5: TOU EV Tariffs offered by Californian non-profit Green Energy Aggregator MrCleanEnergy[7]

Season	Energy Type	RE Mix	PEAK ($/kWh)	PART-PEAK ($/kWh)	OFF-PEAK ($/kWh)
Summer	Light Green	50% RE	0.20	0.08	0.03
	Deep Green	100% RE	0.21	0.09	0.04
	Local Sol	100% Local Solar	0.14	0.14	0.14
	Standard PG&E	N/A	0.45	0.25	0.12
Winter	Light Green	50% RE	0.06	0.03	0.03
	Deep Green	100% RE	0.07	0.04	0.04
	Local Sol	100% Local Solar	0.14	0.14	0.14
	Standard PG&E	N/A	0.31	0.19	0.12

[6] The City of Cape Town has filed a court order demanding the right of the city to purchase electricity from IPPs (Yelland, 2017)

3.5 Registration and tracking

Registration of EV connections and charger types by EV owners would facilitate coordination of electricity distribution planning and operation. EV registration data and/or consumption data from smart meters can provide information on charging behaviour. This data can support the forecasting of loads and the planning of electricity networks (Vector, n.d.).

All chargers should be registered: the City needs to know where EV chargers are and avoid a situation where, in the case of Denmark, charges will have to be retrospectively (manually) counted. Registration that takes place outside of the City will be more difficult to control and will present a risk in terms of the City's potential to enforce TOU or other programme elements on those customers

In the **UK**, the parliament is currently considering a bill that would require all EV chargers, for both domestic and public applications, to have smart meter capabilities to interact with the grid (Pratt, 2017)

The City could incentive registration through a reduction in fixed charges (such as a discount on the Home User Tariff to be imposed from July 2018). This could potentially have multiple impacts:

- Minimal City balance sheet impact: the decrease in fixed charges would be offset (to a varied extent) against the increased electricity demand (revenue). This is bearing in mind that an EV owner driving in the region of 50 km per day would on average use an extra 10 to 15 kWh per day. This will almost double the consumption of many households. Additionally, the low projected penetration of EVs would mitigate the potential for negative revenue impacts for the City for the time being.
- Minimal incentive if applied to public fast charging: users of public fast charging are not likely to be very price sensitive (if they were they would largely charge at home) thus limiting the potential of a discount to materially influence demand for EVs. It would however potentially send a positive signal.
- Larger incentive if applied to domestic consumers: a reduction in the proposed fixed electricity tariff would send a very clear signal and have a minimal (but larger) influence on demand (see Section 3.1.1.1). The marginal benefit of an extra kWh sold on the grid was not available to this project, but for the purposes of exploring the trade-offs we might assume that fixed charges could be halved on the basis of a proportional increase in consumption. This would pass a R900 annual saving to the customer and reduce the cost of ownership per km of the EV by just over 1%. The impact on EV ownership costs would therefore be relatively small, but the incentive power of a large discount on the fixed charge, potentially high.

The City could therefore consider a discount in the fixed charge for domestic users as an option for incentivising registration.

3.6 Meters and grid smartification

EVs have onboard GPS, software, and batteries that can easily network with other devices, creating many more opportunities for cities to become smarter (Fishbone, et al., 2017). There is great potential but most of today's chargers are not "smart" nor connected. The technology is not yet commercially fully ready and it will require a new generation of "smart" charging points and clear communication protocols with energy suppliers and AI enabled energy aggregation platforms, to load balance EV chargers remotely (Jouanna, 2018).

Integration, AI, innovative options (e.g. blockchain) add complexity and may slow down the pace of convergence (Jouanna, 2018). Car/bus/truck OEMs, energy companies, software companies and start-ups are all building different pieces of the jigsaw, which will make the integration trickier.

Noting the challenges, it is still important to smartify. When choosing infrastructure, select smart, networked chargers with IT capabilities to allow you to monitor charger status and usage, invoice users, permit reservations, and much more (Fishbone, et al., 2017).

Domestic charging

A domestic Advanced Metering Infrastructure (AMI) meter is needed for TOU tariffs. There is however currently no meter on the market that allows both TOU and pre-paid functionality. Without a pre-paid function the risk of bad debts increases and there is a potential negative impact on the City's cash flow. Initially, a separate meter might therefore be needed if the City wanted to force domestic users onto a specific EV tariff (e.g. domestic TOU). Locally developed domestic charging units with smart meters retail reportedly for half the price of OEM chargers but it's not known if warranty issues have been resolved. The metering function of these units would also need to be approved if they were to be used for billing.

Commercial charging (including public charging)

Advanced **metering** infrastructure (AMI) enabled meters are commercially available for application in metering and billing for TOU tariffs. About 400 commercial customers in Cape Town have TOU enabled through an AMI meter with a Metering Data Unification Scheme (MDUS) back-end).

The City suggests a stronger back end will be needed than the current MDUS on existing commercial TOU-based customers because MDUS is not scalable to the larger number of customers that would be supported in a residential TOU tariff scenario. Given however that EV penetration would likely remain muted in South Africa for some time due to low model availability and high ad valorem excise taxation, the MDUS system might suffice for a pilot roll-out of domestic TOU rates to registered EV owners only.

In the case of the public charging version, the meter is integrated with a credit billing system which is activated by the customer using an encrypted 13.56 MHz Radio Frequency Identification (RFID) Card. This is a "tap and go" type card like that used for Gautrain. Smart charging can be controlled by the back end which can switch off or control the amount of charge) and can book charging systems (e.g. as done in Europe via an app).

Germany uses their "E-Energy Network" of predictive systems to forecast power consumption and generation levels according to weather conditions. The system creates a foundation for the intelligent integration of electric vehicles into the smart power supply grids of the future (German Trade & Invest, 2016).

Smart charging

The interviews suggested that there are local suppliers of smart charging technology for both public and home charging. These smart chargers can control the amount and timing of charging as well as meter consumption differentiating between green energy and grid energy if required and communicating with online apps.

One of the most advanced and valuable forms of smart charging is vehicle-to-grid (V2G), or two-way charging. V2G allows electric vehicle batteries to discharge power back into the grid when needed, making the batteries an energy storage resource in addition to a mobility device (Vector, n.d.). Concurrently, distribution level storage is approaching economic viability at arbitrage rates. The essential economic difference between the technologies is that with V2G, the EV owner has capitalised the storage and this should be reflected to some degree in the feed-in tariff.
Early leaders in charging infrastructure that started with dumb chargers are now switching to smarter ones (e.g., **Norway** and **California**) (Fishbone, et al., 2017). A Nissan-led V2G trial in **Denmark** revealed that EV owners could earn up to EUR 1300 per year by supporting grid balancing (Shankleman, 2017). In the **UK** Enel and Nissan have also started a V2G pilot where a recharging device allows car owners as well as energy users to operate as individual "energy hubs" (Forum of Regulators, 2017)

Bi-directional charging is limited (and not yet available in South Africa). BMW currently does not offer bidirectional or V2G capabilities. There are warranty issues associated with excessive cycling of the highly optimised battery such that its life is compromised. Nissan gets around this by limiting the amount of trading that can take place.

EV cars' on-board electronics can't currently communicate with the grid directly, however the car can communicate with the charger which can communicate with the grid.

Real time pricing is not currently needed given the volumes in South Africa but this could be easily implemented with software additions to the back end.

uYilo is working with Eskom to pilot smart grid technologies such as V2G. uYilo is currently trying to understand technology readiness and cost implications associated with transitions to smart grid technologies

Chargers have the potential to provide reactive power
Voltage support by distributed control of reactive power provision is seen as one of the potential ways EVSE can help solve local voltage issues in distribution networks (Zecchino, et al., 2017). The loads in grid supported SSEG installations, for instance, consume reactive power disproportionally from the grid (the panels typically only supply active power through the inverters), creating such local voltage issues. Using power electronics based charging infrastructure EVSE's can inject reactive power into the grid while consuming active power during charging to counter this but can also potentially either generate or consume reactive power during charging. Larger public charging is a more obvious application of this but modelling studies have shown the potential for leveraging co-ordinated charging of residential EV chargers (Paudyal, et al., 2017).

While Eskom applies an ancillary charge for supplying excess reactive power during the high demand season, the city currently rather has a problem with excess reactive power that can be of the order of 200 MVAR on the system at night which then has to be exported violating contractual obligations to Eskom. While Eskom is currently satisfied that the general situation is not excessive, the capital cost of equipment to correct this amount of excess reactive power has been estimated at R150 million. As an alternative Electricity Generation and Distribution at the City of cape Town has initiated a pilot with a private 1MW (SSEG) installation which will run for a week overnight in reaction mode to establish the efficiency of generating reactive power from grid active power consumption. There may therefore be an option to buy reactive power from both SSEG and EVSE installations at night and this might be considered as an option in a future tariff.

3.7 Other

3.7.1 Communication

Raising awareness is one of the most important needs in the transition to EVs (Kolokathis & and Hogan, 2018). Good communication is also critical to managing grid impacts and maintaining trust needed to overcome range anxiety and other issues associated with consumer uptake of EVs as a new technology. Drivers need to know when and where they can charge and what it will cost them. Apps enable this (e.g. the Uber app notifies users of a surge charge during peak periods giving the user the option to accept or wait until demand drops).

Standardized and easy to understand tariffs and payment systems are also part of the simple and effective communication required. People like to know what they are paying for and how much it costs. It also helps with transparency and building trust, especially as e-mobility is still a young industry (Fishbone, et al., 2017).

3.7.2 Local policy and regulations

The Draft Green Transport Strategy envisages "Quick wins". The short -term strategic targets expanded below form part of the "quick wins" for the strategy as they will essentially form part of the first phase of the Implementation Plan: (5 -7 years)

- To convert 5% of the public and national sector fleet in the first 5 years of the implementation of this strategy and an annual increase of 2% thereafter, to cleaner alternative fuel and efficient technologies vehicles (ideally powered through renewable energy) and environmentally sustainable low carbon fuels by 2022, including the use of CNG, biogas and biofuels and the use of renewable energy to provide electricity for transport
- To achieve modal shifts in the transport sector that reduce GHG emissions and other harmful emissions, reduce transport congestion and improve temporal, spatial and economic efficiency

in the transport sector. In particular, achieve a 30% shift of freight transport from road to rail by 2022, and a 20% shift of passenger transport from private cars to public transport and eco-mobility transport in the same year
- Invest in sources of green energy's infrastructure, like biogas filling stations, electric car charging points, GIS integrator ICT technology platform for locating stations, regulating future pricing and providing statistics.

A number of relevant interventions are envisaged. DoT will engage with DTI to provide manufacturing incentives to vehicle manufacturers who supply the government fleet with high energy efficient vehicles and EV's, to consider options of manufacturing these vehicles within the country. In order to radically grow the uptake of EVs in South Africa DoT, in conjunction with DTI and National Treasury, will:
- Consider removing or relaxing import duties on electric vehicles, particularly the classification of electric vehicles as luxury imports, in order to stimulate the experience and local capacity development in relation to these technologies.
- Offer producers of EV vehicle manufacturing incentives to both produce and sell affordable EVs in South Africa, for the local and export markets.
- Work with local research institutions to conduct research on EV batteries.
- Work with national, provincial and local government departments and authorities and the automobile industry to set annual targets for the uptake of electric vehicles and hybrid electric vehicles in the government vehicle fleet as well as monitoring the local content of the manufacturing of cars locally, in line with IPAP.
- Introducing the conversion of old technology vehicles, with higher emission factors to be retrofitted with EV technology.
- Consider providing Incentives related the beneficiation using; local resources in the manufacturing of key machineries and or components (e.g. fuel cell).
- Assist in establishing and developing local EV OEMs.

4 International experience

The review of international experience fed into the Key issues identified above and into the subsequent recommendations. This section provides a further reference of relevant EV positions and interventions in key global regions.

4.1 Asia

The central government of **China** is the initiator and main driver for EV development and supports every stage of the system from R&D, demonstration and promotion, commercialization to production and sales, scale-up, and charging infrastructure construction. So far, the subsidy policy of government is the main driver for EV enterprises to produce EVs and for consumers to buy EVs (Forum of Regulators, 2017). 3,600 public charging and swap stations and 49,000 chargers had been built by August 2016 and has a goal of 4.8 million chargers, 12,000 charging stations and bringing No. EV/No. chargers ratio to 1:1 by 2020. Recently the market has been opened to private players as well. By December 2016, electric vehicle fleet of more than 951,000 vehicles including buses and trucks (Forum of Regulators, 2017). The city of Shenzen has a target of 120,000 new electric vehicles to be sold by 2020 and Tianjin has set a goal of 30,000 new energy vehicles sold by 2020 (Hall, et al., 2017).

Incentives are playing a key role. China's central government offered subsidies of 30,000 yuan (HK$35,000) to buyers of plug-in hybrid cars, and as much as 55,000 yuan to purchasers of pure electric cars. Some local governments offered additional subsidies of the same amount, to total 60% of the vehicle's sticker price (Holland, 2017). The central government supports municipalities deploying public charging infrastructure by subsidising the construction of charging stations (IEA 2017, 2017). Other local incentives are at play including public procurement of EV fleets. In 2016, more than 40 % of all electric vehicles sales for the year were booked in the final quarter as local governments ramped up their purchases to ensure they met Beijing's annual targets. In an attempt to tackle these distortions, Beijing has announced plans to reduce the central government subsidies for electric cars and to cap those offered by local governments (Holland, 2017).

The municipality of Beijing has also tried to set attractive pricing (tariffs). The city has set an upper limit on the fee that needs to be paid to use public charging electricity infrastructure (net of the electricity price) at 15% of the price of gasoline (IEA 2017, 2017).

The National Electric Mobility Mission Plan 2020, notified by the Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises, Government of **India** seeks to enhance national energy security, mitigate adverse environmental impacts from road transport vehicles and boost domestic manufacturing capabilities for Electric Vehicles (EVs) (Forum of Regulators, 2017). However, India's Road to an Electric Future has been slow. In April 2017 the then power minister said that not a single petrol or diesel car will be sold in India by 2030. In January 2018 the minister of Road Transport announced that government's think-tank NITI Aayog had drafted an EV policy and was awaiting cabinet approval. In February 2018 the same minister said that there is no need for an EV policy. A month later NITI Aayog has tasked at least seven ministries with framing guidelines to encourage the use of such vehicles (Ghosh, 2018). The U-turn, Ghosh suggests, came after some carmakers protested that they were unprepared for an abrupt shift and that government policy should encourage all clean-fuel technologies (Ghosh, 2018). The situation has interesting parallels with South Africa where a lack of a clear EV industrial policy has slowed national efforts to develop policy related to local EV penetration and use.

Japan has about 150,000 electric vehicles in the fleet and over 40,000 charging stations, more than liquid fuel filling stations. The 'Next Generation Automobile Industry Strategy' has a goal of 20 - 50% EV penetration by 2020 and 50 - 70% EVs by 2030 in the passenger vehicle market. The country allocated USD 356 million in 2011-12 and a further 360 USD million in 2015 to support charging infrastructure and EV purchase and incentives. EVs are also currently VAT exempt. Charging infrastructure is largely being developed under a public-private partnership model. Investments have been made by utilities in grid upgrade and modernisation to absorb renewable energy. Advanced EV charging hubs are integrating local solar power, energy storage and dynamic pricing to manage EV demand on the grid. Many charging stations currently offer a free service, but the Charger Manufacturers Association (CHAdeMO) companies are starting to lay out management and payment schemes they believe are critical to develop a real charger manufacture and management industry. Current public charging pricing models include a 'Hook-up' fee and per minute plans and monthly membership schemes (Forum of Regulators, 2017) (d'Arcier & Lecler, 2014).

4.2 Europe

European Union Directive 2014/94 on alternative fuels for sustainable mobility in Europe obliges member states to develop national policies in this area. European countries have led the way in designing and implementing policies to promote EV adoption. These have focused on parking incentives, preferential access, putting in place necessary infrastructure, providing direct incentives for vehicles, making available information and direct encouragement (Fishbone, et al., 2017). **The use of specific electricity tariffs has played a role but has not been as much of a priority as in the US.** A selection of goals and targets and some of the main incentives are described below.

In the **Nordic region** – Denmark, Finland, Iceland, Norway and Sweden – the stock of electric cars has been expanding steadily since 2010.1 It reached almost 250 000 cars by the end of 2017 and accounted for roughly 8% of the global total of electric vehicles (EVs) in 2016. The Nordic region has one of the highest ratios of electric cars per capita in the world (IEA , 2018).

Norway has the world's highest share of PEVs per capita. In 2015 and 2016, electric vehicles accounted for a 23-29% share of new car sales. The Government supports electric cars by employing "polluter pays principle" in the car tax system (high taxes for high emission cars and lower taxes for low and zero emission cars), which also impacts fiscal revenue (Forum of Regulators, 2017). The City of **Oslo** has set a target of zero-emissions transport within the city by 2030 (Hall, et al., 2017).

Denmark differs from the trend of its Nordic neighbours with fewer sales of new electric cars in 2017 and a significant decline since 2015. This is largely attributable to policy shifts in 2016 and mixed signals in the subsequent period that undermined consumer confidence and limited opportunities for a rebound (IEA , 2018).

Sweden offers financial support for the development of charging infrastructure. In 2015, the funding amounted to SEK 130 million (IEA 2017, 2017). **Stockholm** directly invested in charging infrastructure in a partnership with the private sector (Fishbone, et al., 2017)

The government of **France** provides subsidies towards the purchase of all-electric vehicles and plug-in hybrids with low CO_2 emissions. The stock of light-duty plug-in electric vehicles registered in France passed the 100,000 units milestone in October 2016, making it the second largest plug-in market in Europe after Norway, and the world's fifth (Forum of Regulators, 2017).

As part of its "National Electromobility Development Plan", **Germany** has set itself the goal of becoming the lead market and provider for electric mobility by 2020 as part of its long-term zero emission mobility vision with a further goal of one million electric vehicles on the road by 2020. The country has an "Electromobility Law" (passed in 2014) that benefits electric vehicle owners (German Trade & Invest, 2016). In the first quarter of 2018 Germany overtook Norway as the biggest market for electrified cars (Palazzo & and Behrmann, 2018). **Essen**, the EU Green Capital in 2015, has embarked on a partnership with Nissan.

In the **Netherlands**, the Green Deal has resulted in a governmental contribution for the joint deployment of publicly accessible EVSE with municipalities and a third party (IEA 2017, 2017). **Amsterdam** has set a goal of zero-emissions transport within the city by 2025 (Hall, et al., 2017). Amsterdam has several incentives for electric vehicles. The city added a budget item for EV charging infrastructure years ago but followed a market-driven approach to roll out this infrastructure: residents engage with the city around where they would like a charging station. An intelligent pricing system stimulates other residents to "go electric" and has resulted in a significant number of new EV owners on streets where these charging stations were installed (Fishbone, et al., 2017). The municipality of Utrecht in the Netherlands offers a EUR 500 subsidy per private charging point and a subsidy of EUR 1 500 for a semi-public charging point (IEA 2017, 2017)

The **United Kingdom** has created an Office for Low Emission Vehicles and committing to a 2040 deadline for discontinuing the sale of polluting vehicles in the UK (Energy, 2017). In the UK individuals receive GBP 500 (USD 650) for the installation of a dedicated home charger for an electric car, and businesses are entitled to grants of GBP 300 (USD 400) per socket to fund charge points for fleets and/or employees and receive tax breaks for investment on large EVSE deployment. Local authorities also receive refunds to install roadside charge points in residential areas (IEA 2017, 2017). London has set a goal of 70,000 ultra-low emission vehicles to be sold by 2020 and 250,000 by 2025 (Hall, et al., 2017).

Croatia, the Czech Republic, Hungary, Latvia, Lithuania, Macedonia, Serbia, Poland, Romania, Slovakia, and Slovenia all now offer some form of support to owners or drivers of EVs at local or national levels, further encouraging more EVs and creating lots of work for municipalities to provide the proper infrastructure. The **city of Wroclaw** in southwestern Poland has taken a multi-tiered approach to promoting e-mobility. In 2016, it put out a request for proposals (RfP) for an electric car sharing program to be implemented in the city, requiring a minimum of 200 electric cars. The city offered free parking for car sharing and EVs and offered bus lane access to EVs (Fishbone, et al., 2017).

4.3 North America

The United States has a long history of alternative fuel incentives stemming from clean air programs and now climate change mitigation. Of the competing alternative fuel technologies, by far the largest number of Federal and State incentives and laws now pertain to EV's (474) and PHEV's (415) (US DOE, n.d.)

Pressure on utility viability in the face of both supply and demand disruptions is driving a trend to TVP in various states (ee Publishers, 2018) (Faruqui, 2016). The large scale shift to TOU rates in California is discussed in more detail below. The Massachusetts Department of Public Utilities (DPU), has also ordered the state's electric distribution companies to use a TOU rate with a CPP overlay as the default for basic service customers following the AMI deployment while the Arizona Corporate Commission has required the utility UNS Electric to implement default TOU rates for new customers (Baatz, 2017). There has been a recognition in rate design that EVs as a category represent a more domestic flexible load and many utilities offer a tailored EV TOU rate, in some cases separated metered (e.g. PG&E EV Rate B). Table 4-1 presents selected examples of residential and EV specific TOU rates offered by US utilities.

Table 4-1: Residential and EV Specific TOU Tariffs Offered by Selected US Utilities (Khan, 2018)

Utility	Rate Type	Peak Rate ($/kWh)	Off-Peak Rate ($/kWh)	Super off-peak ($/kWh)
Pacific Gas & Electric	Res. TOU	0.36	0.24	0.17
	EV TOU (Summer)	0.45	0.25	0.12
	EV TOU (Winter)	0.31	0.19	0.12
Southern California Edison	Res. TOU	0.45	0.28	0.13
	EV TOU	0.34		0.14
San Diego Gas & Electric	Res. TOU	0.46	0.40	0.36
	EV TOU	0.50	0.24	0.19
Georgia Power Company	Res. TOU	0.10	0.01	
	EV TOU	0.20	0.07	0.01
DTE Energy	Res. TOU	0.13	0.04	
	EV TOU	0.16	0.04	

** Rates are for summer unless indicated otherwise*

Rate design is being influence both by flexible loads like EVs as well as the growth of distributed generation (DG) on the grid. Growth of Solar PV capacity and solar 'prosumers' in particular has led to instances of negative pricing in states such as Hawaii , which, as shown below, has responded with domestic TOU tariffs that favour daytime consumption and therefore daytime EV charging.

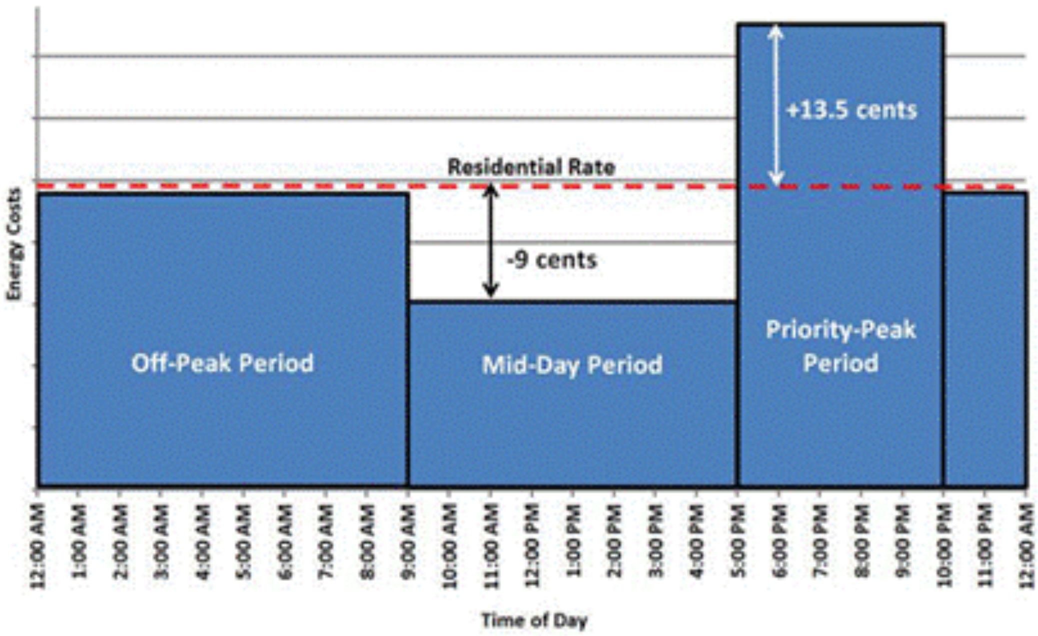


Figure 4-1: Domestic TOU Rates Offered by Hawaiian Electric Company (Khan, 2018)

Canada has taken a leading role in the evolution of the city electricity services space in a number of ways. The City of Vancouver's EV Ecosystem Strategy is discussed in more detail above with respects to public charging stations but Ontario, Canada's most populous province, has also shifted 4 million customers to TOU rates starting in 2006, one of the largest deployments worldwide. This has proved to be an interesting case study because after AMI costs of $1 billion, the shift was successful in the sense of no disruption to service but peak reduction effects have been largely unsuccessful, reportedly only reducing peak demand by 2.5 – 3%. Opinions differ on the reasons. One view that the peak price to off-peak price ratio of around 1.5 to 1 is too low and should be in the region of 4 to 1 or 5 to 1 especially on high demand days if dynamic pricing could be deployed. Dynamic pricing has however been rejected for the time being (Trabish, 2017). Another view based on an agent based modelling study is that the price differential won't promote further shifts but that the peak period needs to be adjusted combined with more seasonal differentiation and supported by promotion of home automation devices (Adepetu & Keshav, 2016).

4.3.1 California

California has a goal of 5 million zero-emission vehicles by 2030 (14% of 2017 vehicles) and is a leading EV market with 65 different EV incentives and laws in place, by far the largest number of any US state. This has expanded choice to 40 passenger models available and growing. The institutional landscape is complex and includes very large investor owned utilities like Southern California Edison (SCE) with 15 million customers as well as local non-profit green energy aggregators such as Mr Clean Energy[7] which provides green energy to 250,000 of PG&Es customers and community owned utilities such as SMUD[8] (Sacramento) with 1.5 million customers.

While many utilities offer voluntary residential TOU rates, the uptake has been small at only around 3% of customers. The investor owned utilities are now undertaking pilots in advance of a full scale rollout of 11 million customers to default (mandatory) TOU rates in 2019 by order of the California Public Utilities Commission (CPUC). This followed a three year process of considering rate reform alternatives (Baatz, 2017) (Public Utilities Fortnightly, 2017). The very large number of solar PV prosumers in California has created a demand curve (Figure 4-2), now infamously called the "duck" curve that is highly unfavourable to utilities. This has two main consequences:

- The need for and value of storage on the grid is greatly enhanced. This could potentially come from EVs
- CPP and PTR features in rate design are increasingly attractive to utilities

This has led to the tabling of proposed rate structures that include dynamic pricing with high peak differentials as well as rebates to customers who make their domestic storage available to the utility at critical times. 15 minute interval monthly demand charges are part of the proposal tabled by PG&E but solar industry associations are strongly opposed to them. They believe larger differentials should rather be used to incentivise storage uptake by domestic customers and that small commercial customers should rather be subject to peak-only demand charges which truly reflect the cost of generation rather than demand in any one 15 minute interval in a month (St John, 2017) (St John, 2015)

[7] https://www.mcecleanenergy.org
[8] https://www.smud.org/

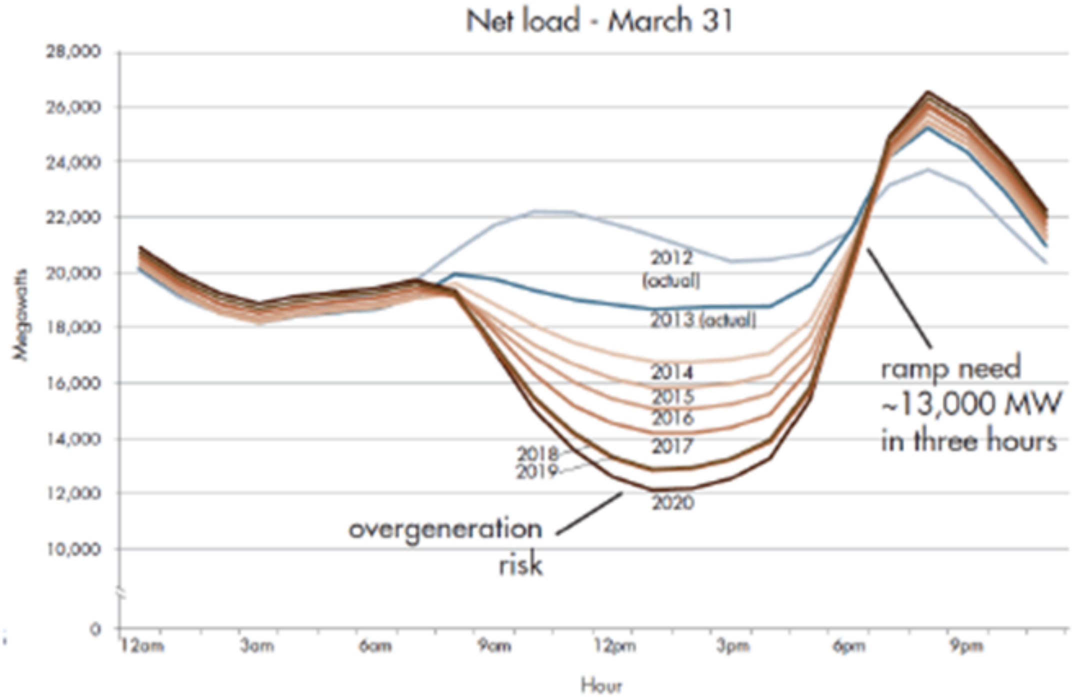
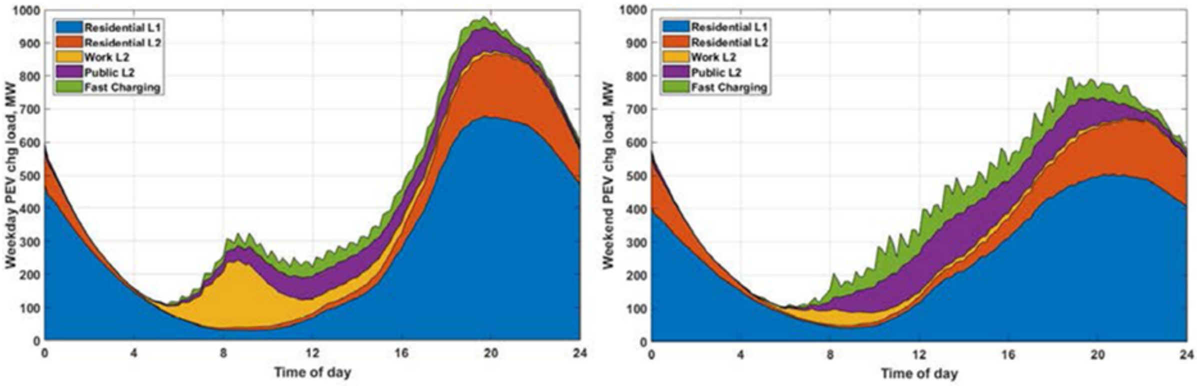


Figure 4-2: The 'Duck' Curve - Evolution of the Demand Curve in California (Faruqui, 2016)

The California Energy Commission (CEC) has undertaken a study to assess the infrastructure needed to effectively support the estimated 1.3 million EVs (plug-in hybrids and battery electric vehicles) estimated to be operating in the state by 2025. The CEC worked with the National Renewable Energy Laboratory (NREL) to develop the Electric Vehicle Infrastructure Projection (EVI-Pro) computer simulation tool for this purpose. The EVI-Pro projects hourly loads and quantifies the types of charging infrastructure needed to support EVs, assuming conservative charging behaviour to avert range anxiety. The simulated load shapes for residential, work and public level two and DC fast charging on weekdays and weekends, shown below in Figure 4-3, show substantial diurnal and sub-hourly volatility. The simulated sub-hourly electricity load shape for DC fast chargers is more volatile than other charging types, more than doubling within one hour in some instances. The implications for local stress on the grid have led the media to dub this the "Dragon Curve" (Ferris, 2018) as a companion to the "Duck Curve" above but the more sober assessment of the California Energy Commission is as follows:

> *"These load profiles may have significant impacts at the local level…..future installations should recognize the likelihood for grid impacts and thus proactively manage costs. The travel simulations of EVI-Pro indicate that weekend DC fast charger demand would more than double within one hour to peak load of 120 MW. This sharp increase in DC fast charging demand, albeit dispersed among local sites, should be managed with appropriate electrical service and distributed generation and storage resources to effectively prevent system overloading and to avoid utility peak demand charges."*



Source: California Energy Commission and NREL

Figure 4-3: Projected Charging Load Profiles for Different Levels of Chargers for California in 2025 (California Energy Commission, 2018)

The study indicated that by 2025, to support about 1.3 million EVs, California needs between 99,000 and 133,000 destination chargers at or near workplaces and in public locations, between 9,000 and 25,000 public DC fast chargers, and 121,000 chargers at multiunit dwellings (MUDs). The total number of chargers needed to support PEVs in California ranges from 229,000 to 279,000, excluding residential charges in single family dwellings.

4.4 Rest of the World

Nationally, **Australia** is still resolving its EV regulatory framework but has undertaken a TOU EV tariff study. Adelaide, with its strategy to achieve carbon neutrality by 2025 has taken a lead. The 'Smart Move Interim Action Plan 2016-2018' aimed to install 40 on and off-street charging points equipped with contactless payment systems. The City of Adelaide Sustainability Incentives Scheme: provides financial rebates to charging station developers of up to $1,000 for each fast charger (<20kW) and up to $5,000 for each super-fast charger (>20kW) installed. The proposed draft EV Charging Tariffs are presented below.

Table 4-4: City of Adelaide, Australia, proposed Public EV Charging Tariffs (Sep 2017)

Location	Charging Duration	AC Fast Charging Stations ≤22kW		DC Fast Charging Stations ≥50kW rated output
		Peak Times (06:00 - 18:00)	Off Peak Times (18:00 - 06:00)	All times
Weekdays (Monday to Friday)		$/kWh	$/kWh	$/kWh
On-street	≤1 hour	$0.00	$0.00	$0.45
	> 1 hour	$0.20	$0.10	$0.45
Off-street (UPark)	≤1 hour	$0.00	$0.00	$0.45
	> 1 hour	$0.20	$0.10	$0.45
Weekends		$/kWh	$/kWh	$/kWh
On-street	≤1 hour	$0.00	$0.00	$0.45
	> 1 hour	$0.10	$0.10	$0.45
Off-street (UPark)	≤1 hour	$0.00	$0.00	$0.45
	> 1 hour	$0.10	$0.10	$0.45

The above rates imply the following EV recharging costs:

Table 4-2: Costs to Charging EV for 100km on Proposed Adelaide Public Charging tariffs

Tariff	Recharge Cost
Residential ($0,4/kWh flat rate)	$7.20
AC < 22 kW off-peak	$1.80
AC < 22 kW peak	$3.6
EV DC ≥50kW	$8.10

In **New Zealand** a national vision aims for 2% penetration of EVs by 2021 and the goal of nationwide coverage of DC fast charging stations every 75 km along state highways. EVs are being incentivised by the exemption form road charges and access to reserved bus and high occupancy lanes. Currently private companies are installing around 100 public fast chargers around the country. One of these, “ChargeNet”, has set public charging rates at 25c/min & 25c/kWh. Wellington City Council plans to install fast & slow (for homes that have no parking) charging stations for public in city & suburbs.

National government in **Mexico** has been the driver of EVSE expansion and in January 2017 Mexico City had 700 public charge stations which for the time being are free to use.

5 Recommendations

Recommendations are organised into contingent recommendations, framed in terms of the relative prioritization of different objectives, and the authors, more subjective, recommendations. The contingent recommendations recognise that further discussion is needed to explore what the City aims to achieve with its EV strategy and then to decide on an EV tariff based on its strategy or framework. The authors’ recommendations reflect actions and approaches that should be considered and factored into the City’s EV Framework.

5.1 Contingent recommendations

IF managing charging impacts on the grid is the primary objective:

- Charge controls provide a guarantee that network integrity will not be breached.
- There is some intelligence in the grid already (in the form of frequency measurement) and technology (in the form of ripple controls) that can influence the time, speed and extent to which charging at a certain site can take place.
- Future technologies promise greater potential for grid smartification and more sophisticated options to achieve this objective.

IF the objective is to incentivize charging at work or public charging stations

- Then there is no need for a domestic component to the EV tariff structure (e.g. domestic TOU).

IF the objective is to ensure the tariff covers cost of supply

- Then an iterative approach is needed where system costs and revenues can be balanced over time. The slow uptake will limit the risk of significant negative impacts if the rate is pitched too low to cover cost of supply initially. Alternatively, the City should invest in a forward-looking cost of supply calculation if it appears that EV growth will be significant (such as is done in California).

IF the objective of the tariff is to lower the Total Cost of Ownership (TCO) and incentivize uptake

- Then the tariff needs to focus on domestic, at home charging, in the case of private car owners and on fleet-owned charging infrastructure in the case of public / shared transport. A favorable rate for public fast charging will have a limited impact on the economic viability for private EV car owners.

IF the objective is to incentivize investment in public charging infrastructure

- The City needs to create an enabling environment: land rights; openness to indirect income (e.g. advertising and ancillary services allowed); freedom to re-sell at a rate that the market can accommodate, etc.

IF the objective is to incentivize EV fleets and MaaS fleets

- The City needs to consider tailored tariffs given the specific use, charging requirements and economics of different users.

5.2 Author recommendations

5.2.1 Policy recommendations

Continue to adopt a proactive approach

The transition to a new transport system where electromobility plays a significant role has unstoppable momentum. The City needs to continue to be proactive to avoid duplication cost, ex-post interventions, as well as developing a positive public image of EVs and EV charging infrastructure. Lessons from international experience clearly show that substantial fiscal incentives are the most important driver of EV uptake and that these need to be supplemented by developing consumer awareness (Forum of Regulators, 2017). However, with a lack of a coordinated national EV policy environment and a lack of incentives, EV tariffs will be important in contributing to uptake. Electricity distribution entities have a key role to play in development of charging infrastructure and establishing clear pricing policies for charging. Developing an EV tariff programme should therefore be a part of the City's EV Roadmap.

Clarify EV objectives and then design the most appropriate EV tariff

The combination of EV tariff options and non-tariff measures will depend on the City's objectives.

5.2.2 Approach recommendations

Iterate

The significant uncertainty regarding future EV penetration rates, use behaviour (charging and driving) and the preferences of the local market, developments in technology and evolutions in the regulatory environment require an iterative approach to designing and implementing the EV tariff. This will allow "learning by doing" and as uptake will likely be slow, this is unlikely to have any significant negative impacts. The trade-off between stability / certainty (required for private sector investment) needs to be balanced against the need to design the most optimal structure. EV tariff setting processes within the City enable such an iterative approach.

Implement pilots

Put in place a number of meters for free to gather data and better understand profiles and charging behaviour. Even if the City installs a single charge point, the City can gain a tremendous amount of valuable knowledge and experience from operating it (Fishbone, et al., 2017).

Register EV users

The City needs to register the drivers of EVs in order to manage or influence charging behaviour and to plan. Where use of any mechanisms, such as a TOU EV tariff, are optional, the default should be an opt-out enrolment programme. It is also important to note that penetration will be slow initially and the City should not be too concerned about the time it takes to develop an appropriate registration (as the number of people who will "slip through the cracks will likely be very few). The City should also be open to an iterative approach.

5.2.3 Tariff & grid management recommendations

Consider different rates for different types of users

In the short term demand for passenger EVs will largely be in the wealthier private car market; a market that must not be subsidized. However public transport users (currently bus users but likely MBT users in the future) should have access to a lower, potentially subsidized, tariff.

Users that deliver a social benefit should have access to lower / more favourable tariffs. Mobility as a Service (MaaS) companies contribute to reducing the number of vehicles on the road and therefore eligibility for a lower tariff should be considered.

An EV tariff for domestic users should be considered especially given that, in the case of passenger vehicles, around 80% of charging has been found to take place at home (Fishbone, et al., 2017). An EV tariff for public charging stations would not have a significant impact Total Cost of Ownership and therefore on price-related considerations for buying an EV.

Set TOU tariffs

Public charging stations should be required to adopt TOU (currently available). Initially this should prioritise covering cost of supply and therefore a standard mark-up could be applied to the Eskom Mega-flex rate.

The City should actively explore, and if necessary drive R&D into, appropriate AMI pre-paid meters for the domestic segment. Once available the City should implement whole-house TOU rates. Again, cost of supply should be a primary principle used to determine the TOU rates.

Once more use data is available, the City should consider incorporating components of the tariff, over and above recovering cost of supply, that further incentivize the desired behaviour (e.g. significant ramp up over peak periods and in grid constrained areas). In the longer term dynamic rates could be considered and it is expected that more lessons could be gleaned from international experience.

Initially all rates should be static. Over time the City could consider dynamic rates (above Eskom Mega-flex to recovery cost of supply) that increase in line with objectives to further shift demand.

Any TOU tariffs will need to be accompanied by measures to gauge monitoring network utilization. Examples of best practices can be found in markets like Sweden, where regulators have implemented regular monitoring coupled with outcomes-based regulation (Kolokathis & and Hogan, 2018).

Consider contractual arrangements with EV fleet owners and managers

In the short to medium term there are unlikely to be a large number of EV fleets in the City. While numbers are low it may be simpler and administratively manageable to establish some form of partnership arrangements with fleet owners that set terms that enable the City to have some direct control over the charging behaviour of the fleets (where, when and for how long). Relationships would need to be tailored according to the different needs of the fleet owner and their potential to accommodate requests from the City.

Aim for a dual approach

The programme needs to combine real time pricing (and trading) and forced load control to leverage the benefits of both mechanisms. This system will require smart systems.

5.2.4 Create an enabling environment for investment in public charging infrastructure

Clarify the electricity reseller clause in the context of EVs

The City should lobby NERSA to rule that the Act does not apply to EVs and that EV charging constitutes a service (i.e. that this is not a regulated environment)

Enable access to land for public charging infrastructure

The City should (and is considering) leasing land so that operators have the rights to put wires across public land.

Explore opportunities to own charging infrastructure

The City should not be blind to undertaking "non-core" activities. Owning the charging infrastructure presents an opportunity to increase revenue, to directly manage potential grid impacts and to own a lever for driving a social objective.

5.2.5 Set appropriate standards

The country and the city need to avoid a lack of preparedness leading to a more costly transition. As first movers the City would be most exposed to risks and would need to pre-empt the need for standardization across payment platforms, charging technology, access to user data and building codes. For example, establishing building regulations requiring all new buildings be wired for charging bays (at least 3 – 7.5 KW charging systems). This is already the case in London and many cities in California, and the EU has already proposed legislation requiring this by 2025 (Fishbone, et al., 2017). In Vancouver, the city council has taken advantage of its unique ability among Canadian cities to modify its building code to require that each new, single-family dwelling is capable of supporting Level 2 charging infrastructure, and that 20% of the parking stalls in multifamily buildings (three or more dwelling units) are equipped with wire conduits for accommodating EVSE outlets. In doing so, Vancouver has become the first North American city to require EVSE connection capability in all new building developments (IEA 2017, 2017). Beijing, Shanghai and Chongqing, among other cities, require 100% charging pre-equipment (IEA 2017, 2017)

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5.2.6 Customer engagement and communication recommendations

Develop a strong communications plan

Customer behaviour will be critical considerations in any tariff transition. Customers need to understand the potential benefits and feel confident that they will have the information they need to be able to meet their charging needs. Greenway and Cleantechnica argue that The city leadership's role in leading the debate, educating the public, and championing electric transport is one of its most important and valuable tasks (Fishbone, et al., 2017).

Design needs to be customer centric

A focus needs to be on customer needs. In the world of tomorrow, customers will want increased easy to use, fair priced and integrated solutions, which cover EV charging at home and on the go into one single offering, and even mobility and energy bundled into one invoice (Jouanna, 2018).

5.2.7 Plug gaps

The following represent areas that require clarity / future work:

- National-level thinking around an EV tariff. For example, what is the likelihood that there will be a nationally set EV tariff such as is the case in the context of the highly regulated petrol price?
- A framework for setting an EV tariff: the tariff department within the City would need to understand the guiding principles including what type of contractual arrangements will be in place, how will contracts be managed and how money will flow).
- Understanding of the residential TOU profile.

- Understanding of EV charging behavior in the South African context.
- Understanding potential synergies with retailers.
- Understanding how the cost passed through from Eskom will influence the EV tariff and its objectives. There is a need to do a sensitivity analysis on the Eskom tariffs to assess the impacts on the CoCT tariff.

6 References

Jacobs, M., 2018. *Electric Vehicles: A utility's perspective.* Cape Town: African Utility Week 2018 Presentation.
NYSERDA, 2015. *Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State,* s.l.: NYSERDA Report 15-17. Prepared by M.J. Bradley & Associates LLC. nyserda.ny.gov/about/publications.
Nelder, C., 2017. *Rate-Design Best Practices for Public Electric-Vehicle Chargers.* [Online]
Available at: https://rmi.org/news/rate-design-best-practices-public-electric-vehicle-chargers/
[Accessed 16 April 2018].
The Regulatory Assistance Project, 2013. *Electric Vehicle Grid Integration in the U.S., Europe, and China Challenges and Choices for Electricity and Transportation Policy,* s.l.: s.n.
Forum of Regulators, 2017. *Study on impact of electric vehicle son the grid,* s.l.: s.n.
Ward, A., 2017. *Households offered first time-of-use energy tariff. Financial Times.* [Online]
Available at: https://www.ft.com/content/ac3b2788-d0eb-11e6-b06b-680c49b4b4c0
[Accessed 2 May 2018].
OFGEM, 2017. *Distributional Impacts of Time of Use Tariffs.* [Online]
Available at: https://www.ofgem.gov.uk/publications-and-updates/distributional-impacts-time-use-tariffs
[Accessed 2 May 2018].
Hall, D., Moultak, M. & and Lutsey, N., 2017. *Electric vehicle capitals of the world: Demonstrating the path to electric drive (ICCT: Washington DC, 2017)..* [Online]
Available at: http://www.theicct.org/EV-capitals-of-the-world
[Accessed 16 April 2018].
Jouanna, J. J., 2018. *The Impact of Electric Vehicles on Energy Markets and Infrastructure.* [Online]
Available at: http://novazure.com/the-impact-of-electric-vehicles-on-energy-markets-and-infrastructure/
[Accessed 30 April 2018].
Garrett, F. a. C. N., 2017. *EVGO Fleet and Tariff Analysis. Phase 1: California.* [Online]
Available at: https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf
[Accessed 18 April 2018].
Reuters, 2018. *German power market could cope with switch to electric cars: research.* [Online]
Available at: https://www.reuters.com/article/us-germany-power-e-autos/german-power-market-could-cope-with-switch-to-electric-cars-research-idUSKBN1F425I
[Accessed 12 May 2018].
German Trade & Invest, 2016. *Electromobility in Germany: Vision 2020 and Beyond.* [Online]
Available at:
https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/electromobility-in-germany-vision-2020-and-beyond-en.pdf?v=3
[Accessed 12 May 2018].
Kari, L., 2017. *For European utilities, demand for dynamic pricing on the rise. Accenture.* [Online]
Available at: https://www.accenture.com/us-en/blogs/blogs-european-utilities-demand-dynamic-pricing
[Accessed 12 May 2018].
The Brattle Group, 2017. *The Value of TOU Tariffs in Great Britain: Insights for Decision-makers Volume I: Final Report.* [Online]
Available at:
https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/The%20Value%20of%20TOU%20Tariffs%20in%20GB%20-%20Volume%20I.pdf
[Accessed 18 May 2018].
Vector, n.d. *EV Integration Green Paper.* [Online]
Available at: https://vectorwebstoreprd.blob.core.windows.net/blob/vector/media/the-spin-off/ev-network-integration.pdf
[Accessed 18 May 2018].
Pratt, D., 2017. *All electric vehicle chargers sold in the UK to be 'smart' under government plans.* [Online]
Available at: https://www.cleanenergynews.co.uk/news/transport/all-electric-vehicle-chargers-sold-in-the-uk-to-be-smart-under-government-p
[Accessed 18 May 2018].

IEA, 2017. *Digitization and Energy.* [Online]
Available at: http://www.iea.org/publications/freepublications/publication/DigitalizationandEnergy3.pdf
[Accessed 2 May 2018].
Shankleman, J., 2017. *Parked Electric Cars Earn $1,530 From Europe's Power Grids.* [Online]
Available at: https://www.bloomberg.com/news/articles/2017-08-11/parked-electric-cars-earn-1-530-feeding-power-grids-in-europe
[Accessed 2 May 2018].
Vertelman, B. a. B. D., 2016. *Amsterdam's demand-driven charging infrastructure.* [Online]
Available at: https://www.amsterdam.nl/publish/pages/799470/planam-03-2016_art2_2_1.pdf
[Accessed 12 May 2018].
C.M. Flath, J. I. S. G. H. S. C. W., 2014. Improving Electric Vehicle Charging Coordination Through Area Pricing. *Transportation Science,* 40(2), pp. 619 - 634.
Clover, C., 2017. *Subsidies help China sell the most electric cars. Financial Times.* [Online]
Available at: https://www.ft.com/content/18afe28e-a1d2-11e7-8d56-98a09be71849
[Accessed 2 May 2018].
Ensslen, A. et al., 2018. Incentivizing smart charging: Modeling charging tariffs for electric vehicles in German and French electricity markets. *Energy Research & Social Science,* Volume 42, pp. 112-126.
Department of Transport, 2017. *Draft Green Transport Strategy,* s.l.: s.n.
Ghosh, M., 2018. *Now an 'action plan' in place of policy for electric vehicles.* [Online]
Available at: https://www.livemint.com/Industry/tlCseS1lEHCW6aMqu5hU4O/Now-an-action-plan-in-place-of-policy-for-electric-vehicle.html
[Accessed 18 May 2018].
Fishbone, A., Shahan, Z. & and Badik, P., 2017. *Electric Vehicle Charging Infrastructure: Guidelines for Cities.* [Online]
Available at: http://ev4cities.greenwaynetwork.com/
[Accessed 10 May 2018].
Palazzo, A. & and Behrmann, E., 2018. *Germany takes European lead from Norway on electrified car sales.* [Online]
Available at: https://www.stuff.co.nz/motoring/news/103690981/germany-takes-european-lead-from-norway-on-electrified-car-sales
[Accessed 19 May 2018].
Good Energy, 2018. *Electric Vehicle Tariff.* [Online]
Available at: https://www.goodenergy.co.uk/about-us/
[Accessed 19 May 2018].
Yelland, C., 2017. *Cape Town takes govt to court in bid to buy electricity from IPPs.* [Online]
Available at: https://www.fin24.com/Economy/Eskom/cape-town-takes-govt-to-court-in-bid-to-buy-electricity-from-ipps-20170807
[Accessed 20 May 2018].
Hagman, J., Ritzen, S., Janhager Stier, J. & Susilo, Y., 2016. Total cost of ownership and its potential implications for battery electric vehicle diffusion. *Research in Transportation Business & Management,* Issue 18, pp. 11-17.
Kolokathis, C. & and Hogan, M., 2018. *Use Europe's Electricity Underuse To Promote Electric Cars.* [Online]
Available at: https://cleantechnica.com/2018/04/15/use-europes-electricity-underuse-to-promote-electric-cars/
[Accessed 20 May 2018].
Energy, U., 2017. *The Electric Vehicle Revolution A report from Energy UK.* [Online]
Available at: https://www.energy-uk.org.uk/publication.html?task=file.download&id=6282
[Accessed 20 May 2018].
Holland, T., 2017. *BEIJING'S GRAND PLAN FOR ELECTRIC CARS: LOOKS GOOD, BUT UNDER THE BONNET ....* [Online]
Available at: http://www.scmp.com/week-asia/opinion/article/2108353/beijings-grand-plan-electric-cars-looks-good-under-bonnet
[Accessed 20 May 2018].
IEA , 2018. *NordicEV Outlook 2018.* [Online]
Available at: http://www.iea.org/publications/freepublications/publication/NordicEVOutlook2018.pdf
[Accessed 20 May 2018].
IEA 2017, 2017. *Global EV Outlook 2017.* [Online]
Available at: https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf
[Accessed 20 May 2018].

City of Vancouver, 2017. *User Fees for City Owned and Operated Public Electric Vehicle Charging Stations,* s.l.: s.n.
City of Vancouver, 2016. *Vancouver's EV Ecosystem Strategy.* s.l.:s.n.
Gear, J., 2015. *The Big Problem with the Latest Plan to Build EV Chargers in California.* s.l.:Wired Magazine.
Khan, S. a. V. S., 2018. *Strategies for Integrating Electric Vehicles into the Grid. Report T1801,* 529 14th Street NW, Suite 600, Washington, DC 20045: American Council for an Energy-Efficient Economy.
Biviji, M. et al., 2014. Patterns of Electric Vehicle Charging with Time of Use Rates: Case studies in California and Portland. Issue 978-1-4799-3653-3/14.
Pacific Gas and Electric Company, 2017. *Electric Schedule EV - Residential Time-of-Use Service for Plug-in Electric Vehicle Customers,* s.l.: s.n.
Eskom, 2018. *Tariffs and Charges 2018/19,* s.l.: s.n.
City of Cape Town, 2018. *Energy- Electricity Generation and Distribution (Consumptive),* s.l.: s.n.
Pacific Gas and Electric Company, 2018. *PG&E Customers Eligible to Save $10,000 on a New BMW i3 Electric Vehicle,* s.l.: s.n.
Wagner, F., Roberts, D., Francfort, J. & White, S., 2016. *Drive Electric Vermont Case Study,* s.l.: US Department of Energy.
Zecchino, A., Marinelli, M., Traeholt, C. & Korpås, M., 2017. *Guidelines for distribution system operators on reactive power provision by electric vehicles in low-voltage grids.* s.l., The Institution of Engineering and Technology.
Paudyal, S., Ceylan, O., Bhattarai, B. & Myers, K., 2017. *Optimal Coordinated EV Charging with Reactive Power Support in Constrained Distribution Grids.* s.l., SciTech Connect.
US DOE, n.d. *All Laws and Incentives Sorted by Type.* [Online]
Available at: https://www.afdc.energy.gov/laws/matrix?sort_by=tech
[Accessed 2018].
Trabish, H., 2017. *Beyond ToU: Is more dynamic pricing the future of rate design?.* [Online]
Available at: https://www.utilitydive.com/news/beyond-tou-is-more-dynamic-pricing-the-future-of-rate-design/447171/
Adepetu, A. & Keshav, S., 2016. *Improving Time-of-Use Electricity Pricing in Ontario.* s.l.:Cheriton School of Computer Science, University of Waterloo, Canada.
Baatz, B., 2017. *Rate Design Matters: The Intersection of Residential Rate Design and Energy Efficiency,* Washington: American Council for an Energy-Efficient Economy (ACEEE).
Public Utilities Fortnightly, 2017. Abstract Only - The Impact of Time-of-Use Rates in Ontario. *Public Utilities Fortnightly Magazine*, February.
ee Publishers, 2018. Time for variable pricing for feeding into the grid. *Technology and Business for Development*, 12 February.
Faruqui, A., 2016. *Residential Rates for the Utility of the Future.* s.l.:The Brattle Group.
St John, J., 2017. *California Solar Industry and Utilities Unveil Dueling Solar-Storage Tariffs.* s.l.:s.n.
St John, J., 2015. *SDG&E Proposes a 'Bring-Your-Own-Battery' Tariff.* s.l.:s.n.
d'Arcier, B. & Lecler, Y., 2014. Promoting next generation vehicles in Japan: the smart the smart communities and their experimentations. *J. Automotive Technology and Management,* 14(3/4), pp. pp.324-346.
SEA, 2016. *Well-to-Wheels Greenhouse Gas Emissions and Energy Comparison between Battery Electric Vehicles, non-Plug in Hybrids and Conventional Passenger Cars for South Africa.* s.l.:Sustainable Energy Africa.
California Energy Commission, 2018. *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025 Future Infrastructure Needs for Reaching the State's Zero-Emission-Vehicle Deployment Goals.* s.l.:California Energy Commission (CEC).
Ferris, D., 2018. *Electric vehicles should fear the 'dragon curve,' researchers say.* [Online]
Available at: http://governorswindenergycoalition.org/electric-vehicles-should-fear-the-dragon-curve-researchers-say/

7 Annexures

7.1 Annex A: List of interviewees

Individual	Organization	Organization Type
Carel Snyman	Electric Vehicle Industry Association	Industry (Association)
Reyhaan Aboo	Portman Global Partners	Industry (Charging Infrastructure)
Winstone Jordaan	Grid Cars / NAAMSA	Industry (Charging Infrastructure / Association)
Alan Boyd	BMW	Industry (OEM)
De Villiers Botha	SolarEff	Industry (Project Developer)
Justin Coetzee	GoMetro	Industry (smart mobility)
Karel Steyn	Eskom	Industry (Utility)
Donovan Leeuwendaal and Gary Ross	City of Cape Town: Electricity, Tariffs	Municipality
EV Charging Stations: Tariffs and Procedures working group	City of Cape Town: Electricity & Sustainable Energy Departments	Municipality
Niki Covary	City of Cape Town: TDA	Municipality
Hiten Parmer	uYilo	Research Programme

7.2 Annex B: Comparing Vehicle Technologies using the Levelised Cost of Transport Model

A levelised cost of transport (LCOT) model was developed to establish the impact of electricity tariff on the cost of ownership of electric vehicles and compares the following vehicle types:

- Internal Combustion Engine Passenger Car (ICE PC)
- Battery Electric Vehicle Passenger Car (BEV PC)
- Internal Combustion Engine Passenger Commuter Bus (ICE Bus)
- Battery Electric Vehicle Passenger Commuter Bus (BEV Bus)

The levelised cost of transport approach establishes the cost of supplying the transport service over the life of the vehicle and is expressed in units of Rands per passenger.km (R/pkm) and is calculated as follows:

$$\textit{Levelised Cost of Transport} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

….Equation 1

Where:

I_t = Investment expenditures in the year t
M_t = Operations and maintenance expenditures in the year t
F_t = Fuel expenditures in the year t

E_t = passenger.km delivered in the year t
r = Discount rate
n = Life of the vehicle

A number of parameters have been included in determining the expenditures I, M and F as follows:

- Investment Cost
- Interest Rate on Finance
- Discount Rate
- Economic Life
- Technical Life
- Fixed Costs: Licensing, insurance etc.
- Maintenance Costs (These are modelled to escalate with mileage)
- Fuel Costs
- Real Fuel Cost Escalation
- Time Penalties associated with limited fuelling infrastructure or range (costed @ R50/hr currently)

The approach is therefore similar to a Total Cost of Ownership (TCO) approach that has been used to compare emerging vehicle technologies (Hagman, et al., 2016). In this case however all costs are discounted as is the transport/energy service delivered (passenger.km – p.km) in the same way that electricity power plants are typically compared with one another. The interface where assumptions can be entered by the user and final results viewed is shown in Figure 7-1 below.

Calculating the Levelised Cost of Passenger Transport

Global Assumptions		
EV Maintenance Discount	30%	(relative to ICE)
EV Maintenance Escalation Discount	30%	(escalation of maintenance costs with mileage)
CNG Relative Fuel Economy ICE	0%	(+ve less fuel efficient on an equivalent basis)
CNG Maintenance Discount (rel. Diesel)	20%	(300 ppm diesel)
CNG Bi-fuelled CAPEX Premium (PC)	R35,000	
CNG Bi-fuelled CAPEX Premium (Bus)	10%	

Results		
ICE Pass Car	3.06	R/p.km
BEV Pass Car	4.03	R/p.km
CNG Pass Car	2.76	R/p.km
ICE Bus	1.15	R/p.km
BEV Bus	1.24	R/p.km
CNG Bus	1.18	R/p.km

Vehicle Tech. Assumptions

	ICEPC	BEVPC	CNGPC	ICEBus	BEVBus	CNGBus	
Fuel	Petrol	Electricity	CNG	Diesel	Electricity	CNG	CODE
Investment Cost:	R210,000	R474,900	R245,000	R4,500,000	R6,000,000	R4,950,000	CAPEX
Nominal Interest Rate:	12%	12%	12%	12%	12%	12%	IR
Inflation	5%	5%	5%	5%	5%	5%	INF
Repayment Period	5	5	5	15	15	15	N
Deposit	0%	0%	0%	0%	0%	0%	D
Base Maintenance (c/km)	32	22	32	250	175	200	MAINT
Licensing (R/annum)	450	450	450	1000	1000	1000	LIC
Parking (R/annum)	0		0				PARK
Insurance (R/annum)	6000	6000	6000	50000	50000	50000	INS
Battery Replace Cost		R 15,000			R 80,000		BATTCOST

Methodology | **LCOPKM Model** | Sensitivity Results | Bus FE | Conversions | Gas Distribution | ...

Figure 7-1: User Interface of Levelised Cost of Transport Model

The purpose of the model is to find the tipping points in levelised cost where EVs start to become cheaper to own than conventional ICE technologies. It has therefore been set up to automatically run sensitivity analyses across a range of parameters, for example the investment costs premium of a BEV PC car relative to an ICE PC as shown below in Figure 7-2.

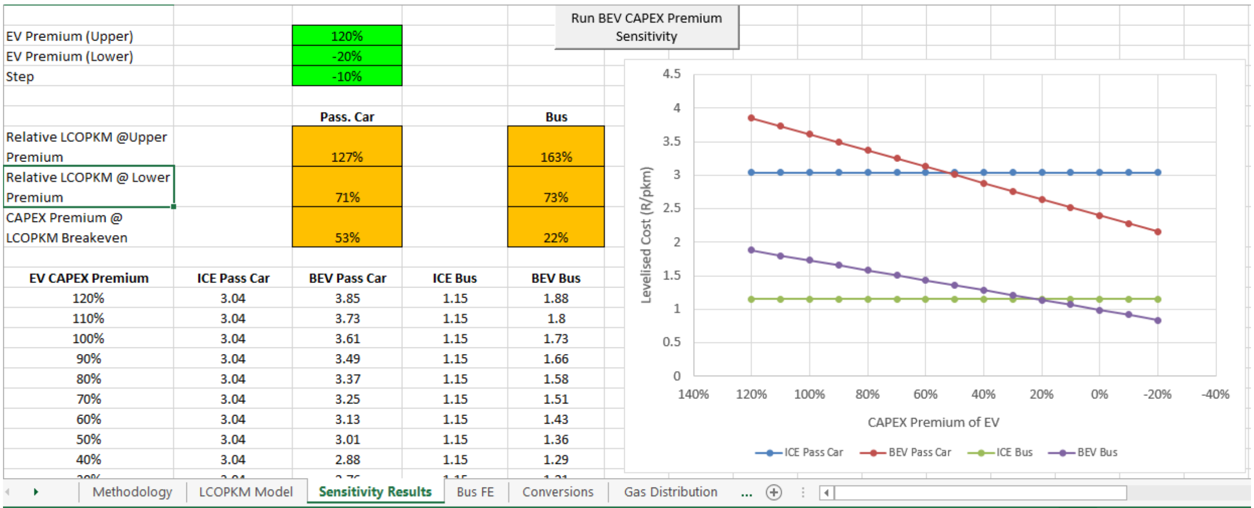

Figure 7-2: Sensitivity Run Interface of Levelised Cost of Transport Model

7.2.1 Initial Results Levelised Cost of Transport Model (LCOT)

The LCOT model was used to run a number of sensitivity analysis for the following scenarios:

Table 7-1: Sensitivity Scenarios for BEV versus conventional ICE Comparison

Scenario	ICE Car Price	Discount Rate	EV Recharging Time Penalty[3]
1	Entry[1]	8%	5 min
2	Entry	20%	5 min
3	Entry	8%	0 min
4	Mid-range[2]	20%	5 min

1: for cars this was assumed to be the 20th percentile price of a sample of 159 models = R208,100
2: assumed to be the average of the 20th and 80th percentile prices of a sample of 159 models = R454,931
3: assumed to occur on 300 days a year

For each scenario a sensitivity analysis was run which varied the investment cost premium of EVs relative to ICE vehicles to find the breakpoint. The LCOT tool has both graphical and tabular output. The graphical results for Scenario 1 are shown below in Figure 7-3. The breakeven point for levelised cost is where the lines cross.

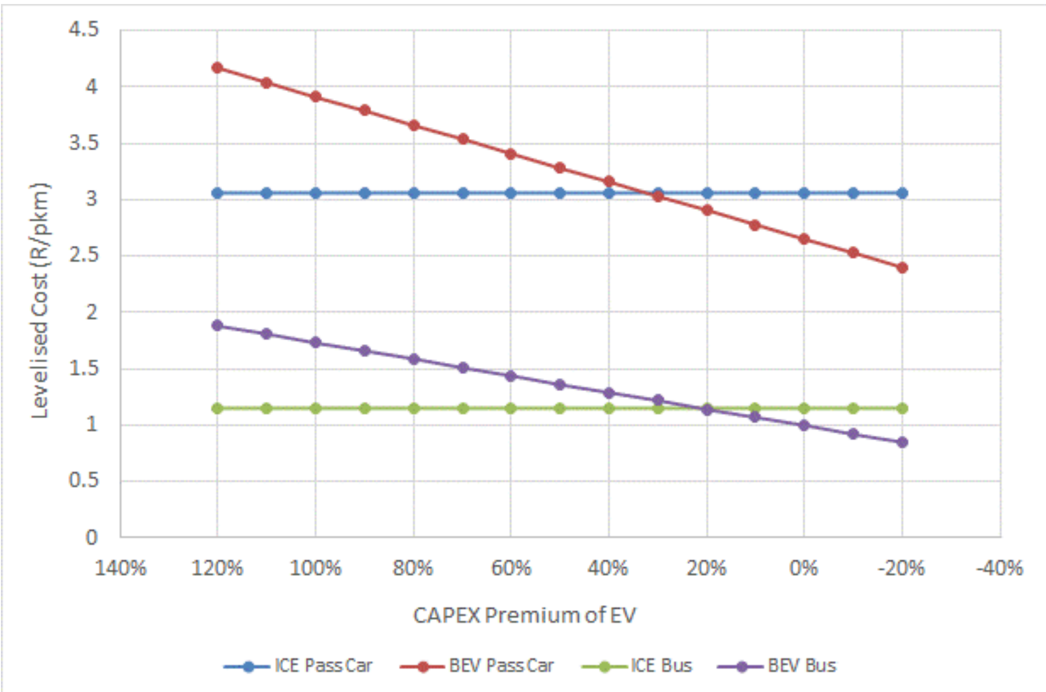

Figure 7-3: Graphical Sensitivity Analysis Results for Scenario 1 – BEV versus conventional

ICE

The breakeven points for all 4 scenarios are shown below

Table 7-2: Results of Sensitivity Analyses on ICE versus BEV Comparison

Scenario	Passenger Car		Commuter Bus	
	Breakeven	Current Premium	Breakeven	Current Premium[1]
1	35%	166%	20%	33%
2	26%	166%	16%	33%
3	79%	166%	23%	33%
4	18%	22%	16%	33%

1: Electric Bus (R6 million) versus Euro 6 Bus (4.5 million) so represents high ambition around emissions (national standard is only Euro 2) – information from City of Johannesburg. The upper end of the premium range could be as much as 200% depending on the basis for comparison.

The following is evident from these initial results:

- The passenger car comparison is more sensitive to discount rate than the bus comparison with lower discount rates favouring the BEV because the future fuel savings have a greater contribution.
- The passenger car was also very sensitive to reduction in refuelling time penalties compared to the bus because both its fixed and variable costs are far lower and so the time penalty is far less diluted by these. Against this, it needs to be considered that a bus is part of a public transport system and if extra refuelling time requires the purchase of an additional vehicle/s to meet demand, the cost of that time would be very much higher than that assumed above.
- For an entry level consumer, the BEV passenger car is relatively expensive with the current price premium quite far from breakeven. In the mid-range segment however, the current price premium (average of Nissan Leaf and BMW i3) is around breakeven at a 20% discount rate. Relative to a luxury car, buying one of the two EV models would likely offer a significantly cheaper cost of ownership.
- EV Bus price premiums are approaching breakeven with ICE but only if compared to diesel buses of the highest emission standard. For most of the market, EV bus prices will still need to drop significantly to compete.

The indications are then that given falling battery prices, battery electric vehicles pose a significant threat as a disrupter. In general, given reasonable vehicle cost parity, the determining factor for penetration would be the expansion of the refuelling infrastructure which for CNG is a challenge and even more so for hydrogen (fuel cells). An extensive electricity network is however already in place to support charging stations and significantly, home charging would cater for much of EV refuelling.