Policy options for electric vehicle charging infrastructure in C40 cities

For

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The cover page photograph is of Portland city Mayor Sam Adams announcing a collaboration with Nissan for an electric vehicle charging network in Oregon, USA. Photo source: gas2.org[1]

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Alfred Wiederer & Ronald Philip

MPP Class of 2010, Harvard Kennedy School

Index of abbreviations

A-STAR	Agency for Science, Technology and Research in Singapore
BEV	Battery electric vehicle
C40 EVN	C40 Electric Vehicle Network
CCI	Clinton Climate Initiative
CPUC	California Public Utilities Commission
EV	Electric vehicle
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
HOV	High occupancy vehicle
ICE	Internal combustion engine
kwH	Kilo watt hour
NPV	Net present value
OEM	Original equipment manufacturer, in this case car manufacturer
PHEV	Plug-in hybrid electric vehicle
PPP	Public private partnership
ROCI	Return on capital invested
ROI	Return on investment
TCO	Total cost of ownership
TEPCO	Tokyo Electric Power Corporation
TfL	Transport for London

Executive Summary

This Policy Analysis Exercise seeks to make policy recommendations to the Clinton Climate Initiative (CCI), on the deployment of electric vehicle (EV) charging infrastructure in C40 cities - a group of the world's largest cities, which have committed to take action on climate change by reducing greenhouse gases, including from the transport fleet. The C40 Electric Vehicle Network (C40 EVN) is a C40 initiative to facilitate the successful introduction of EVs through collective municipal actions including planning and deployment of charging infrastructure, streamlining permitting processes associated with charging infrastructure, providing monetary and non-monetary incentives and mobilizing demand for EVs in city fleets.

CCI had requested us to undertake analysis and make recommendations on the deployment of EV charging infrastructure in C40 cities. This analysis included understanding potential barriers (policy, technological, economic, etc) to the deployment of EV charging infrastructure, understanding how various cities were approaching the issue, and the policy levers that cities could employ in increasing the availability of EV charging infrastructure. Based on this research, we have made a series of recommendations on policy actions that cities can take to increase the deployment of EV charging infrastructure.

Key recommendations

1. **Cities should design EV strategies / programs that are unique to their individual circumstances, objectives and players, but should draw on lessons from peer cities**

Different cities across the world face different circumstances (in terms of parking availability, etc) and different objectives with regard to EVs. Cities with high percentages of private off-street parking, should focus mainly on setting a regulatory framework conducive for investment in charging infrastructure networks, increasing EV deployment by switching public fleets to EVs and leveraging city-owned real estate to speed up infrastructure deployment. Cities with low levels of private off-street parking can expect to see a significantly lower EV uptake, due to less favorable economics – and might be forced to subsidize on-street residential charging infrastructure if they want to speed up this process. Cities also have differing objectives for EV deployment. For industry development purposes, small test-runs with the latest technology seem appropriate, whereas wide-spread adaptation required to achieve an environmental impact will require more elaborate planning, coordination between public and private stakeholders, public awareness campaigns, investment in charging infrastructure, and the use of proven technologies. Each city will have to develop its own strategy based on its unique set of objectives connected with EVs and

charging infrastructure. There is also immense value from sharing lessons about what works and what doesn't in regard to charging, across cities, to overcome information deficiencies.

2. **City governments have limited resources to mitigate up-front EV cost but can use other policy levers to affect TCO of EVs**

The upfront cost of EVs is the single biggest barrier to adaptation / deployment of EVs. However cities have limited means at their disposal (if any) to influence upfront EV cost, but have other instruments at their disposal which affect the TCO of EVs and therefore enter into the overall value equation of an EV from a consumer's perspective. The most prominent levers are waiving congestion charges & parking fees, providing electricity discounts, etc.

3. **Cities should use their regulatory influence smartly to create a conducive environment for private investors of charging infrastructure – and only provide subsidies under specific circumstances**

There are several regulatory barriers to the deployment of EV charging infrastructure including permitting of charging infrastructure, the lack of a technical standard for charging infrastructure, policy uncertainty regarding sale of electricity, regulation regarding EV-related investment by utilities, etc. Cities which face these regulatory barriers should address them as early as possible by building political consensus and then mandating the relevant government agency to address each issue whether it be modifying building codes, streamlining permitting, deciding a standard in consultation with OEMs, etc. As mentioned in Chapter 4, city governments hold a comparative advantage in zoning and building codes and permitting, and they should use those levers to good effect. Cities should use their regulatory influence smartly to remove / mitigate barriers to create a conducive environment for private investors. This report also shows that per-se a direct subsidy to private infrastructure providers is not required because charging networks offer a viable business opportunity – the notable exemption being cities with large proportions of on-street residential parking where residents might be undersupplied with charging infrastructure as the economics under those conditions are less appealing. Another circumstance where city investment might be necessary is the case of very high demand uncertainty – under these circumstances cities can also consider running pilot projects or demonstration projects for proof of concept, which if proved economically viable, can then subsequently be sold to the private sector.

4. **If cities or city utilities do offer charging infrastructure services, there is a strong case for subscription fee based business models to gain consumer acceptance**

Two key insights emerge from the analysis of the economics of public charging infrastructure. First, from a pay-per-use perspective, the mark-up required to make the infrastructure economically feasible might look prohibitively expensive to consumers. Second, annual subscription fees required to finance a network would be, even under conservative assumptions, appear modest and in line with amounts consumers are prepared to pay for other services. To make consumers accept public charging and allow for a profitable charging infrastructure business, there is a strong case to push for subscription fee models. Cities which run / own the charging infrastructure themselves (or by city owned utilities) should therefore have subscription-fee based business models.

5. Cities should be aware of technological uncertainties and not commit prematurely

There are significant technology barriers and uncertainties that exist. EV battery swap technology and smart grid technology, for example, have generated tremendous media and investor attention, but our research show concerns regarding these technologies. The EV industry is young and highly dynamic, and changes in technology while the industry matures are likely. However, for the key components of charging infrastructure, like Level I, II and III charging, the norms have been set and it appears to be safe for cities to commit to these standards now. Slowing down EV adaptation for certainty regarding smart grid technology does not make sense. If a particular smart grid application in the future makes economic sense, it will generate economic returns that allow for the charging infrastructure to be updated. The argument that the smart grid is required for the charging infrastructure's economic viability is not supported by the analysis in this report – and also not by the reality of public and private sectors currently investing in charging infrastructure without any smart grid component.

The authors believe that taking these seven recommendations into consideration, cities can increase their likelihood of a successful and rapid adaptation of EVs. EVs are a reality, and during the next decades there will be a significant uptake of EVs on streets around the world. Cities that want to actively steer this development have to act decisively and comprehensively.

1. Introduction

Electric vehicles (EVs) are vehicles that use electric motors for propulsion. Conventional **internal combustion engine** (ICE) vehicles use the combustion of a fuel (typically a fossil fuel like gasoline) for propulsion. **Electric Vehicles**[2] (EVs) use only an electric battery to power the vehicle and need to be charged by plugging into an electric socket. There are a number of variants on the continuum between a pure ICE and a pure EV. **Hybrid Electric Vehicles**[3] **(HEVs)** like the popular Toyota Prius have both a conventional ICE engine and a small electric motor in parallel. The vehicle's battery is charged through regenerative braking and can power the vehicle for roughly 40 miles. **Plug-in Hybrid Electric Vehicles**[4] (PHEVs), like HEVs have both ICE and electric engines in parallel but need to be plugged in to an electric socket to charge the battery. For hybrid EVs, the ICE is typically the primary source of energy while the battery is uses as a secondary source. This report focuses on pure EVs i.e. battery electric vehicles that only use battery power for propulsion. This includes EV variants that have range extenders (engine generators serving as a secondary source of electricity). For an overview of the different technologies see Appendix III - Figure 1.

1.1 Client background & client research needs

The William J. Clinton Foundation launched the Clinton Climate Initiative (CCI) to create and advance solutions to the core issues driving climate change. Working with governments and businesses around the world to tailor local solutions that are economically and environmentally sustainable, CCI focuses on three strategic program areas: increasing energy efficiency in cities, catalyzing the large-scale supply of clean energy, and working to measure and value the carbon absorbed by forests. CCI is the delivery partner of the **C40,** an association of large cities around the world[5] that have pledged to accelerate their efforts to reduce greenhouse gas emissions. Cities have an important role to play in tackling climate change, particularly as cities bear a disproportional responsibility for causing it.

In December 2009, at the "Climate summit for Mayors" in Copenhagen, which was held alongside the UN Climate Change Conference (COP15) in Copenhagen, fourteen[6] of the C40 cities came together to form the 'C40 Electric Vehicle Network (C40 EVN)' and pledged to collectively address four areas of municipal action deemed critical to the successful introduction of electric vehicles.[7] Through the C40 EVN, the cities have pledged to:

1. Facilitate the planning and deployment of charging infrastructure and related electricity supply systems in collaboration with local utilities.

2. Work with relevant stakeholders to streamline permitting processes associated with charging equipment to encourage the safe and expeditious installation on customer premises and elsewhere.

3. Coordinate monetary and non-monetary incentives available to the general public and organizations purchasing electric vehicles, and contribute to the package appropriately.

4. Develop and publish a plan to mobilize demand for electric vehicles in city fleets for the period 2010 - 2013 and rally private fleets to the safe end.

So far, four private sector companies have committed to work with the C40 Electric Vehicle Network toward the shared goal of growing the market for electric vehicles. This group includes car manufacturers, BYD, Mitsubishi Motors Corporation (MMC), Nissan and Renault. These companies will help inform cities' EV policies, vehicle procurement and infrastructure investment decisions through advice on vehicle specifications, charging parameters, business models for electricity supply, and incentives.

The CCI is consciously focusing on cities as means to fight climate change as cities play an important role in making real and significant progress in reducing GHG emissions. Half the world's population lives in cities that account for more than two-thirds of carbon emissions. Road transportation, at 11%[8], ranks as one of the largest discrete end-use contributors to GHG emissions and is among the fastest growing[9] of GHG sources. The conversion of major vehicle fleets to electric power, especially light-duty vehicles such as cars and vans, is an important opportunity to reduce urban GHG emissions, due to the potential magnitude and speed of implementation.

CCI research needs

Stephen Crolius, Director of Transportation at the CCI, coordinates the C40 EVN and asked us to help recommend policy options for C40 cities regarding EV charging infrastructure. Mr. Crolius asked us to take the need for EVs as a given and focus downstream on EV charging infrastructure – to understand what the key barriers to deployment of ubiquitous charging infrastructure were, what the economics of a single charger and a charging network were, what policy options and levers city governments had for increasing deployment of charging infrastructure and what recommended actions cities should take in this regard. The CCI has asked us to put a special emphasis on the economic dimension as well as which potential policy measures are available to cities.

1.2 Research methods

The research methods employed for this report include extensive primary and secondary research. The primary research involved interviews with policymakers, EV OEMs, utilities, EV charging infrastructure providers and EV users in various cities around the world. We traveled to Singapore and Bangalore to understand the city's EV pilot program and meet various stakeholders associated with it. Furthermore we benefited from Mr. Crolius' updates and feedback from his extensive travel and engagement with key EV players around the world. The secondary research involved a review of academic reports, analyst and consulting firm forecasts and reports, policy documents, etc. We have also built models and sensitivity analyses to understand the economics of charging infrastructure.

1.3 The role of EVs in achieving emissions reduction & other public policy objectives

The client requested us of this report to take the need for BEVs as a given and focus instead specifically on issues downstream related to EV charging infrastructure. Hence though this report will not delve into answering the question of whether EVs are an effective means of achieving public policy objectives, this section briefly highlights the various public policy objectives that governments have stated EVs can potentially help achieve and present some of the analysis addressing this question.

The most commonly cited public benefit of EVs is in the reduction of GHG (Greenhouse Gas) emissions. Road transport is responsible for 66% of particulate emissions and 42% of NOx emissions in London[10]. Research shows that each EV that displaces a conventional car produces savings of approximately 1.5 tons of CO2 per year[11], compared to a conventional vehicle. This represents a 62% reduction compared to a petrol-powered car, and a 53% reduction compared to a diesel-powered car. Vehicle tailpipe emissions include hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM), formaldehyde (HCHO), etc. EVs generate significantly fewer emissions – in most cases, close to zero – compared to regular ICE vehicles. Looking only at the emissions created by exhaustion is not sufficient – many of the emissions created by electric vehicles are produced in earlier steps of the fuel energy value chain, e.g. at electricity production. The relevant measure is therefore "well-to-wheel emissions" that looks at emissions along the whole energy production process. Depending on how the electricity used for charging EVs is generated, i.e. renewable sources or fossil fuels, EVs can lead to significant well-to-wheel emission reductions[12]. An interviewee from a utility in California mentioned that under a scenario where 12% of cars in their service territory were EVs by 2020, that could constitute 11% of total load served. Unless new renewable energy capacity comes online, this additional load will probably be served by incumbent fossil fuel generation power generation capacity, thereby limiting the emission reduction potential.

Some of the other public policy objectives associated with EV deployment include:

- **Industry development:** Many governments believe the nascent and growing EV industry can serve as a generator of employment i.e. “green jobs”. Singapore has stated that it considers the EV industry a source of great potential for the development of industry, business, standards and R&D in Singapore.[13]
- **Energy security / reduced dependence on imported oil –** The Obama Biden Energy Plan (2008), the London Electric Vehicle Delivery Plan (2009) and other policy documents mention the role of EVs in reducing the dependence on imported oil, thereby improving energy security.
- **Others including lower fuel costs & reduced noise –** EVs have a lower per-mile cost compared to ICE vehicles. EVs are significantly quieter compared to ICE vehicles is minimal engine and transmission noise. (London Electric Vehicle Delivery Plan, 2009)

Needless to say, there are several options beyond deployment of EVs, for addressing reduction of emissions from transport fleets and for reducing oil consumption. These include and are not limited to:

- Investment in mass transit systems
- More stringent fuel efficiency standards
- Investment in other alternative fuel vehicles including fuel cell vehicles, etc
- Urban planning measures to reduce VMT (vehicle miles travelled)
- An economy-wide CO2 cap-and-trade system
- Fuel taxes

It is clear that EVs aren’t a silver bullet for dramatically reducing GHG emissions and oil consumption. They would need to be part of a multi-pronged strategy that includes many elements – fuel taxes, mass transit, compact development, etc – in parallel.

1.4 Current EV & EV charging landscape

There has been an immense amount of media and automotive industry focused on EVs over the last few years.[14] This has been coupled with announcements from governments – federal and municipal – committing to promoting the deployment of EVs through various investment schemes, subsidies, EV programs, etc; a sample which is included in Table 1.4.1 below.

Table 1.4.1: Select recent municipal government EV announcements

City / Country	EV-related announcement
London / UK	"Electric Vehicle Delivery Plan for London" – Mayor of London – May 2009 – building of infrastructure, EV procurement, incentives & marketing
Singapore, Singapore	"Electric Vehicle Test Bed program" – CEO, Energy Market Authority – May 2009
Los Angeles / USA	"Southern California Regional Plug-In Electric Vehicle (PEV) Plan" – Mayor of Los Angeles – Dec 2009 - Investment in charging infrastructure, streamlining permitting, fleet acquisition
San Francisco / USA	9-step plan to make Bay Area "EV Capital of US" – Mayors of San Francisco, San Jose & Oakland – Feb 2009
Portland / USA	Mayor Sam Adams announcement with Nissan for electric vehicle pilot project
Paris / France	Mayor Delanoe announces "Autolib"[15], a 4000 EV rental program – Oct 2009

There are also several federal government initiatives or projects funded by federal governments across the world. These include an EV test-bed program in Singapore, a $99.8M stimulus grant awarded by the US government to ECOtality of Arizona, for an EV test pilot across 5 US states, involving the deployment of up to 4700 Nissan LEAF EVs and 11,210 charging stations[16].In September 2009, China & the USA announced the launch of the US-China EV Initiative under which both countries would work together on standards development, demonstrations, a technical roadmap as well as public awareness and engagement.[17]

Governments are not alone in showing increasingly high levels of activity in regard to EVs. Almost all large OEMs have by now either announced EV prototypes, models or even concrete launch dates of EV models. Nissan will launch its LEAF electric car in 2010, as will Renault. GM, Ford, Volkswagen and BMW have not only shown prototypes of full EVs but also announced concrete launch dates. Even Porsche, a sports car manufacturer, has recently shown its first EV prototype. The supplier industry is also jumping on the bandwagon. First tier suppliers like Valeo and Bosch are announcing EV products, are joining forces with battery manufacturers or are publishing white papers that take a bullish position on EV adaptation.[18] Even consulting companies seem to believe that EVs is a defining topic for the future of the car industry – both McKinsey and the Boston Consulting Group have recently released extensive studies on the EV market.[19]

These are all strong indicators that the EV market will take off. There is a concerted effort of both governments and industry to push EVs into the market. Against this background it seems unlikely that EVs will meet the same fate that they did in the mid 80s when they disappeared after a short while and never could gain significant market traction.

EV charging

EVs need to be charged with electricity from either an internal or external source. An internal source includes a motor inside the vehicle used to generate electricity (typically through regenerative braking), while an external source would be a source of electricity with a specified voltage / current / wattage rating. Throughout this report, "EV charging" refers to charging from an external source. Though the definitions vary in different cities, a rough guide to EV charging equipment nomenclature is included in Table 1.5.2 below. This varies across countries / cities depending on each city's particular electric grid characteristics / electrical standards.

Table 1.4.2: EV charging equipment nomenclature

Charging level	**Specifications**	**Typical use**	**Time to charge battery**
Level 1 (Slow)	120 V / 13A	Charging at home / office	7-8 hours
Level 2 (Fast)	240V / 32A	Charging at supermarket, gym	3-4 hours
Level 3 (Rapid)	Up to 500V / 200A	Like a normal gas station	30 minutes

Charging location

The location where EV users charge their EVs is important and affects charging behavior, the economics of charging and planning for investment in charging infrastructure networks, etc. This report categorizes charging location into three classes:

Home charging – Charging at users residences, including in garages of single homes and multi-unit apartment complexes as well as on-street residential spaces. Expected to be mostly Level 1 charging as it exists already in most residences and can be used to charge EVs overnight.

Office charging – Charging at office workplaces including in outdoor office garages, commercial complex parking garages, etc. Similar to home charging, is expected to be mostly Level 1 charging as EV users can charge their EVs.

Convenience charging – All non-home and non-office charging including on public streets, public garages, supermarket garages, etc. Expected to be a combination of Level 2 and Level 3 charging for quick top-ups of battery power, while users shop at supermarkets, go for movies, run short errands, etc.

1.5 City government role in EV deployment

City governments have a potentially important role in the deployment of EVs and charging infrastructure. There are varying degrees of city government involvement in EV charging markets, ranging from an enabling role – providing a conducive regulatory environment for private sector providers of charging infrastructure e.g. San Francisco, to providing incentives, to getting directly involved in the provision of charging infrastructure e.g. Singapore & London. In cities, where the electric utilities are owned by the city and are contemplating investing in EV charging infrastructure, e.g. the LADWP (Los Angeles Department of Water & Power), city government has a key role sanctioning the use of public funds, influencing regulation regarding whether EV charging infrastructure investments are included in the rate base, and whether cost recovery will come from the EV users or all utility customers, etc. This is an example of one of many policy decisions city governments may be confronted with, as the EV market picks up. There are many policy levers that city governments possess to influence the deployment of EVs and EV charging infrastructure. These levers can be clubbed under a few categories:

- *Regulatory:* Government influence on permitting, building & zoning codes, electric utilities and charging standards.
- *Procurement:* Purchase of vehicles for public fleets

- *Incentives:* Monetary (tax waivers, congestion charging waivers, subsidies, free parking, etc) and non-monetary (access to HOV (High Occupancy Vehicle) lanes for EVs, etc).
- *Ownership:* Leveraging city owned real estate, like parking spots, street sides, etc.

A more detailed discussion of these policy levers, how cities should approach the question of which levers to employ, is included in Chapter 4.

1.6 Key questions addressed in this report

Given the background on various city announcement regarding EV deployment and the client's request to focus downstream on charging infrastructure, this report is structured to address two key questions and subsequently present recommendations. The questions are:

1. Is the availability of charging infrastructure a barrier to the deployment of EVs?

2. What are the barriers to large scale deployment of EV charging infrastructure?

The subsequent two chapters delve into these questions.

2. Is the availability of charging infrastructure a barrier to the deployment of EVs?

This chapter first explores what consumers desire from EVs which is important to understand for large scale adoption of EVs and subsequently addresses the question of whether the availability of charging infrastructure is a barrier to the large-scale deployment of EVs.

2.1 What consumers desire from EVs

There have been several surveys (e.g. by McKinsey and BCG) on what consumers would like from their EVs in terms of range, reliability, etc.[20] We complemented the insights won by secondary research with in depth interviews with the Bangalore-based EV OEM REVA, which already has a number of EVs on the road for several years and therefore has a firsthand perspective on needs of EV consumers.

Research indicates that there are multiple segments in the EV consumer market, with consensus on the fact that there is a continuum of sorts, with enthusiastic early adopters, followed by groups who are willing to try EVs after being overcoming some initial skepticism, and finally the traditional ICE faithful, who are reluctant to switch from ICE vehicles to EVs.

In Shanghai, McKinsey identified 6 consumer segments and analyzed their general and EV-specific attitudes & concerns. Though the breakup amongst segments may differ across cities, the segments may be broadly similar to other cities.[21]

Early adopters (30% of all consumers)

1. **Trendy greens (15%)** – Willing to pay premium and sacrifice performance for green. Like EV designs & lower running costs, willing to pay for a home charger.
2. **Running cost sensitive (15%) –** Willing to pay upfront premium for lower running costs / TCO. Less concerned about safety and reliability.

Shapeable groups (33% of all consumers)

3. **Bargain hunters (16%) –** Care about both upfront and running costs and shop to find lowest price. Like low EV running costs but concerned about upfront cost and reliability.
4. **Performance seekers (17%)** – Like new technology and like to show off. Convenience seekers. Not very price-sensitive. Attracted by EV technology, concerned about range / charging / performance.

Late adopters (37% of all consumers)

5. **Trend followers (22%)** – Try new products after majority. Prefer popular models and have clear brand preference. Concerns about new technology. Concerned about EV choices, price and reliability.
6. **ICE traditional (15%)** – Highly reluctant to change behavior for new products. Not green conscious. Have strong concerns about EVs and reject EVs on all attributes.

The CCI has the explicit aim of pushing EV adaptation beyond the early adopters to guarantee a mass deployment of the technology. On the other hand convincing late adopters to switch earlier in the product life-cycle of EVs might be over proportionally expensive or even impossible. This leaves a focus on the shapeable group. In this group reliability and availability of charging infrastructure become critical. It is for the purpose of winning those groups over and making them adopt EVs that the CCI is looking at the deployment of charging infrastructure.

We also looked at several EV consumer studies and spoke to EV OEMs (Reva) and consumers to understand what EV consumers are looking for, from their EV experience, to understand how what that meant for planning and deploying charging infrastructure networks.[22] Some common themes include:

- Lower running and maintenance costs
- Recognition for environmental awareness / green attitude
- Distinctive design
- Convenience of charging and use
- Strong driving power and quick acceleration
- Easy access to information on EVs and installation / usage / availability of charging infrastructure

2.2 Barriers to large scale adoption of EVs

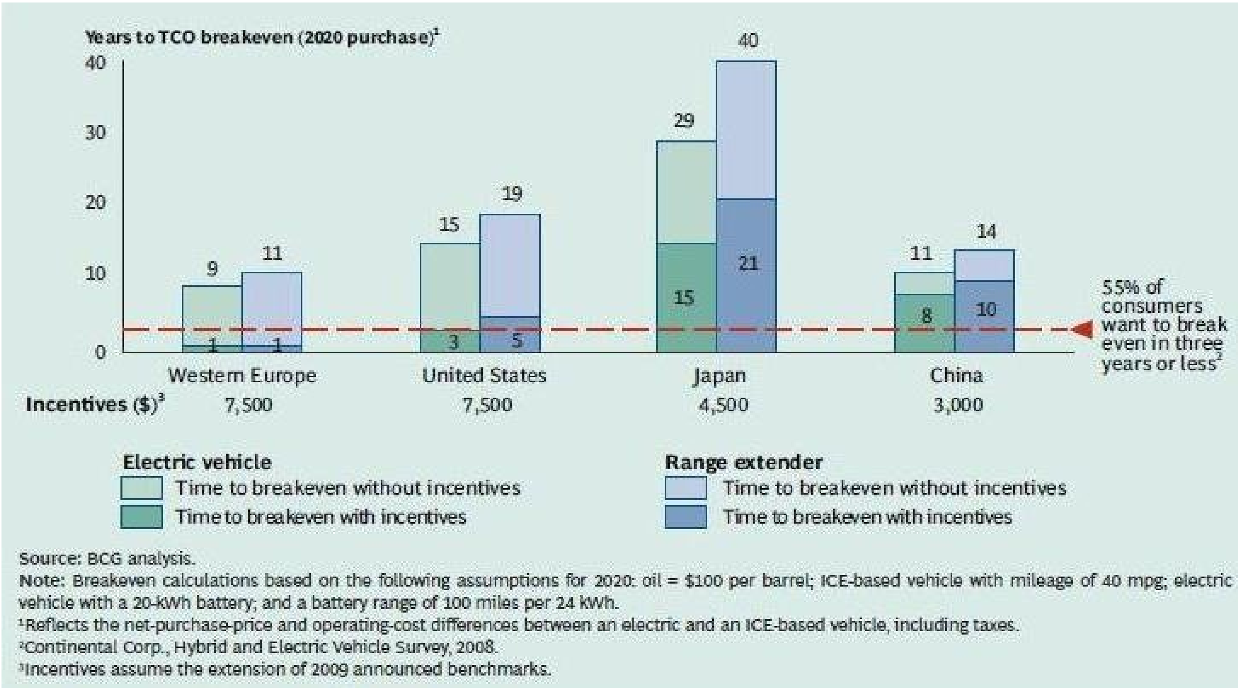
Given the needs of EV consumers discussed above, it is important to understand what the barrier to large scale adoption of EVs are. Research[23] indicates that there are several key barriers to the large scale adoption of EVs, of which availability of charging infrastructure is one. The barriers include:

1. Upfront cost of EVs
2. Range anxiety
3. **Availability of charging infrastructure**
4. Technology uncertainty
5. OEM inertia & current supply chain sunk costs
6. Lack of information

1. Upfront cost of EVs

Our research indicates that the biggest barrier to the large scale deployment of EVs is the high upfront cost of an EV. EVs cost significantly more than regular ICE vehicles, in terms of upfront costs. Total cost of ownership (TCO) or lifecycle economics that take into account fuel & maintenance costs can tell a very different story though, especially under $100+ / barrel oil scenarios. A recent BCG study looked at the TCO breakeven period for EVs compared to an ICE-based vehicle, for various combinations of oil prices, ICE mileage, EV battery range characteristics and government incentives, showing that EV purchasers in some countries could break even in one to five years as depicted in Figure 2.2.1 below.

Figure 2.2.1: Years to TCO breakeven for EVs



Source: The Boston Consulting Group (2010), "Batteries for Electric Cars"

The key drivers of EV costs are the cost of the battery and the current lack of scale and early stage in the learning curve. Though lead acid batteries are significantly cheaper than lithium ion batteries, they offer less range, making them a potentially less attractive proposition. The key metric with regard to battery cost is the cost / kWh which currently hovers around $650-790 per kWh for a battery cell. Forecasts estimate that this should go down to $270-330 / kWh by 2020.[24]

There are various schemes and initiatives – existing and proposed - to reduce the upfront cost to customers including:

a) **EV incentives (rebates / tax credits, etc)** e.g. The US federal government provides a tax credit of up to $7500 for the first 200,000 electric vehicles produced by an EV manufacturer.[25]Some cities also have additional incentives, e.g. the city of Austin, Texas provides incentives of up to $500 for electric vehicle purchases.

b) **Battery leasing** – EV OEMs, battery manufacturers or financial services companies can offer battery lease options to EV customers that reduce the initial upfront cost of the EV, but add monthly / periodic lease payments for the battery that the customer must make. REVA mentioned that they had run a battery leasing pilot with some customers that met with a positive response.

c) **Battery re-use & recycling** – Related to battery leasing models, models that allow for future battery re-use and recycling can potentially reduce the upfront cost of EVs. After a certain number of charging cycles, the capacity & performance of EV batteries drop to below 80% of their original rated capacity and hence may not be optimal for EV use. They can then be re-used for other storage applications including for grid storage, for re-use in cars with smaller range requirements, for stationary applications e.g. buildings & hospitals and for non-car powertrains e.g. airport vehicles, forklift trucks, golf-carts, etc.

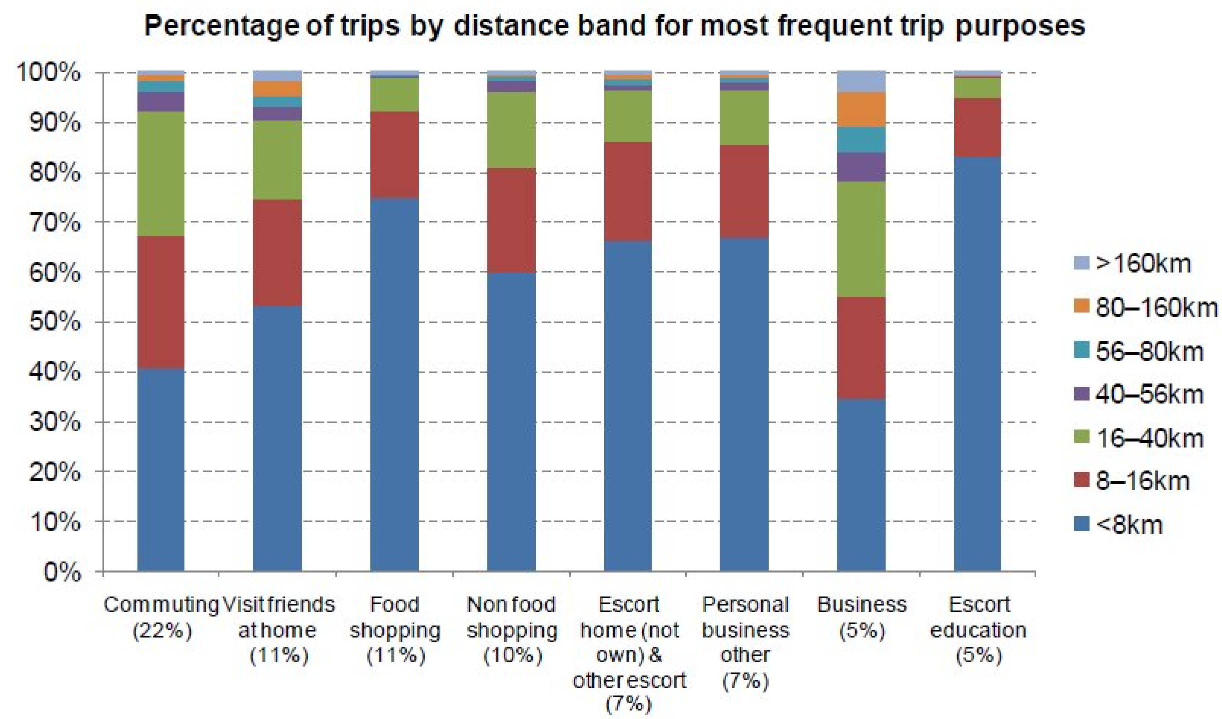
At this stage it is difficult to say which of the above schemes will prove most effective and find wide-spread use going forward. Changes in battery technology and the economics of each option will dictate which of these schemes will find widespread adoption.

2. Range anxiety

A significant concern for EV users is their driving range on a single charge. Range anxiety is the fear of being stranded in an EV due to inadequate battery capacity / performance. The calls for extensive public charging networks are largely in response to range anxiety. EV OEMs have sought to address range anxiety concerns through increased battery capacities, which allow one to drive up to 100 miles on a single charge. Some OEMs have also developed other mechanisms for emergency situations, e.g. REVA has a proprietary Revive technology, which is a battery reserve that can be released by EV users texting / calling a REVA operations center.

To understand whether range anxiety is a valid concern it is prudent to compare trip types and lengths with the stated range of EVs. In the UK, a high proportion of trips for a given purpose fall into lower distance bands under 40km (25 miles) as depicted in the graphic below. This would fall well within the range of most EVs on a single charge.

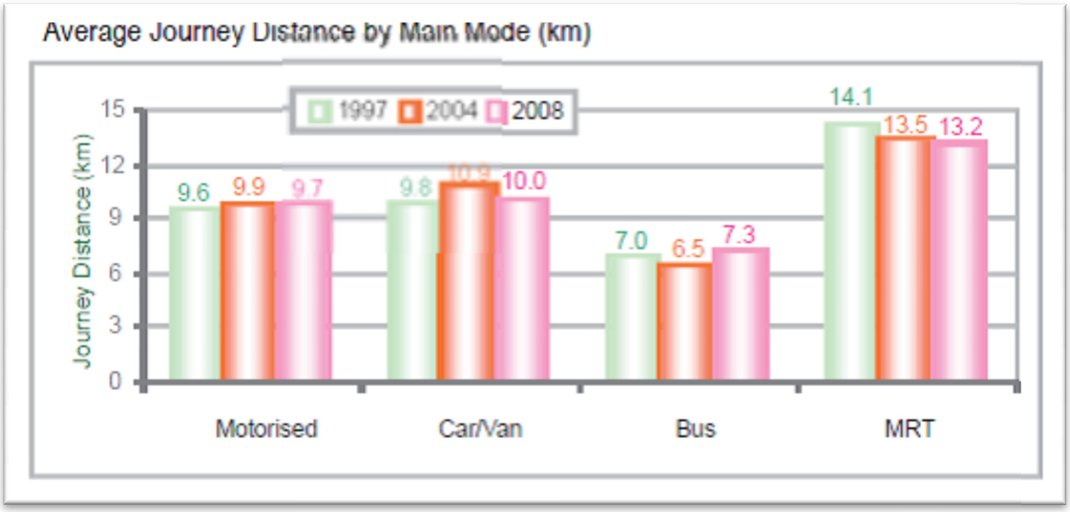
Figure 2.2.2: Trips in the UK by distance band and trip purpose of the most frequent trip types



Source: Element Energy, "Strategies for the uptake of electric vehicles and associated infrastructure implications", Oct 2009

Singapore, which has a land transport policy that focuses on mass rapid transit, has an average car / van trip distance of 10km (6.25 miles). Hence we see a general trend of low average trip lengths across most cities that fall well within the range of EV batteries.

Figure 2.2.3: Singapore – average journey distance by main mode

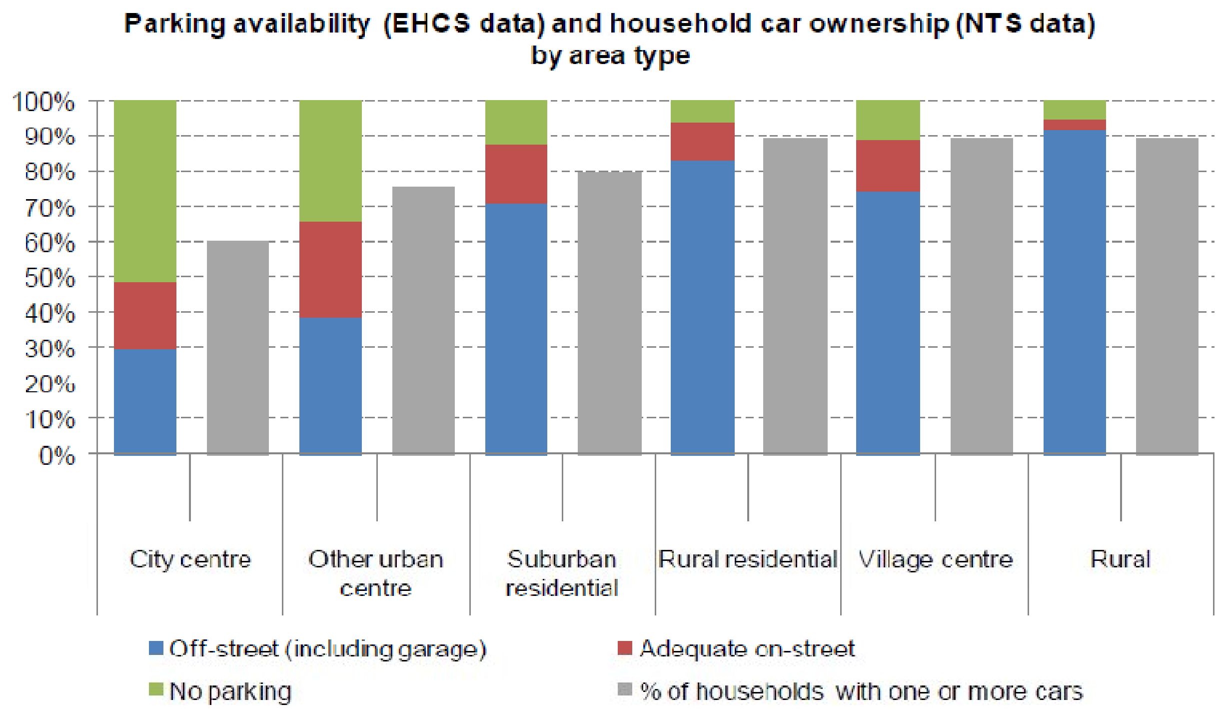


Source: Land Transport Authority Singapore, "Land Transport Statistics in Brief, 2009"

3. Availability of charging infrastructure

The availability of charging infrastructure is a barrier to large scale deployment of EVs that is closely intertwined with range anxiety. As mentioned in Chapter 1, barring EV variants that have internal motors that generate electricity, EVs need to be charged from an external source of electricity. EV OEMs foresee that most EV charging can take place at home overnight. This is easier for homes with garages where the EV can be plugged in to a regular 110V plug for slow charging. For households that do not have off-street (garage) parking, and that park on the street or in public garages, charging becomes more of a challenge if there is no public charging infrastructure. In the UK, less than 40% of urban households have off-street parking availability though around 70% of suburban residential households have off-street parking availability.[26] Anecdotally, most stakeholders interviewed for this report, expect early adopters to be suburban multi-car households who have more disposable income and access to off-street parking. For large-scale adoption though, in cities with limited home / garage parking, investment in EV public charging infrastructure will be required. Public charging infrastructure is a means of addressing range anxiety, with EV users having the opportunity to access public charging infrastructure at times when they are running low on charge. Public charging infrastructure would allow EV users to recharge their batteries at varying rates. The constraint though, is that there is very little or no public charging infrastructure available currently.

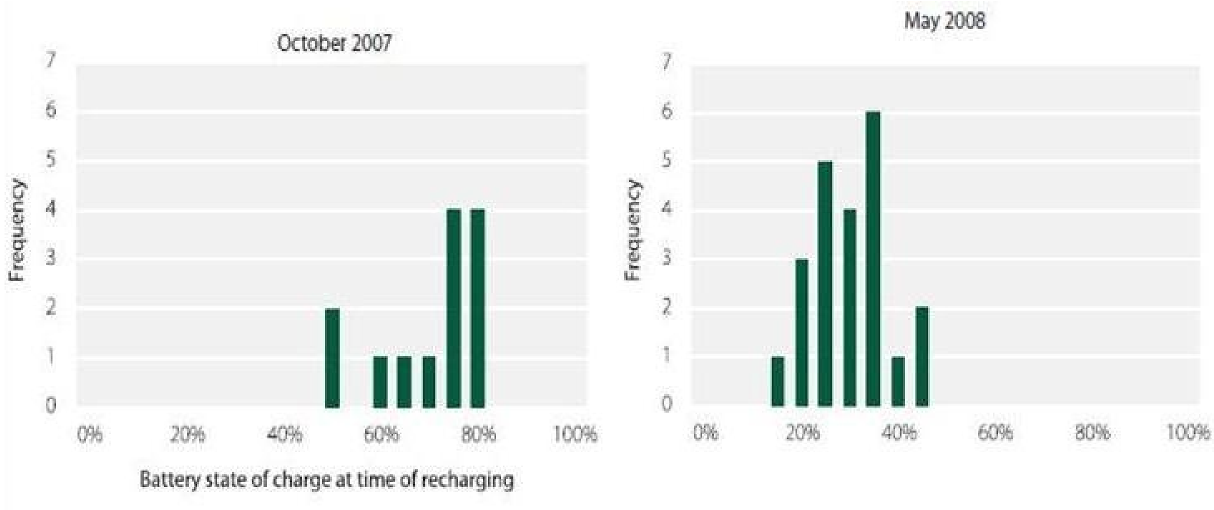
Figure 2.2.4: Parking availability & household ownership in the UK



Source: Element Energy, "Strategies for the uptake of electric vehicles and associated infrastructure implications", Oct 2009

The linkages between range anxiety, availability of charging infrastructure and consumer willingness to change their behavior to match battery & charging availability constraints are interesting and are likely to vary across cities. Our primary research in Bangalore and a TEPCO study on an EV trial in Tokyo offer interesting perspectives on range anxiety. In Bangalore, where a number of REVA EVs are on the road, there is no designated public EV charging infrastructure, implying that EV users there are charging entirely at home, as well as relying on the battery reserve mentioned earlier. A TEPCO (Tokyo Electric Power Corporation) study[27] showed that the addition of a second fast charger in an EV test pilot led to EV users using more of the range of the EV coming to charging stations with less charge remaining in the batteries, compared to when there was only a lone charger available. This is depicted in Figure 2.2.5 below.

Figure 2.2.5: Impact on utilized range of EVs from installation of additional charger



Source: TEPCO

This also calls into question an often mentioned chicken-and-egg problem regarding EVs that goes along these lines: "You need readily available charging infrastructure for an EV roll out, but you also need a significant number of EVs on the road to make this infrastructure economically feasible." Heavy reliance on home charging could break this argument effectively. A recently published McKinsey study also argues along these lines: the main charging will be done at home, a wide-spread public charging infrastructure is not necessary, at least at the beginning. On the other hand we have already seen, this logic will not hold for cities with a low degree of home and garage parking which will have to rely already for the early adopters on public charging infrastructure if they want to see a significant uptake.

4. Technological uncertainty

There is a limited number of EVs currently on roads and hence limited data and experience regarding their performance. A number of the pilots running in different parts of the world have been undertaken to study the performance of the vehicles and batteries under various conditions as well as driving behavior. The Singapore pilot for example will seek to understand the performance of batteries under the country's tropical climate. Lithium-ion batteries are prone to thermal runaway which is a condition where a sealed battery can overheat during recharging and potentially explode. This has significant safety concerns and hence can be a barrier to EV deployment. Research into battery management systems and pilot tests to understand thermal runaway & EV performance are important to gain the confidence of both consumers and public agencies – fire safety, regulatory (car safety), etc. Building consumer confidence in EV technology is critical to mass adoption. One interviewee spoke of a loss of confidence in EV technology after the withdrawal of EV01 – GM's electric vehicle – earlier this decade. In 2006, GM axed their electric vehicle program, withdrawing their EV01 cars from the market. This has been covered in the documentary "Who killed the electric car". This led to significant loss of public confidence and continuing skepticism about EVs.

There is also uncertainty about the fast evolving EV battery space with significant government funding being spent on battery R&D. The battery of today might have very different characteristics from batteries built in a few years. Hence battery leasing might allow consumers to share in the benefits of technological improvements in batteries allowing them to lease more advanced batteries in the future.

5. OEM inertia & current supply chain sunk costs

The large automobile OEMs have large sunk costs in existing ICE supply chains – factories, dealer networks, maintenance networks, etc and hence have limited incentive in making a rapid transition to having EVs make up a large part of their product portfolios. This can potentially be a barrier to the rapid deployment of EVs. Renault-Nissan is an exception to this general trend as the company sees EVs as a key part of their growth strategy.[28] A number of other EV players are relatively new smaller start-ups e.g. Fisker, Miles, BYD, etc who do not have the constraint of significant sunk costs in ICE supply chains.

6. Lack of information

Electric vehicles come with significant benefits and challenges for users and there is currently inadequate information available to the public about these. The PlaNYC study indicates that providing clear information about electric vehicles and installation of charging equipment at homes could significantly boost early adoption of EVs.

There is also a lack of information for other stakeholders including governments, OEMs and utilities. Governments know very little about EVs, utilities do not know what how many EVs will impact the grid and OEMs do not how much demand there will be for EVs and what government policy will be in this regard.

3. Barriers to large scale deployment of EV charging infrastructure

Having established in the previous chapter that availability of charging infrastructure is a significant barrier to the deployment of EVs, a follow-up question is what the key barrier to the large scale deployment of EV charging infrastructure are. The client is particularly keen on understanding this question as many C40 city governments are focusing on the provision of charging infrastructure and an understanding of the key barriers will serve them well.

Our research indicates that there are several barriers to the large scale deployment of EV charging infrastructure. These barriers can be clubbed in three categories – regulatory, economic & technology. This chapter delves into these barriers with a particular focus on understanding the economics of EV charging. The main barriers to the large scale deployment of EV charging infrastructure are:

Regulatory barriers:

- Finalization of standards by international standard setting bodies
- Policy uncertainty regarding sale of electricity, EV-related investment by utilities
- Permitting of EV charging equipment

Economic barriers

- Uncertainty regarding demand
- The economics of a single charger and a charging network make a pay-per-use model unappealing – a subscription model may be a more suitable alternative

Technology barriers

- Uncertainty regarding charging technologies and smart grid applications

3.1 Regulatory barriers

Regulatory barriers are an area where the city has the most influence and power to mitigate / remove. Some of the key regulatory barriers across cities are:

Lack of agreed upon standards for charging infrastructure

There is currently no single agreed-upon standard for EV charging infrastructure. A technical standard is important so that EV OEMs and charging infrastructure providers can cater to a particular plug design / voltage rating specification. There are a few standards currently available internationally. The Society of Automotive Engineers (SAE) J1772[29] standard is a standard for electrical connectors for electric vehicles. The International Electrotechnical Commission (IEC) 62196[30] standard also permits conductive charging of EVs. It is important to note that this lack of standard is not because of technological uncertainties – the technologies of charging are well understood. What is missing is the final adaptation of these technologies in the regulatory framework of the international standard setting organizations.

Stakeholders we spoke to, particularly in Singapore, mentioned that this was a key barrier to the deployment of charging infrastructure. Singapore has set up its own technical Committee, led by the Agency for Science, Technology and Research (A-STAR), to decide on a technical standard for charging infrastructure in Singapore. The Committee is scheduled to issue the standard by March 2010, which will be used in the Request for Proposals (RfP) for charging infrastructure that is scheduled to be released in June 2010. Most interviewees expect this to be a short-term barrier that will be overcome. Cities that are more entrepreneurial in this regard, like Singapore, will remove this barrier quicker.

Policy uncertainty regarding sale of electricity, municipal investment in infrastructure, etc

Municipal governments have a potential role to play in various aspects related to EV charging infrastructure, from regulating to provision to municipal investment in charging infrastructure to providing incentives. Policy uncertainty in any of these aspects can potentially be a barrier to the provision of charging infrastructure. Some examples of areas of policy uncertainty include:

Regulation over sale of electricity

Whether third-party charging infrastructure providers become regulated entities (like electric utilities), when engaging in the sale of electricity, influences business model decisions and the economics for third-party charging infrastructure providers. Some markets have taken legislative measures to address some of the policy uncertainty mentioned above. The US state of California amended its Senate Bill 626 in July 2009 to "require the California Public Utilities Commission (CPUC), in consultation with specified parties, to adopt rules by July 1, 2011, to evaluate policies to develop fueling infrastructure for plug-in hybrid and electric vehicles."[31]This is a powerful best practice that can be replicated across other C40 cities that have similar regulatory environments.

Government policy regarding investment in infrastructure

If there is extensive public investment in charging infrastructure, then this public competition might make the business case unattractive and private providers might not enter the market. Conversely, if government provides incentives – free electricity - or subsidies (as in Los Angeles), then that may improve the economics for charging infrastructure providers. There are various stakeholders who could potentially fund the charging infrastructure – federal or municipal governments, utilities, the private sector or a combination of both, through a public-private-partnership (PPP) or through the use of public subsidies. At one end of the continuum of choices, is obtaining full cost recovery of charging infrastructure from EV users. Alternatively, federal or municipal governments could allocate a budget for funding charging infrastructure as in the case of the UK and Singapore. In markets where regulated utilities are allowed to earn a specified rate of return on their asset base from electricity customers / ratepayers, public charging infrastructure they fund and operate could be added to their asset base. The question is whether regular utility rate-payers share in utility infrastructure costs related to EVs or whether those costs are borne solely by EV users. The California-based advocacy group TURN (The Utility Reform Network) in its comments filed[32] with the CPUC, expressed its concerns, saying that "residential customers should install additional equipment in order to support PHEVs and BEVs, the customer using the service should pay for all equipment and improvements" and "It is not the job of ratepayers to promote particular vehicle choice by paying for the full cost of wiring and end use equipment that is tied to specific customers and houses."

OEMs are also waiting to see whether city governments offer incentives / subsidies for charging equipment. The City of Los Angeles, in December 2009, announced that it would provide a subsidy for home chargers of up to $2000 for the first 5000 residential customers. The lack of clarity on policy regarding investment in infrastructure by utilities and subsidies from government, can be a barrier to investment in charging infrastructure by private investors and utilities and it is recommended that cities release policies in this regard as early as possible.

Permitting

One potential barrier to installation of charging equipment at homes and public places is the permitting process which research indicates is cumbersome, time-consuming and expensive. One of the stated actions of the C40 Electric Vehicle Network will be to work with relevant stakeholders to streamline permitting processes associated with charging equipment to encourage the safe and expeditious installation on customer premises and elsewhere. Some cities are already taking action in this regard. Los Angeles Mayor Antonio Villaraigosa announced that cities in December 2009 that Southern California will work to streamline the process for installation of new charging infrastructure including local city permitting and inspections[33]. The San Francisco building code will soon be revised to require that new structures be wired for car chargers.[34]

Key takeaways regarding regulatory barriers

For each of the regulatory barriers mentioned above, there are often several city government agencies that share responsibility and that need to work together to remove the barrier. This needs to be done in consultation with OEMs, charging infrastructure providers and utilities so that policy outcomes are sustainable and optimal. These barriers retard the deployment of EV charging infrastructure and impede private investment; hence removing them at the earliest is important for unleashing a more rapid rate of deployment of charging infrastructure.

3.2 Economic barriers

Critical to the participation of private investors in the EV charging infrastructure market is a viable business case. Our interviews with cities, utilities, charging infrastructure providers have provided interesting and varying perspectives in this regard, from Singapore where the government recently tried in vain to attract private charging infrastructure providers to invest in networks, to RWE in Berlin which foresees significant revenue opportunities in the charging space, to Better Place which is betting heavily on its battery-exchange technology being integral to large-scale EV adoption.

This section explores the economic barriers to the deployment of EV charging infrastructure, with an analysis of the economics of both an individual charger and an entire charging network.

3.2.1 Main determinants for structure of charging infrastructure

One of the main problems for determining how the charging infrastructure of the future will look like is the uncertainty regarding the demand side for charging. The demand for charging infrastructure is driven by three main factors:

- Adaptation rates
- Degree of convenience charging
- Degree of range anxiety

Why are these three drivers critical? **Adaptation rates** determine how many electric cars are out on the streets at any given moment in the future. Based on the information gathered in our interviews it became clear that certain minimum numbers of electric cars are necessary to support a charging network. For example, officials in Singapore mentioned that private sector charging providers had been reluctant to invest in charging networks in Singapore, even with a matching government grant, stating that the number of EVs forecasted to be on roads, did not provide an appealing business case in the short term. Assuming that electric cars will reach a significant market penetration eventually, this factor becomes mainly an issue of timing. The key question is here when and how fast consumers are switching to electric cars. Estimates about this vary widely and are likely to depend on the political and regulatory environment in each region as well as technological progress.

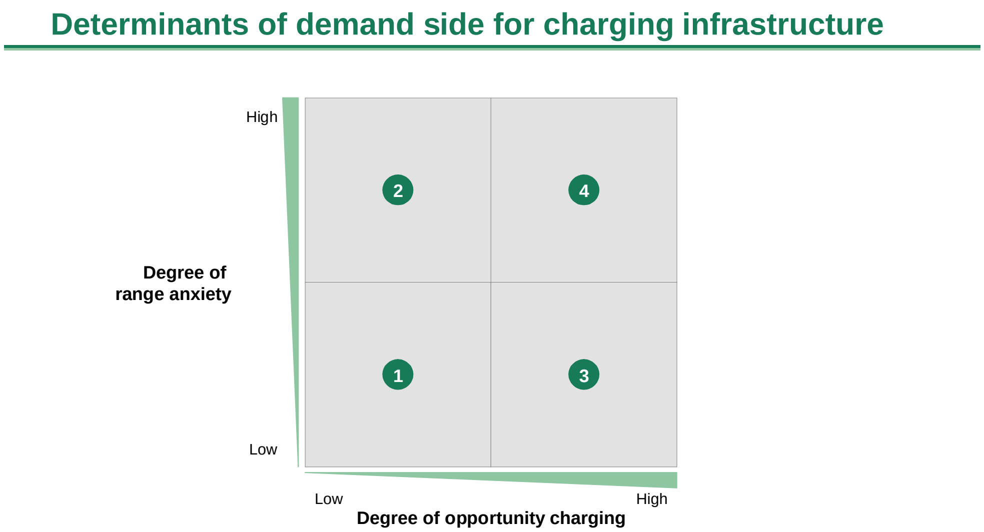
The degree of **convenience charging** measures how often each car uses external charging stations compared to how often it uses home charging. Low degrees of convenience charging would require a relatively limited amount of public charging stations complementing a very comprehensive home charging infrastructure. High degrees in comparison would require a large number and a broad geographic coverage of public charging stations enabling people to do many of their charging cycles away from home. Different degrees of convenience charging therefore impose largely different requirements of size and structure for charging infrastructure.

The degree of convenience charging only measures the actual use of the public charging infrastructure not the perceived need by consumers. As explained previously, **range anxiety** is the psychological phenomenon where people are afraid of running out of charge on a highway and want the assurance that in this case a charging station is close by. It is important to note that range anxiety is not describing the actual charging process for such a case – but people being afraid from such a hypothetical case and therefore demanding a certain kind of charging infrastructure, even though they might not actually use it.

What are the most probable or realistic values for the degrees of convenience charging and range anxiety? At this point this is unclear. Interviews with various cities and with various players have shown that each of them faces a high uncertainty regarding these factors because empirical values are missing. Players like RWE and Singapore are acknowledging this and are setting up test cases right now to gather this kind of data. Dependent on the outcomes of these test runs and the estimates for the parameter values, the actual charging infrastructure that will be installed might vary significantly. But even without the results of these test runs being available yet, one can show the option space opened by variations of these two parameters and what each of these options means in terms of requirements for the charging infrastructure.

The option space defined by these two parameters is shown in Figure 3.2.1.1 Based on this matrix there are four generic options. How would each of these options translate in charging infrastructure requirements?

Figure 3.2.1.1



Option 1:

In this option consumers would largely rely on home charging and only show low degrees of range anxiety. Under these conditions only minimum degrees of charging infrastructure would have to be installed because no significant demand either in real terms or in psychological terms is to be expected. Charging infrastructure would be limited to few, strategically well placed spots.

Option 2:

In this option consumers don't actually show a high real demand for public charging infrastructure, but their fear of running out of charge creates a "psychological" demand for infrastructure. Given these conditions charging infrastructure would be rather limited but strategically placed at highly visible locations to allay these consumer fears.

Options 3 and 4:

Both these options share a high real demand for opportunity charging and therefore require an extensive public charging infrastructure. The different degrees of range anxiety are unlikely to make a huge difference in terms of the design for the infrastructure, given that the physical demand alone is enough to drive the installation of a comprehensive infrastructure.

It is important to note that each of these scenarios not only has implications on the design and structure of the charging infrastructure but also on the viability of different business models. In options 3 and 4 a strong real demand for charging infrastructure supports the economic feasibility of such an infrastructure. Business models based on real usage as for example pay-per-use models can potentially be feasible under such conditions. The situation is different under option 2. There we need some (even so arguably not as comprehensive as under option 3 or 4) public charging infrastructure but real demand will not create a major share of income supporting this infrastructure. Pay-per-use models are therefore unlikely to be feasible. More promising could be subscription models in which consumers pay for the provision of the infrastructure instead of actual usage. Another option are subsidized schemes in which parties profiting from different parts of the electric car value chain (e.g. car suppliers) support the installation of charging infrastructure as a business enabler. We will spend more taught about these different models later in this chapter.

The EV market in 2020

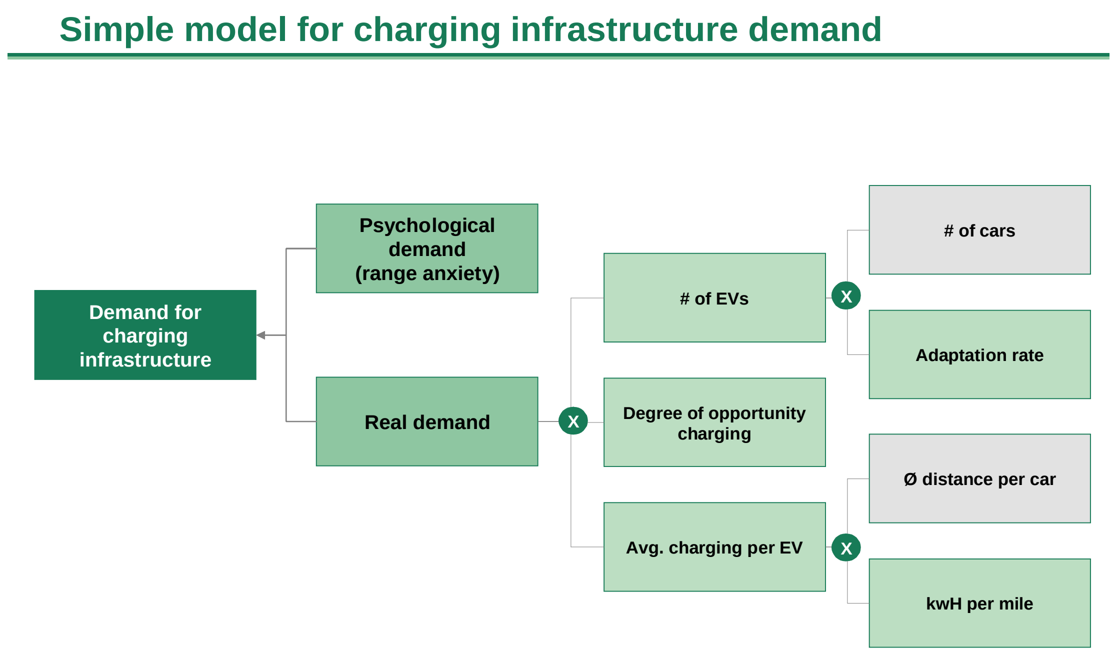
Another important factor for determining the mid-term demand for charging infrastructure is obviously the number of EVs on the street. This number is determined by the amount of cars on the street in total and the adaptation rate of EVs as a percentage of these cars. This has to be distinguished from the share of electric cars sold in any given year, the number most research reports and consultancies focus on. If we look at medium term estimates for the market share of electric cars sold in 2020 we get widely diverging views. Estimates range from 1.5% to 10% for purely battery powered cars.[35] Numbers get significantly higher if one considers plug-in hybrids also as electric cars. A consulting report for example estimates that such plug-in hybrids will make up to 20% of the market in 2020.[36] How can divergence in forecasts be explained? First, the forecasts are based on driver models using specific assumptions for e.g. battery and oil price developments, subsidies, etc. There is a huge uncertainty for all these factors and differing assumptions can lead to significantly differing outcomes. Second, especially for car manufacturers the forecasts also function as signaling device. As one interviewee, who wanted to remain unidentified, put it: “If you bet your whole company on electric vehicles, you will publish estimates of high adaptation rates no matter what you believe internally.” Questioning the basic assumptions of each forecast and coming up with an own estimate for EV adaptation would be beyond the scope of this paper. We will therefore move forward using three different scenarios instead, representing an expected (5%), high (10%) or very high adaptation rate (20%).

Are these numbers realistic? A short back of the envelope calculation indicates so. Taking an average age of the US car fleet of approx. 8 to 9 years, leads to car replacement rates of around 11% to 12% p.a. Assuming that mass adoption of EVs will start in 2013 with a sales share of approx. 1% and then ramp up to the numbers forecasted by the consulting study for 2020 means that by 2020 something between 4% and 9% of the cars on the road will be battery powered depending on which of the growth scenarios developed in the study is used[37] – roughly equal to our expected and high scenarios. We included the very high adaptation scenario for two reasons: First the numbers forecasted are based on the overall car market – we however look only at cars sold in large cities whose car requirements are arguably more in line with the characteristics of EVs then hose of rural communities or smaller cities. Second, one can interpret the very high scenario also as a glance into a little more distant future where a 20% market penetration is likely and so get a feeling for infrastructure levels required then.

A simple model for charging infrastructure demand

In the next step we formalize the insights won in the last chapters. The main drivers for charging infrastructure demand are the "psychological" and the "real" demand (see Figure 3.2.1.2). Whereas we cannot break down the psychological demand further, we can develop a driver tree model for real demand. Real demand in such a simple model can be calculated by the number of EVs times the degree of opportunity charging times the average charging load per EV. The number of EVs in turn is determined by the number of cars in any given region/city times the adaptation rate. The average charging load per EV is the product of the distance in miles driven on average per car and the amount of kwH required per km.

Figure 3.2.1.2



Plugging in forecasts for the values described in this model we can come up with estimates for the likely demand for electricity sold through public charging spots. We have done these calculations for three of the cities in our sample for each of the three adaptation rate and degree of opportunity charging scenarios.

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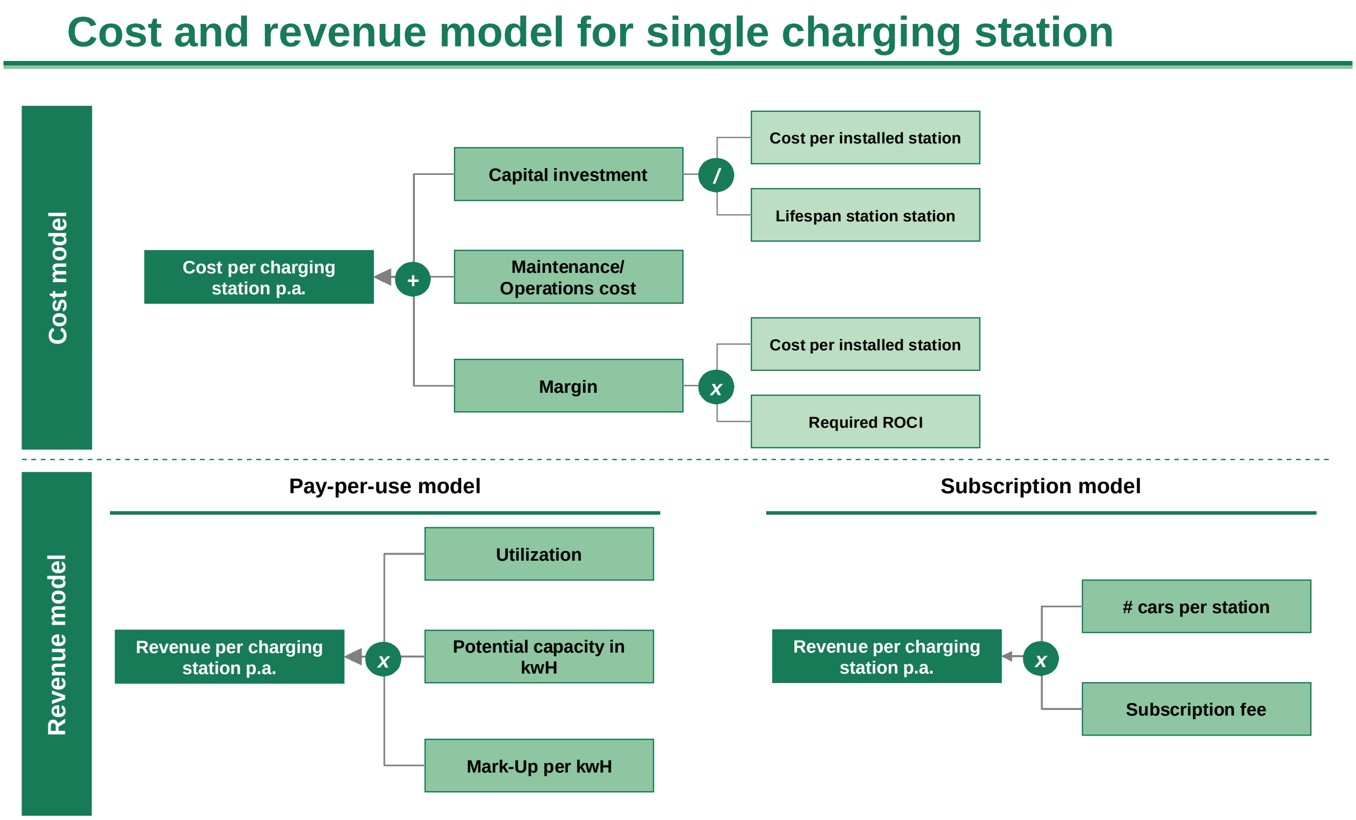
Understanding the economics of charging infrastructure

After having identified and discussed the drivers for infrastructure demand, we are analyzing the drivers for infrastructure supply in the next section. To do so we will look at the economic feasibility of charging infrastructure – starting with a single charging station as the smallest entity and then building on this to develop an economic model for more complex charging networks.

3.2.2 Economics of a single charging station

The smallest entity of a charging network is a single charging station. To determine the economic feasibility of a single station we have to look at a simple cost and revenue model comprising the most important profitability drivers, as depicted in Figure 3.2.2.1.

Figure 3.2.2.1



The cost side

The costs of a single station are determined by the following factors:

- **Cost per installed station:** These costs consist of the cost for the actual station plus the one-time installation cost. Both costs vary widely depending on the type of charging station installed. Whereas home charging stations (Level 1) are relatively inexpensive, additional safety and stability requirements drive the costs for public charging stations (mostly Levels II & III) significantly up. Earlier in Chapter 1, we made the distinction between slow (Level 1), fast (Level II) and rapid (Level III) charging stations. The latter are able to charge a car to up to 80% of its capacity within 30 minutes and are therefore ideal for fast, public charging. However, their costs are up to 7-9 times higher than those of ordinary slow and fast chargers. Especially for rapid chargers there is also a significant difference in installation cost between different countries – dependent on how modern the underlying grid is. Whereas most German and French grids can handle rapid chargers without significant additional grid investments, most American grids would probably need to be upgraded, hence driving up the costs. For an overview of investment and installation costs per charging location and type see Figure 3.2.2.2. One has to keep one caveat in mind while discussing the cost of charging infrastructure. The technology is currently relatively new and charging stations are not mass produced – one would therefore expect the cost to decrease over time given the increasing scale of production. However, our interviews have shown that this anticipation might be misguided. First, approx. 50% of the investment costs are caused by the physical labor of installing the device at a specific place, getting permits and changing street/parking lot structures. These costs can be expected to be relatively neutral to scale. The other 50% are caused by the actual charging device. This device mainly consists of low tech electronics and standard commodities like stainless-steel for the body etc. – which prices are again are relatively insensitive to scale. The general expectation is therefore that scale cost reduction will not play a major part for individual charging stations.

Figure 3.2.2.2

Estimates for investment and installation cost for single charging outlets

in US $	Level II: Private home/garage	Level II: Commercial garage/ public street	Level III	Battery swap
PlanNYC/ McKinsey	1,500-2,500	2,000-7,500 dependent on location	more than 40,000	-
BCG, Element Energy and other studies	500-2,000	3,000 -8,000 dependent on location	more than 50,000	-
Interviews and author's estimates	500-1,000	3,000 –7,000	40,000 – 75,000	+1,500,000

Source: PlanNYC, "Exploring Electric Vehicle Adoption in New York City", p. 15; BCG, "The future of batteries for electric cars – other cost factors", p. 9 and 16; Element Energy, "Electric Vehicles – Strategies for uptake and infrastructure implications", p. 62; Interviews

- **Lifespan per installed station:** The costs of an installed station have to be spread over the life-span of a charging station. Since only now the first modern charging stations are installed in public spaces it is still uncertain what their final life will be. Experts estimate typical life-spans of 10 up to 15 years.[38]

- **Maintenance/ operation costs:** Maintaining the charging stations, conducting necessary repairs, controls and cleaning tasks as well as generally operating tem is another cost factor. These costs are estimated by experts to be between around 10% of the original installation cost annually.
- **Margin:** The required margin is obviously not a direct cost – however, the margin has to be earned by the generated revenue stream and is therefore treated as a cost component in our model. We set up the margin as a return on capital invested – in line with how many utilities are regulated right now. The required ROCI differs of course based on company, location and business model and the regulatory framework under which the charging station operates.

We have explicitly not included two other cost types in our calculation. First, we have not included typical sales and operation costs apart from the costs mentioned above. To offset this factor we have assumed small-household prices for electricity instead of wholesale prices. The assumption being that apart from the charging specific costs for the infrastructure, car charging is merely a new distribution channel for electricity with a similar generic cost base. Second, we have not included rental cost for parking spaces. This decision is mainly driven by the largely varying cost per space we expect to see across regions and cities. One has to interpret our mark-up scenarios therefore as a mark-up before additional parking fees a consumer has to pay. This is a reasonable assumption given that consumers are willing and used to pay these parking fees already today. Looking at it from this perspective, charging is simply an additional service provided while parking – for which an additional service-fee is charged. This seems also reasonable looking at operations: it is unlikely (and based on the interviews conducted not common currently) that charging infrastructure operators will rent the parking lots from current owners and take over the parking utilization risk. More likely are models in which charging infrastructure provider will partner with the owners of parking spots for mutual benefit: increasing the attractiveness of the parking slot for consumers from a parking slots owner's perspective and available space from an infrastructure owner's perspective. If, however, on the long run charging proves to be a profitable business model it is possible that the real estate owners want to participate in this profitability – most probably by a revenue sharing model which would translate in higher required returns.

The revenue side

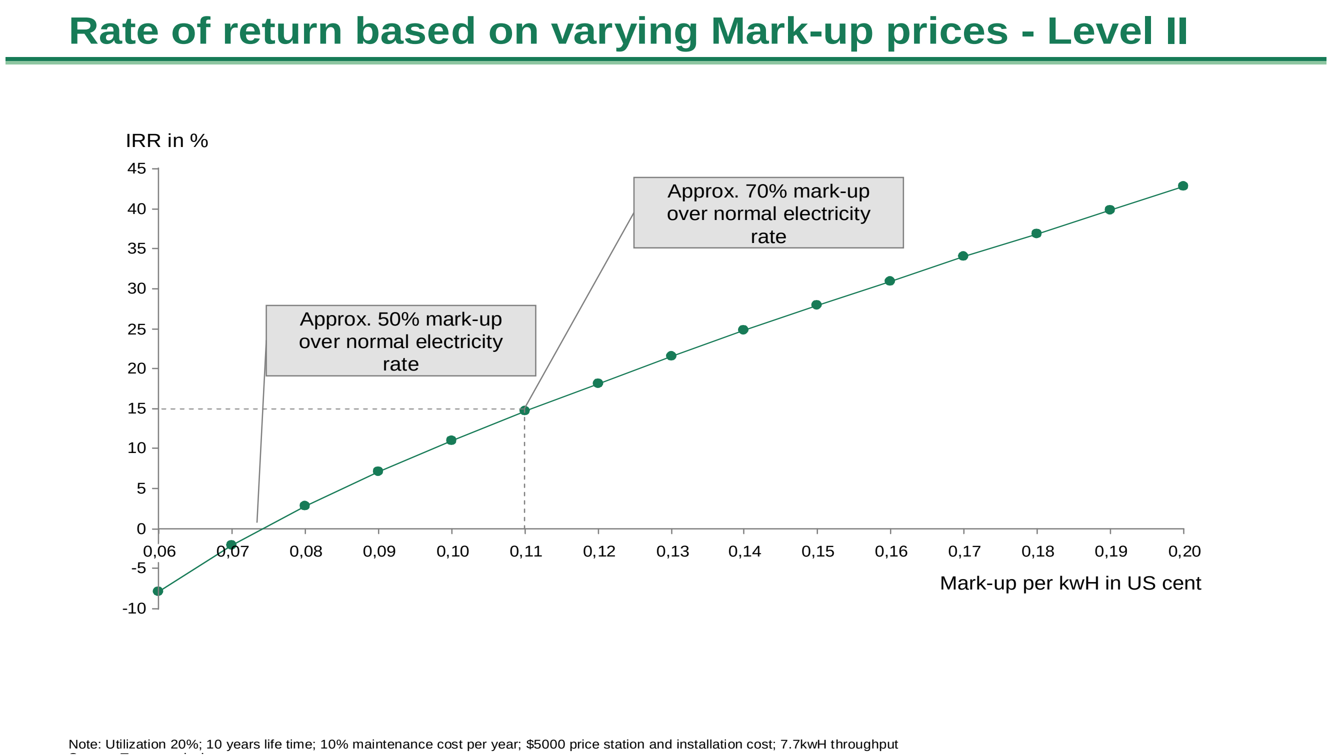
Regarding revenues there are two basic models - either a pay-per-use model in which consumers pay a mark-up per kwH charged or a subscription model in which consumers pay a annual or monthly subscription fee for using the charging infrastructure.

- **Pay-per-use model:** Revenues in a pay per use model are the degree of the utilization of a single charging station (how many hours per day are cars actually charging at the station) times the electric throughput (how many kW are delivered to a car per hour) times the mark-up charged per kWH by the charging provider.
- **Subscription model:** Here the revenues per charging station is the subscription fee times the number of cars per charging station.

Whereas there is relatively comprehensive data and forecasts for the cost side of the equation given, the same is not true for the revenue side. Because of the missing experience regarding the charging behavior of potential customers and there willingness to pay, it is currently unclear which utilization rates can be expected (for the pay-per-use business model) or how many installed charging stations are required per car (subscription model). Furthermore, the willingness of the customer to pay a mark-up or a subscription fee is untested so far. One of the main goals of the currently running test cases in Berlin, Singapore or London is to gather exactly this data and base the business models on it. All our interviews have so far shown that no player has a very good understanding of what to expect regarding these variables.

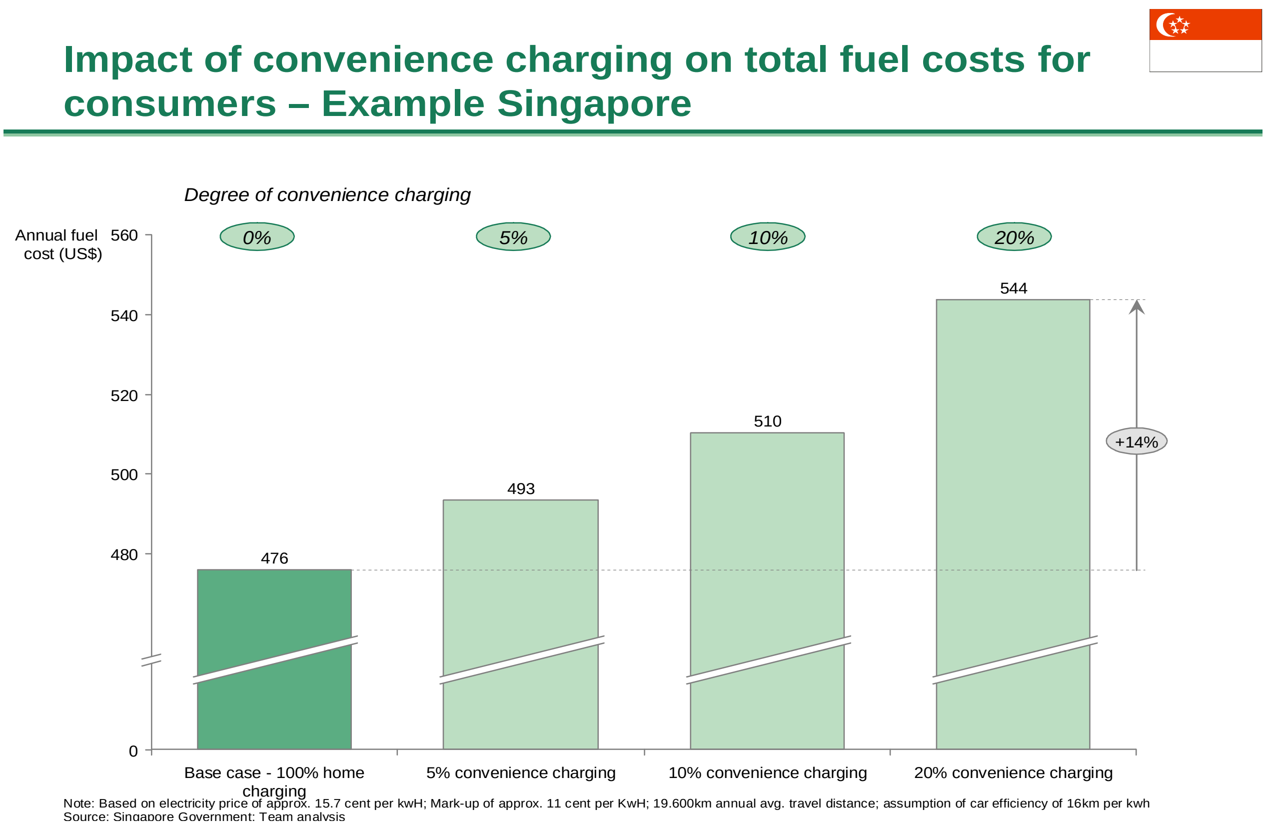
To gain a better understanding under which circumstances and parameter values a single charging station is economically feasible we did a ceteris paribus analysis, looking at the expected rate of returns while varying either expected utilization rates or mark-up premiums.

Figure 3.2.2.3



We looked first at today's charging standard, the Level II charging station that is able to deliver approx. 8 kW of charge per hour. Assuming a utilization of 20%, which means that each charging station is used at least approx. 5 hours per day for 365 days a week and which was deemed realistic in the various discussions we had with experts, approx. a 50% mark-up over private household electricity prices is required to achieve positive returns.[39] To get to a return of around 15% a mark-up of approx. 70% over current electricity prices is required. To understand the significance of this finding one has to translate it into the concrete consumption decision a potential customer is facing. He has to ask himself: "Am I willing to pay a 70% premium to charge at this public station compared to what I would pay charging at home?" Even though no data is available for how a consumer facing this decision would behave, one can doubt whether the willingness to pay this premium will be high if there is no practical reason (e.g. running out of charge) present. On the other hand one could also look at the impact of the usage of convenience charging on the overall annual fuel costs. Looking at this metric it becomes clear that even a 70% premium does only translate into a relatively low increase in overall fuel costs even under aggressive convenience charging assumptions. Take the example of Singapore – even if convenience charging would represent 20% of the overall charging per car, this would only translate into an annual fuel cost increase of approx. 14% compared to a no convenience charging case for the average user. And, perhaps even more importantly, the difference would only result in a cost increase of approx. 70$ p.a. in absolute terms. (see Figure 3.2.2.4).

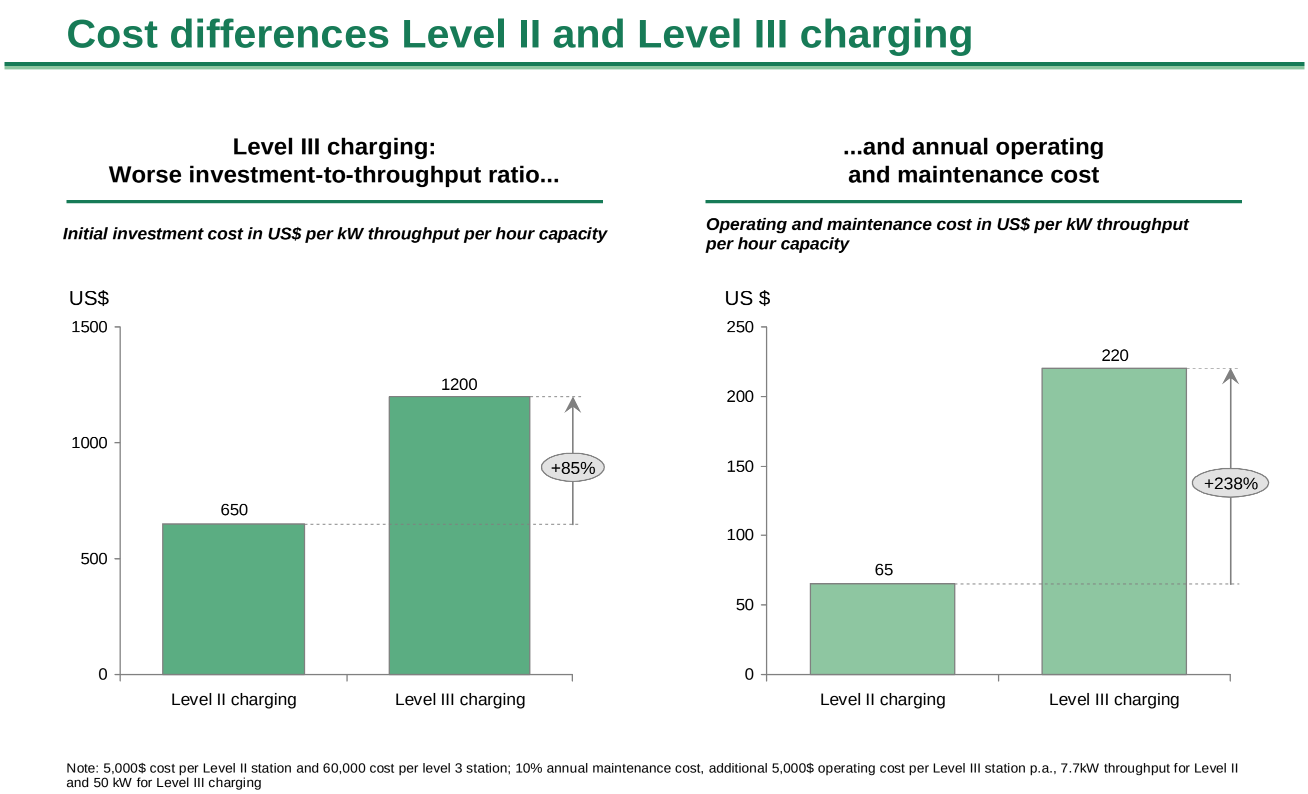
Figure 3.2.2.4



Looking at the convenience charging pricing from this perspective might seem cheap for consumers. Especially once one compares this annual premium with the average annual household income of Singapore which is around $48,000. Results are similar for other cities, like London and Berlin (see Appendix III – Figure 4 and 5.). These two perspectives on the additional cost of convenience charging, the high mark-up per kwH and the low total additional cost per year, also offers another explanation why subscription models dominate in the market place. Consumers tend to have problems calculating total cost of ownerships and annual costs and by offering subscription model the supplier is doing this work for the consumer and thereby strengthening the “low additional cost per year” perspective.

How does the picture change if we look at the upcoming Level III charging standard? Simplified one can say that the economics get worse, requiring higher mark ups, but not altering the overall logic developed so far dramatically. The worsening of economics are driven by the investment cost-to-electricity throughput ratio as well as the maintenance and operations cost-to-throughput-ratio. To acquire the capacity to transfer one kW per hour, the Level II investment costs are $650 whereas a premium 85% has to be invested for the same capacity of Level III charging. The higher investment costs also translate in estimated higher annual maintenance and operation costs. The higher technical complexity and the faster required turnover of cars at Level III charging spots makes it likely that their business model will more resemble those of traditional patrol stations – requiring additional personal and more maintenance. In Figure 3.2.2.5 we estimated these cost differences based on inputs received during interviews.

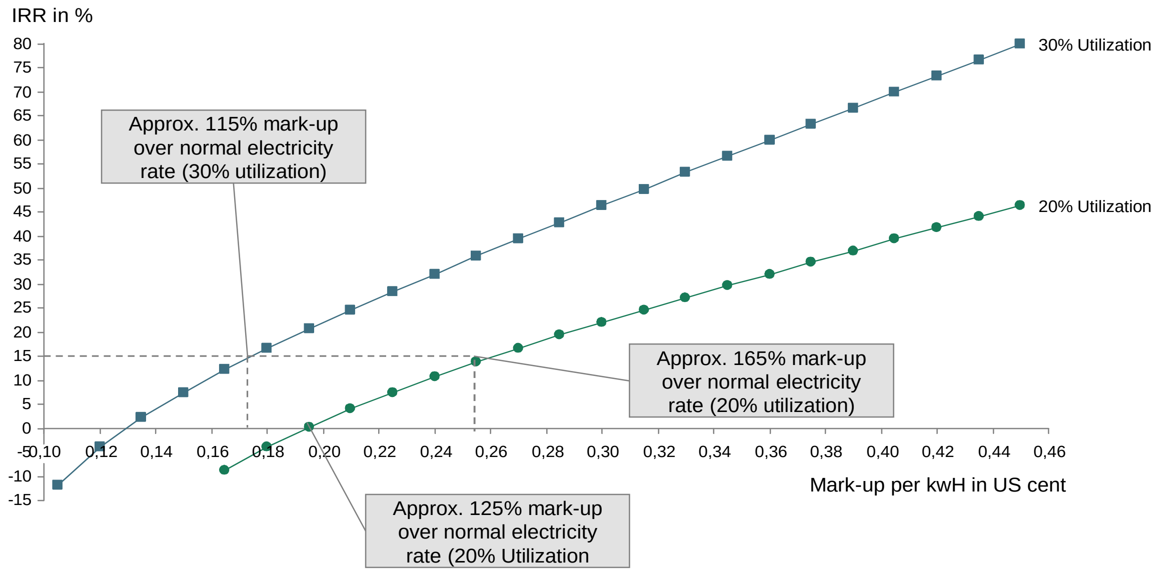
Figure 3.2.2.5



The impact of these additional costs on the break-even analysis is significant. The mark-up to break even is now 19.5 cent (compared to 7.5 cent for Level II charging). To achieve a 15% return on investment a mark-up of approx. 26 cent is required – or of around 165% to today's electricity prices per kW.

Figure 3.2.2.6

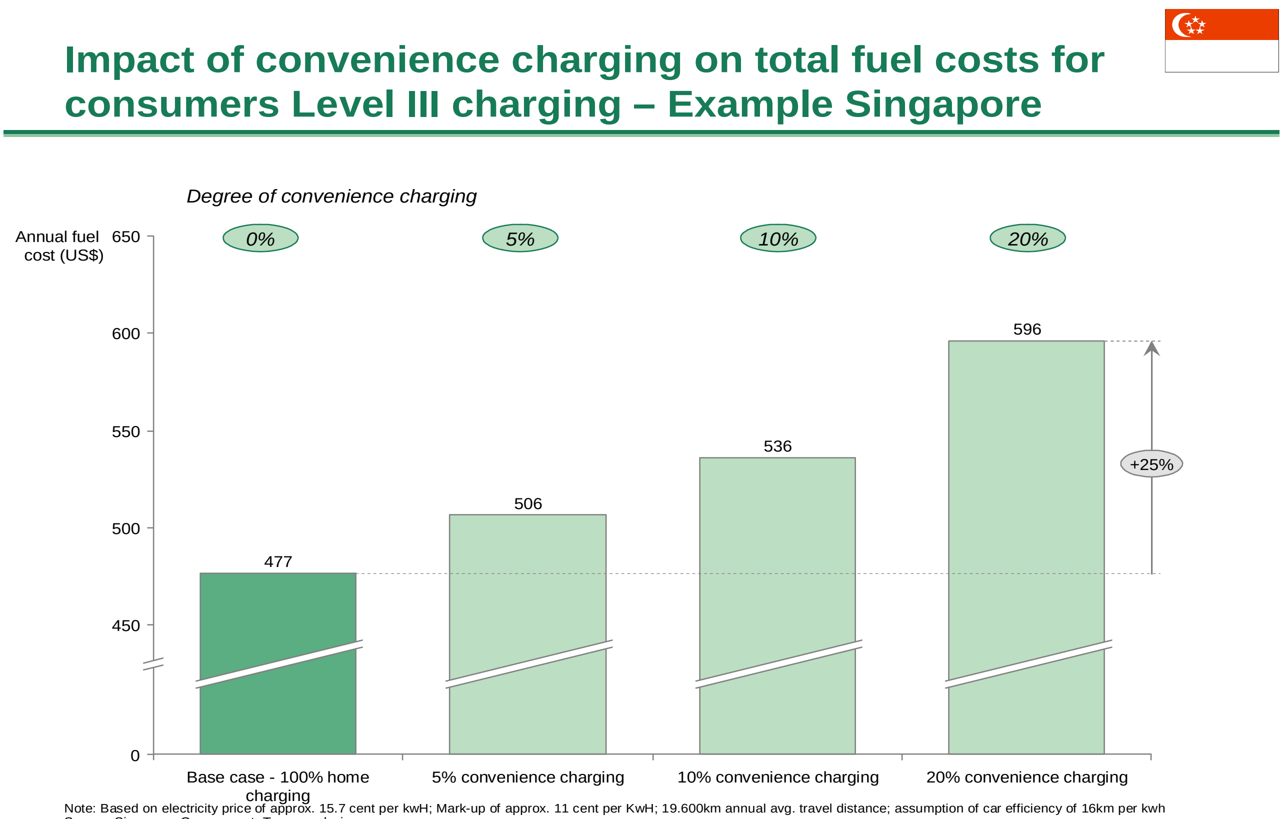
Rate of return based on varying Mark-up prices - Level III



Note: Utilization 20% respectively 30%; 10 years life time; 10% maintenance cost per year; $5000 additional operation cost p.a.; $60000 price station and installation cost; 50kwH throughput
Source: Team analysis

These numbers assume a similar utilization rate as for Level II charging of 20%. In the author's discussion with the CCI the hypothesis emerged that the utilization rates for Level III charging are potentially higher. The reasoning is the different business model: While for Level II charging cars will park for 3-8 hours to get a significant load and the model will therefore most likely resemble that of typical parking slots, people will only stop at Level III stations for 15 to 20 minutes to top-up their battery (within 15 min a car can load electricity for up to 80km distance). In the first case it is most likely that many spots are only used during peak business hours and during the week, whereas for the second case a much broader usage (and more use cases) is likely. However, there is no reliable data regarding likely usage patterns or utilization rates available and the whole industry is relying heavily on estimates and guesses. Interviews have indicated that 30% utilization might be the upper, very optimistic limit, while lower utilization rates are more likely. As one can see in the graph, as 30% utilization rate would reduce the mark-up required for break-even or a 15% return significantly – in the later case a mark-up of 115% would suffice compared to a mark-up of 165% under the 20% utilization scenario. As the is a large uncertainty regarding potential utilization rates we will use the conservative 20% estimate to look the impact of Level III charging on total annual charging cost for users. If we take again the Singapore example (see Figure 3.2.2.7), we see that even under the most aggressive convenience charging scenario of 20% convenience charging and 20% utilization rate, the total charging cost would only increase by approx. $120 p.a. or $10 a month. See Appendix III – Figures 7 and 8 for the Berlin and London cases.

Figure 3.2.2.7



There are a few caveats to this discussion: First, as mentioned Level III charging will require significantly higher infrastructure investments per charging station. Estimated costs as used in the model per charging station including installation are appox. $60,000 – this is a broad estimate, because currently there are no commercial stations on the market and therefore their actual cost and scale-curve development is highly uncertain. Furthermore, level III charging has high demands on the underlying electricity grid. Costs for each single station are therefore also driven by how much investments into the grid are required – and this will differ dramatically based on which country or even city one is looking at, as the interviews have pointed out. Based on these interviews and in close coordination with the CCI this report therefore sets the base rate cost at $60,000 and conducted a sensitivity analysis of how the economics change given varying cost scenarios (see Appendix III – Figure 9). Second, our analysis only covers the direct investment, maintenance and operation costs. Other costs are not included that might benefit Level III infrastructure. Most prominently here is certainly the space argument – to offer a comparable amount of kW per hour you need between six to seven parking slots with Level II charging and only one with Level III. For the unlikely case that our previously discussed assumption regarding costs for parking slots does not hold true this might seriously influence the economics. For cities that own public parking space and can use parking slots free of cost (assuming that they are able to charge the typical parking fees on top of the charging fees) this is not relevant to the decision process. Third, Level III charging offers a significantly different value preposition to the customer. Whereas Level II offers to recharge a typical car battery between 4 to 8 hours, Level 3 charging can do the same in half an hour. While 10 minutes of charging at a Level II station does not add significant range, the same can add up to 50 km range using a Level III charging station. It is likely that users would be willing to pay more for this additional convenience level – however, no first hand user data is available yet to substantiate this claim.

The specific case of residential on-street parking

How do the economics of a single charging station change if it is not employed on busy roads in the center of the city but on-street in residential areas where no in-house parking is provided for? To understand the economics in this case one has first to think about the use case under such conditions. These parking spaces will most probably be occupied by an individual car during the non-business hours, parked there after work by its owner, while being empty during the day. This use case makes it clear, that for such a purpose level II charging is the best technology. Depending on the average km driven per year by this single car and the amount of charging done at other convenient charging spots, the utilization of such a station would be significantly lower than the assumed 20% we used before. The following table provides utilization rates for such stations used by a single car for different cities based on avg. km driven p.a. in these cities.

Table 3.2.2.1 Estimated Utilization rates of residential on street parking slots with level II charging

	Utilization of residential on street charging spot with		
	5% charging at other spots	10% charging at other spots	20% charging at other spots
Berlin	2,6%	2,5%	2,2%
London	3,3%	3,1%	2,8%
Singapore	4,3%	4,1%	3,6%

One can easily see that utilization levels for such a case would be far below any assumption we have so far operated with. Even when following a policy where it is implicitly assumed that every car is charged only every second day and therefore each spot could be used by two cars, utilization would only double to still insufficient 5%-8%. Looking at it from another perspective: In such a case, each electric car purchaser implicitly would also have to be a charging station or, for the second case, half a charging station for approx. $7,000 (respectively $3,500) when buying a car, de-facto seriously increasing the ownership cost of an EV for this user group. So far no answer to this challenge has been found. One of our interview partners from Better Place acknowledged this problem and at the same time admitted that they were also still struggling with it. Potential solutions could be significantly stripped down and therefore cheaper charging stations specifically adapted for this use case (which are, according to the CCI in development), changed consumer behavior with 100% opportunity charging or other technologies, like battery swap. But most likely is a very late adoption of EVs from this user group in the product life cycle of the EV, when technical solutions have been found to this problem and the overall cost of the EV ecosystem have significantly dropped. On its own residential charging spots do not provide a viable business case.

Major insights into economics of single charging slots

What has this analysis shown so far? For a single charging station break-even, users would have to pay a substantial mark-up on current electricity prices. Depending whether we are looking at a Level II or Level III charging station, these mark ups would be in a range between 50% and 125%. To generate a realistic return on investment, even higher mark-ups would be required. Looking at the prices from this perspective, convenience charging might not be overly attractive to consumers. However, translating these mark-ups into additional annual cost for convenience charging illustrates that these additional costs are relatively small, ranging somewhere between 20$ and 40$ for the anticipated case of low convenience charging, and even in the worst case not exceeding 10$ per month. Looking at it from this perspective might indicate a way higher willingness of consumers to pay for convenience charging infrastructure when presented to them in the right way. We believe that this is one of the reasons why most offerings today work based on a subscription model – which is a way of pushing the total annual cost perspective. Based on these insights one can also understand the industry experts that have uniformly confirmed in interviews that a charging infrastructure business case has to be based on a holistic, annualized perspective and not on a single station return model. Our analysis has also shown that the specific usage patterns of residential charging spots are likely to lead to significantly lower utilization rates than anticipated in our main model and therefore might not offer a viable business case on their own.

3.2.3 Economics of a charging station network

Based on the economics of a single charging station we can do a next step and look at the overall charging network of a large city. The CCI was especially interested to see how large charging networks in typical C40 cities would have to be in 2020, what kind of investments would have to be undertaken and how pricing of charging services would have to look like to support these networks. In order to be able to answer all these questions we first have to come up with estimates for charging demand and more specific convenience charging demand in 2020. As already mentioned, coming up or even taking a distinct perspective of the most likely EV adaptation for the year 2020 is beyond the scope of this paper. We therefore looked at different, varying scenarios covering most of today's estimates. For this purpose we picked three typical cities and analyzed what the range for convenience charging in 2020 given different level of EV adaptation and degrees of convenience charging could be. To do so we used the charging infrastructure demand model developed in a previous chapter and focused on the physical demand component which is the relevant for determining the actual demand of kwH by EVs.

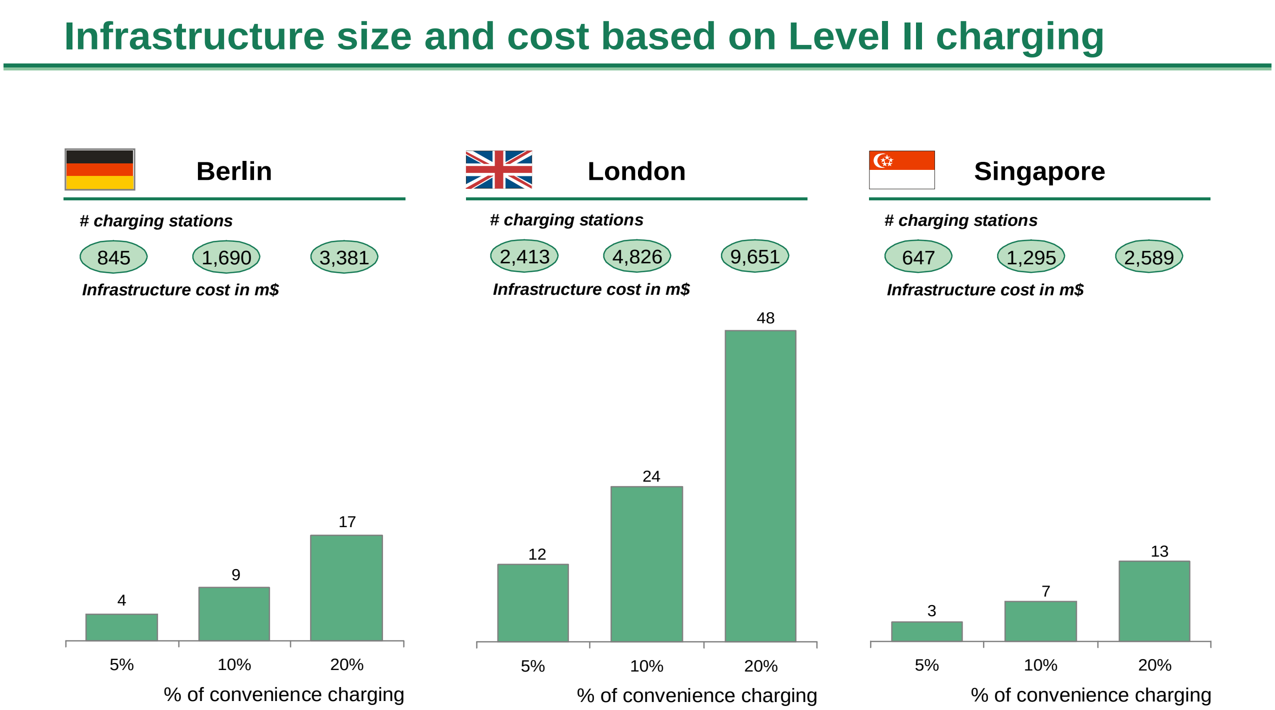
Figure 3.2.3.1

Estimated public charging demand for selected cities

	City	# of EVs 2020		x Ø kwH per EV p.a.		x % opportunity charging			= Estimated demand 2020 (m kwH)		
		# cars	x % adaptation	Ø dist. (km)	x Ø kwH/mile	low	medium	high	low	medium	high
Expected adaptation	Berlin	1.200.000	5%	12.000	16	5%	10%	20%	5.7	11.4	22.8
	London	2.800.000	5%	15.000	16	5%	10%	20%	16.3	32.6	65.1
	Singapore	570.000	5%	20.000	16	5%	10%	20%	4.4	8.7	17.5
High adaptation	Berlin	1.200.000	10%	12.000	16	5%	10%	20%	11.4	22.8	45.6
	London	2.800.000	10%	15.000	16	5%	10%	20%	32.6	65.1	130.2
	Singapore	570.000	10%	20.000	16	5%	10%	20%	8.7	17.5	34.9
Very High adaptation	Berlin	1.200.000	20%	12.000	16	5%	10%	20%	22.8	45.6	91.2
	London	2.800.000	20%	15.000	16	5%	10%	20%	65.1	130.2	260.4
	Singapore	570.000	20%	20.000	16	5%	10%	20%	17.5	34.9	69.9

In a next step we have looked at how many charging stations would be required to fulfill this demand given the realistic utilization and technical assumptions we have used while looking at the economics of a single station. Furthermore, given the costs for individual charging stations we have estimated total network investment costs. For conciseness reasons we have focused here on the medium adaptation case, which was also the focus of the CCI. See the appendix for the other cases. What do these results mean? Let's look at London to illustrate the findings. Given a 10% adaptation rate, London would have to transform approx. 2,400 public parking slots into Level II charging spots by 2020 if consumers gravitate towards a 5% convenience charging degree. If user data shows higher degrees of convenience charging those numbers would have to increase (approx. 4,800 stations with 10% convenience charging or 9,700 with 20% convenience charging). To offer this infrastructure London would have to invest something between $12m (5% convenience charging) and $48m (20% convenience charging) for charging stations. Note, that these costs only cover the stations themselves – not potentially required investments in additional electricity generation or transmission which might come on top.

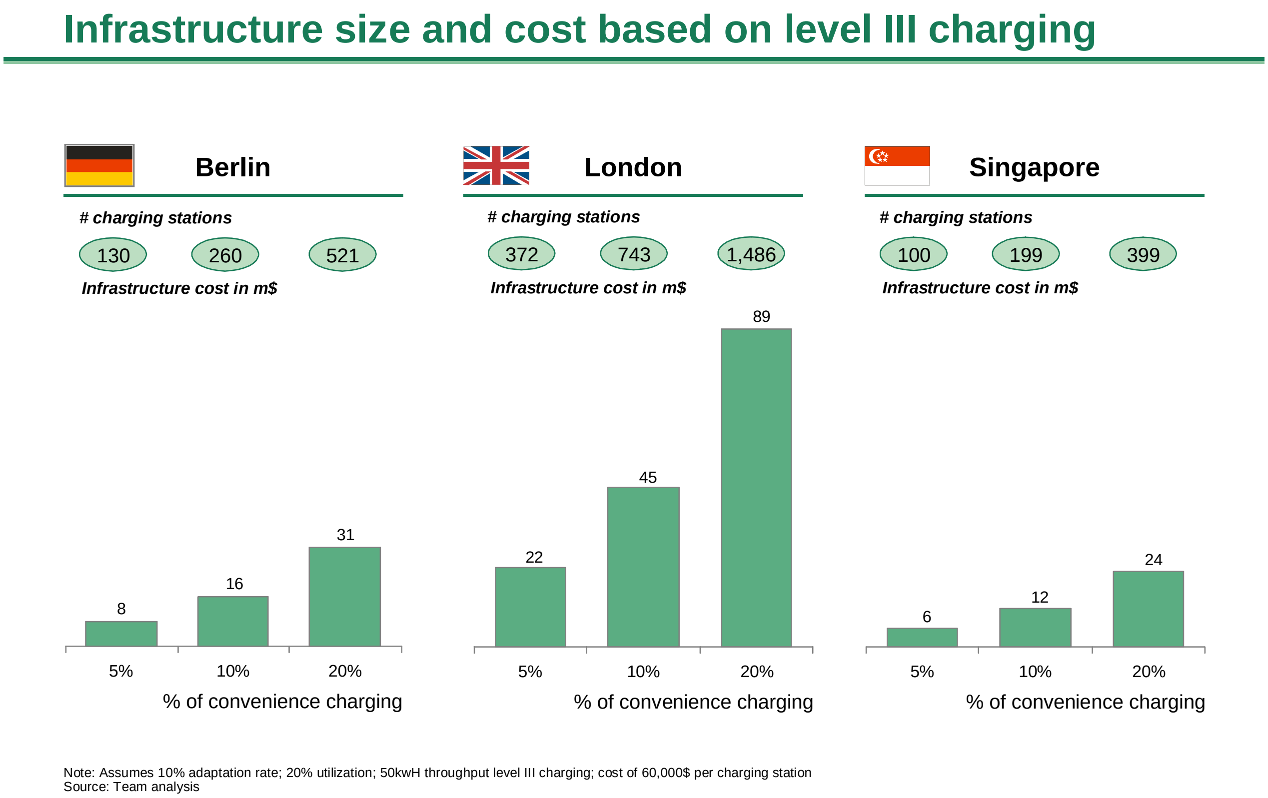
Figure 3.2.3.2



Note: Assumes 10% adaptation rate; 20% utilization; 7.7kwH throughput level II charging; cost of 5,000$ per charging station
Source: Team analysis

We have done the same calculations also for a Level III infrastructure network. As to be expected, the number of stations would be significantly reduced under such a scenario, but the costs would be higher.

Figure 3.2.3.3

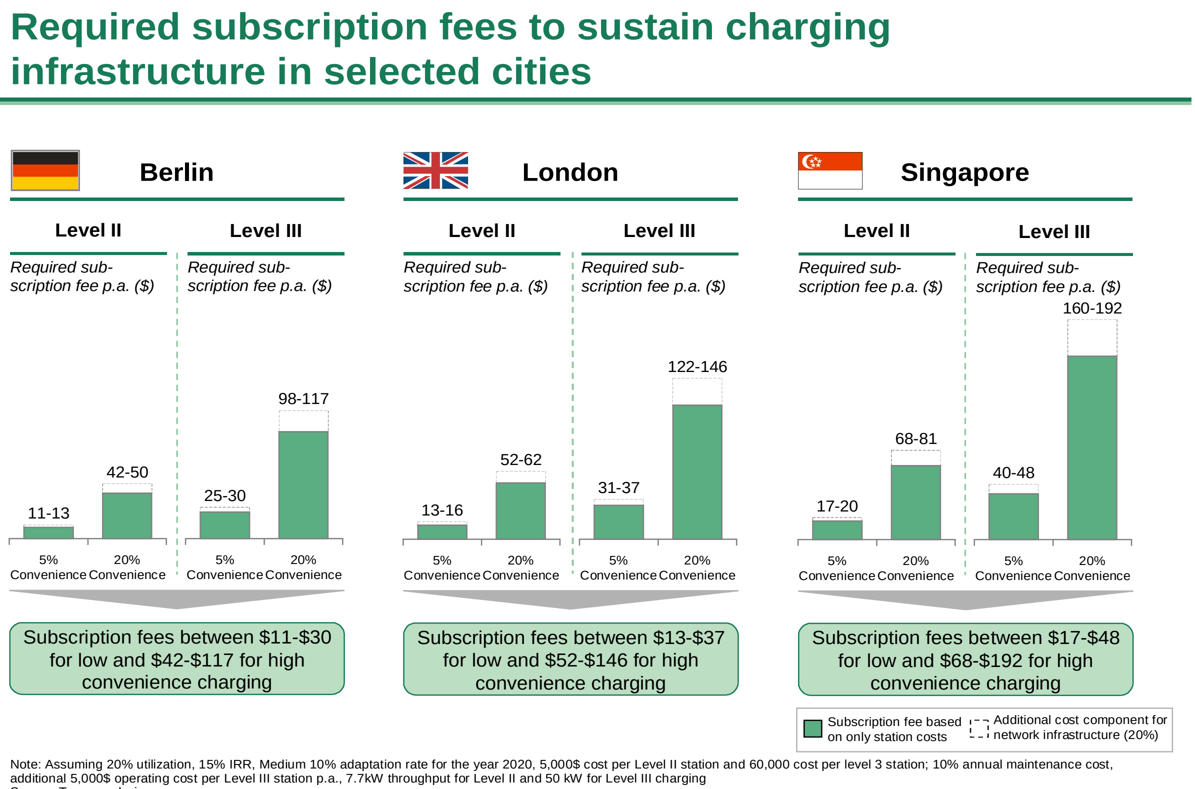


Looking back at the demand framework we have developed in chapter 3.2.1, it is important to note that we have so far only looked at the physical side of demand – the number of stations calculated is the number required to supply EVs with the electricity that is likely to be consumed. We have not included the psychology factor, which is driven by range anxiety, in our considerations. The basic question is whether the amount of charging stations calculated is large enough to cover the geographic area of a city in a way that there is always a station close by the consumer and a sense of availability is reached. To test this we have gathered information about the number of petrol stations currently operational in the cities analyzed. The most reliable data we got for the City of London, where petrol sales are regulated and every sales outlet hast to be registered. According to these official numbers London has currently 900 petrol stations.[40] We also gathered a rough estimate for Singapore based on an analysis of Singapore's yellow pages and business directory. According to this source Singapore has something between 175 and 200 petrol stations. Comparing these numbers with the amount of stations installed under a 10% convenience scenario, we see that the number of level III charging stations is roughly in line with the number of patrol stations currently in operation. Should convenience charging only attract 5% of the charging market share or should the numbers of EV on the road be significantly lower than estimated in our base scenario, this comparison would indicate that the stations required to fulfill the physical demand might not suffice the psychological demand. However, one should note that patrol stations are not a very good predictor of psychological demand – patrol stations are profitable and there deployment is driven by real petrol demand not by psychological factors. The number of petrol stations therefore can only provide an upper boundary of required outlets, their predictive power as a lower limit is questionable.

Major insights into the economics of a charging network

What are the most interesting insights from this analysis? First, investments required to provide opportunity charging to even large cities like London are relatively modest. For the case of 10% convenience charging the pure investment cost would be somewhere between $24m and $45m depending on the technology chosen – given an investment horizon till 2020 this seems to be a manageable investment especially comparing them to some of the more prominent public investment schemes in London like public transportation. Second, based on these cost estimates we can calculate what subscription fees would be required for such a network to break even or generate positive returns. In Figure 3.2.3.4 you see the results of this analysis for the medium adaptation case in which it is assumed that 10% of the cars in 2020 are EVs. Since the cost estimates we used so far only cover the pure station and installation costs, we depict the subscription fees as a range that of pure station costs plus 20% to cover any potential additional costs that might emerge to connect the stations and run them as an integrated network. This rather crude method is used because there are no current estimates for these network costs available and even experts have difficulties quantifying them. The interesting insight is, that even when considering these additional network costs, subscription fees per consumer are moderate. Depending on city, technology used and the degree of convenience charging they are somewhere between $11 and $192 – all numbers that seem to be moderate giving the income levels of the countries we are looking at. Also compared to other subscription services people are used to pay for, these numbers seem to be in line. In Berlin a consumer can easily pay more than $300 p.a. for a mobile phone service. Even though there is of course no real “willingness to pay” data available, it seems that these subscription costs are not unreasonable from a consumer perspective and should not seriously limit the employment of charging infrastructure.

Figure 3.2.3.4



Some caveats to the economics of charging networks

Our economic analysis so far has shown that economics seem to be no major obstacle to the private roll-out of charging infrastructure. There are, however, some caveats to this analysis. The three major ones will be presented here.

First, we have so far only looked at the year 2020 and analyzed whether charging infrastructure can be economically feasible under the conditions present then. A charging network has a minimum amount of stations required to cover a geographic area to fulfill the requirements imposed by range anxiety irrespective of the amount of EVs on the road. Because only a very limited amount of EVs will be on the roads during the first years of the EV lifecycle, the revenues of these cars will probably not suffice to cover the cost of this minimum network. These loses during the first years of operation can discourage private investment. Interview partners in Singapore for example mentioned that because of these initial losses and the long time frame required to reach positive returns was one main reason why no private investor could be found. This might also be the reason why London decided to install and operate charging infrastructure itself for the first years or why the federal government is granting subsidies to the Berlin test runs.

Second, we have seen that there is a large and significant number of unknowns, like consumer behavior and preferences, utilization rates, etc, which have a major impact on charging infrastructure. Initial investors in charging infrastructure bear the discovery cost for identifying these currently unknown parameters, but they are unlikely to gain a significant competitive advantage from this, because this information can hardly be kept confidential (because behavioral patterns are easily observable). For a private investor it therefore makes sense to wait and see and let others bear the expenses of discovery. This can lead to a dynamic in which no player wants to take the role of first mover thereby delaying the installation of the infrastructure. We have found no conclusive evidence whether this is phenomenon can be observed in the market right now. Federal subsidies that cover the discovery cost, like in Berlin, or a city acting as first mover and thereby bearing the discovery cost, like in London or Singapore, might be interpreted in this regard. On the other hand there are private companies like Better Place who have willingly taken on the role as first mover.

Third, we have assumed utilization rates of at least 20% on average for our calculations of the network economics. However, our analysis of the utilization rates of residential charging spots has shown that a 20% average utilization rate might be not obtainable in cities with a very high share of residential parking. A significant drop of utilization rates would increase the number of required charging stations and thereby the network cost and subscription fees. Whether this effect could make charging networks in some cities economically not feasible, will depend on the percentage of required residential charging spots and the willingness of consumes to pay higher subscription fees. The former is different from city to city, the latter is yet unknown. We therefore cannot come to a final verdict here whether this problem will become critical in some cities – but we want to point out that the potential exists and that in those cases a public intervention might be necessary.

3.3 Technology barriers

All the interviews and research that we conducted have indicated that the core elements of charging infrastructure technology are ready for implementation. Level II charging stations have been installed in significant numbers already in London, Berlin and across the US, Level III charging station specifications are finalized and their production has been announced by leading manufacturers like Coulomb. Also on the demand side, things are moving fast – Nissan has launched a US wide marketing campaign to promote the Leaf, their first full electric vehicle. Other large OEMs are following suit; BMW for example just announced that it plans to launch its fully electric 3-series sedan in 2015. Charging and EV technology seems to be available and, apart from some standardization issues which will be resolved soon, ready for employment.

There are however certain emerging technologies that might slow down adaptation of charging infrastructure. Based on our interviews these issues relate mainly to two technologies that are not yet employed on a large scale, but have the potential to heavily influence the structure, city strategies and logic of charging infrastructure. These two technologies are battery exchange and smart grid.

Battery exchange

The concept of battery exchange is straight-forward. Whenever a car is running low on battery power, it can stop at dedicated battery exchange stations where the battery is replaced by a automatic mechanism within a few minutes. The batteries removed from the car is then fast charged and ready to be redeployed with approx. 30min to another car thereby holding the battery stock low. The main proponent of this technology is the Californian start-up Better Place which has entered a partnership with Renault which will offer cars compatible with this technology. Shai Agassi, founder and CEO of Better Place, argues that batteries allowing for long enough ranges to allow EVs to leave the niche they are currently inhabiting, won't exist for another 15 to 20 years.[41] According to Agassi the solution is not postponing the mass introduction of EVs for several decades but to establish "a ubiquitous infrastructure". His proposed panacea to this problem is battery exchange technology, which allows for "exceptional long drive[s]" through the opportunity to swap a drained battery with a new fully-charged battery. Better Place's powerful marketing machine has made the battery exchange a symbol for the electrification of the car – with whomever non-expert we talked to about this project, the battery exchange topic was brought up. Battery exchange becomes relevant for overall charging infrastructure because it potentially could change the patterns of how cars are charged or lead cities to postpone charging infrastructure deployment / investments until the exchange technology is ready for large-scale deployment.

We have found strong evidence that battery exchange is unlikely to become widespread within the mass market – if it materializes at all it will most probably be a niche application for fleets. There are three main reasons driving this assessment. First, battery exchange technology is expensive. Interviewees mentioned cost figures ranging from $1m to $1.5m – equaling the cost of between 15 and 25 fast charging stations. Perhaps even more significantly, using a battery exchange concept practically increases the number of batteries required per car from currently one (the one installed in the car) to a number larger than one – depending on how large the number of batteries on hold at charging stations has to be. Especially if there emerge different form factors for different car types and different battery performance classes the battery stock might have to be significant, factually resulting in an increase of the cost per car. Second, investing in exchange stations is factually a bet against battery technology and further performance increases of these batteries in the future. However, battery performance has increased significantly in the past and potentially will do so in the future. Third, and perhaps most importantly, many OEMs are highly reluctant to engage in this technology. This reluctance has mainly two reasons. Allowing for batteries to be exchanged limits OEMs in their freedom to place the battery within the car. But since batteries constitute a significant portion of the car weight (the relatively small battery of the Renault Kangoo be bop for example weights 250kg – or 17% of the total weight of the car), this makes car balancing more difficult – a problem especially for high performance manufacturer like BMW or Mercedes.[42] BMW for example mentions how the battery is spread out over different locations in its Active-E concept car to achieve optimal balancing.[43] Perhaps even more importantly OEMs seem to see battery performance to be a factor they can potentially compete on. As a study by the Boston Consulting Group (BCG) illustrates, there are currently two competing business logics emerging.[44] In one, OEMs closely partner or even vertically integrate with battery suppliers to differentiate their offering. In the other, battery suppliers will team with tier one suppliers to allow for larger scale effects. Should scenario one materialize battery exchanges would become difficult to realize, if not impossible, because this would require exchange stations to have a stock of different battery packs for each major car manufacturer increasing costs and complexity significantly.[45] BCG expects the first scenario to dominate during the infancy years of the industry and only foresees a switch to the second model once battery technology becomes more of a commodity later in the product life-cycle. But this late in the life-cycle one could expect battery technology to have improved already significantly and offering far longer ranges rendering battery exchanges pointless.

For all the reasons cited above, we have encountered an enormous skepticism regarding Better Place and its exchange concept in all of their interviews (apart from the interview with Batter Place of course). Also a clear sign: So far only one supplier, Renault, has committed itself to offer cars with exchangeable batteries. And even Renault is hedging its bets – its sister company Nissan is not offering battery-exchange ready cars diversifying the risk of the technology not catch on and the first fully electrical car of Renault will, in fact, not offer an exchange option.[46] One area in which battery exchanges might be able to establish themselves are large, high mileage fleets like cabs. These fleets are often using only a limited number of car models, would extremely benefit by the lower expected TCO cost of EVs and require the non-interruption recharging exchange stations can offer. However, even though this might be a lucrative market, it is a niche. A more interesting point from that can be learned from battery exchange concept. As mentioned the concept was extremely popular initially and a number of countries have committed themselves to it by collaborating with Better Place – now it seems that this technology might not play a major part in the overall charging infrastructure and the cost of developing and potentially rolling it out might even slow down other components of the infrastructure. A premature commitment to certain technologies might yield risks for cities and countries alike.

Smart grid

The smart grid is a catch-all term used to refer to a wide family of grid applications from smart metering to demand response to using EVs as a storage mechanism. Some of the expected benefits include increased grid asset utilization, peak smoothing through the use of storage capacity connected to the grid, and better integration of intermittent renewable sources like solar and wind energy. The key players in the smart grid space include conventional utilities, IT / networking / telecommunications companies that offer the software and communications technology, storage companies, renewable energy providers, EV OEMs and EV charging providers.

There is considerable uncertainty regarding the impact of the smart grid on EV batteries and EV charging infrastructure. Using EVs as a storage mechanism would require bi-directional flow of electricity through charging equipment. We spoke to a California-based utility that is carrying out a smart grid pilot as well as with the key stakeholders involved in Singapore's smart grid pilot. Interviewees mentioned that there are several concerns. Frequent charging and discharging of the EV battery could potentially cause damage to it and reduce its life. An interviewee from Singapore mentioned that connecting an EV battery to the grid could lead to “dirty signals” of a different frequency from the battery being transmitted onto the grid, which could cause the grid to trip. The pilot projects would help provide more data on this issue.

From all the interviews and secondary research reviewed, we also gleaned that smart grids are some years away from large-scale commercial application. Apart from the technical concerns expressed earlier, the economics are also still unproven. We believe that cities should not hold back their charging infrastructure plans for certainty on smart grids and should instead go ahead with them. In the future it is likely that smart grid applications will require upgrades to charging infrastructure. We believe it is reasonable to expect that the benefits of these smart grid applications will need to outweigh the costs of upgrading the infrastructure and provide ample incentives to EV users and charging infrastructure providers to actually be used.

3. Policy options for EV charging infrastructure

The earlier chapters of this report analyze the key barriers to the large scale deployment of EVs and EV charging infrastructure as well as the economics of charging infrastructure. This chapter delves into the various policy options for city governments in terms of the levers they can exercise to mitigate the barriers and favorably influence the economics of charging infrastructure. Understanding the levers that city governments possess as well as their strengths and weaknesses is important in understanding the role a particular city government can play in encouraging the deployment of EV charging infrastructure.

City governments have a tool-kit of several policy levers at their disposal to influence the deployment of EVs and EV charging infrastructure. They can be broadly clubbed into the following categories – monetary and non-monetary incentives, regulatory, real estate, advocacy and public relations and procurement. Early in this chapter, some of these policy levers are listed (with a more detailed description in the Annexure), followed by an analysis of the strengths and weaknesses of city government with regards to these levers, and subsequently frameworks are proposed for deciding which policy-levers from a city tool-kit to employ to overcome barriers to the deployment of EVs and EV charging infrastructure. Each city has its unique environment, within which different incentives will have different appeal for policy-makers, consumers, utilities and charging infrastructure providers.

4.1 Policy levers

Depending on a particular city's EV objectives and main barriers to deployment of charging infrastructure; it can exercise particular policy levers in order to achieve its objectives. The major categories of policy levers are described below. Detailed descriptions of each lever are given in Annexure II along with examples of cities that have already employed them.

Regulatory levers

- Zoning and building codes
- Approval for technical standards for charging equipment
- Regulation regarding utilities sale of electricity, whether EV-related investments get included in utility asset bases, etc
- Permitting rules and guidelines

Monetary and non-monetary incentives

- Subsidies / tax credits for EVs
- Discounts or waivers on registration / annual taxes on EVs

- Subsidies for charging infrastructure
- Investment tax credits for charging infrastructure
- Production tax credits for charging infrastructure
- Free parking for EVs
- Waiving congestion charges for EVs
- Electricity discounts for EV charging
- Access to HOV lanes

Real estate

- Ownership of public garages & on-street space that can be used for charging infrastructure

Advocacy and public relations

- Demonstration projects
- Advocacy by public figures

Procurement for public fleets

- City government procurement of EVs for public fleets.

4.2 Analysis of city government policy levers

Of the various levers mentioned above, cities have a comparative advantage in some and a weakness in others. The main comparative advantage that cities have is in regulation, advocacy and procurement and to an extent, non-monetary incentives. Monetary incentives for EVs is a weakness for cities as cities typically have limited local tax resources and many spending needs so subsidizing EV ownership might be difficult for city governments. State or national governments are more likely to be able to subsidize EVs.

City strengths: With building codes, cities can mandate that EV charging equipment of a certain level is included in any new construction, while with zoning regulation, cities can influence where and how many EV charging stations can be installed in a particular area. This is a key lever that can influence the availability of charging infrastructure in the future. Similarly streamlining and expediting permitting processes is something that cities can undertake to make the installation of charging infrastructure easier and cheaper for EV users and charging infrastructure providers. Many cities have already committed to such actions already including Los Angeles and the Bay Area cities of San Francisco, San Jose & Oakland.[47]

Regulation regarding standards for charging infrastructure and utility investments in EV-related infrastructure might not be as easy though, depending on the degree of control the city government has on that regulation. For standards for example, typically a national or international standards agency decides on a standard in consultation with all stakeholders, which city governments can then include in building codes, permitting processes, etc. Cities can lobby these organizations to develop standards that suit their local grid conditions and work to implement them in their building codes quickly. Singapore for example has mandated that it's Agency for Science Technology & Research develop a standard for charging infrastructure by a certain timeline and has included the Housing Development Board and other agencies required to implement and roll out the standard.

Regulatory leverage regarding utility investment in EV charging infrastructure is a function of whether a city owns the utility and has regulatory control over utilities. For example the city of Los Angeles owns the LA Department of Water & Power, one of the major utilities serving the city. LADWP has taken the lead in rolling out charging infrastructure in the city, under a mandate from the city council. LADWP however, like other utilities in the area like PG&E and SCE, is regulated by the California Public Utilities Commission which decides what assets a utility can include in its asset base for rate-making, etc. The city government can however mandate, or work with a state or national government to mandate that the regulator a policy decision on that issue, as in the example of the California Senate cited earlier.

The other significant competitive advantage cities have is in real estate, in terms of on-street space and in some cities, public garages. Cities can build charging infrastructure on streets or lease out space to private sector charging infrastructure providers. This can be done through a concession where a particular charging infrastructure provider covers a particular area or neighborhood or on an ad-hoc application basis. This is obviously an asset with revenue-generating potential in terms of rental income, but as argued earlier in the economic analysis, cities would ideally want to waive this rental opportunity as it meets the objective of increasing deployment of charging infrastructure, and positively impacts the economics of charging infrastructure.

Another strength cities have is in advocacy and public relations. City government leaders can play an active role in promoting electric vehicle adoption and building awareness about charging, etc. There has been significant publicity and media coverage of the various announcements by Mayors of cities with EV programs, which comes free of cost to city governments, EV OEMs and charging infrastructure providers. The picture on this report's cover page, for example is of Portland Mayor Sam Adams announcing a city government partnership with Nissan for EV deployment.

Another significant lever that cities have is in procurement of EVs for city fleets. London, in its Electric Vehicle Delivery Plan has set a target of procuring 1000 EVs by 2015 for the Greater London Authority fleet, making use of the increased volumes to reduce cost. The Plan also mentions working with suppliers in terms of specifications, etc.

Weaknesses: Monetary incentives might be more challenging for cities, as cities typically have limited local tax resources and many spending needs. Monetary incentives that reduce the upfront cost of EVs are more likely to come to come from national government programs. London though has offered a congestion charging waiver to EV users and some boroughs in the city offer free parking for EVs.

Some cities have rolled out subsidies for charging infrastructure e.g. Los Angeles announced a Home Charger Early Adapter Incentive Program to subsidize the installation up to $2,000 for the first 5,000 residential customers, in Dec 2009. Cities that do not have the fiscal flexibility to offer monetary incentives can however make use of other non-monetary incentives like access to High-Occupancy-Vehicle / bus lanes, to incentivize EV adoption.

For cities that have fiscal flexibility and an entire spectrum of policy levers to choose from, it becomes necessary to have a framework for evaluation and choice of appropriate policy levers.

4.3 Frameworks for evaluation and choice of appropriate policy levers

Each city has its unique environment, within which different incentives will have different appeal for policy-makers, consumers, utilities and charging infrastructure providers. This section proposes frameworks for evaluation of the various available policy levers, which can then enable choice of appropriate policy levers.

Framework 1: Matching levers to barriers: This framework matches each of the policy levers mentioned above to the specific barriers (to adoption of EVs and EV charging infrastructure) and assessed how much impact each lever may have on overcoming / mitigating that barrier.

Table 5.2.1:

	Barriers to EV deployment						**Barriers to charging infrastructure**					
Policy lever	Upfront cost	Range anxiety	Avbty chrg inf	Tech uncertainty	OEM inertia	Lack of info	Lack of standard	Policy ncertainty	Permitting	Demand uncrtnty	Economics	Tech uncertainty
Zoning & building codes			✓		✓				✓		✓	
Deciding technical standards							✓				✓	✓
Utility regulation			✓					✓			✓	
Streamlining permitting	✓								✓			
Subsidies / tax credits for EVs	✓				✓					✓	✓	
Waivers on registration / taxes on EVs	✓				✓							
Subsidies for charging infrastructure			✓								✓	
Investment tax credits for charging infrastructure			✓								✓	
Production tax credits for charging infrastructure			✓								✓	
Free parking for EVs	✓											
Waiving congestion charges for EVs	✓											
Electricity discounts for EV charging											✓	
Access to HOV lanes	✓											
Real estate for charging infrastructure		✓	✓								✓	
Demonstration projects				✓		✓					✓	✓
Advocacy by public figures				✓		✓						
Procurement of EVs for public fleets				✓						✓		

Framework 2: Cost-benefit and NPV analyses: There are several other policy frameworks that can be used for evaluation and choice of appropriate levers. These include cost-benefit analyses and NPV analyses. Many governments already have formal criteria and methodologies for carrying out cost-benefit analyses of government interventions. An NPV analyses can be used to understand how much of a subsidy would be required to make the purchase of EV or EV charger positive / profitable.

4. Recommendations

The earlier chapters in this report cover many of the complex issues that cities need to address with regard to influencing EV adaptation and more specifically charging infrastructure deployment. C40 cities are facing differing circumstances, initial positions and objectives, as well as differing key actors with varying levels of expertise / capacity - which call for individually tailored approaches for charging infrastructure deployment. However, we believe that based on the arguments presented in this report, five broad and generally applicable recommendations / learning points emerge that are of relevance for all the C40 cities that our client is advising. These recommendations regarding policy options for EV charging infrastructure for C40 cities are built on some of the key insights that emerge from the research covered in this report. These key recommendations are:

1. **Cities should design EV strategies / programs that are unique to their individual circumstances, objectives and players, but should draw on lessons from peer cities**

As discussed in this report and as highlighted in more detail in the case studies in Annexure I, different cities across the world have different circumstances and different objectives with regard to EVs. In terms of parking availability, while wide-spread cities like LA have high percentages of parking in private off-street garages, other more densely-populated cities like Paris or San-Francisco rely more on residential on- street parking. Our analysis has shown that private charging networks are economically feasible in the former, but costs for on-street residential charging infrastructure might be prohibitively high. Consequently the behavior of these cities should be different: The role for cities with high percentages of private off-street parking is to focus more on setting a regulatory framework conducive for investment in charging infrastructure networks, increasing EV deployment by switching public fleets to EVs and leveraging city-owned real estate to speed up infrastructure deployment. Cities with low levels of private off-street parking can expect to see a significantly lower EV uptake, due to less favorable economics – and might be forced to subsidize on-street -residential charging if they want to speed up this process.

Furthermore, cities have different objectives for deploying EVs and EV charging infrastructure. Singapore is mainly interested in being a leading test bed for EV and EV charging technology, thereby leading to industry development, while London is looking primarily at the environmental benefits, while L.A. is following a mixture of these two objectives. As a consequence, cities will and should follow different strategies. For industry development purposes, small test-runs with the latest technology seem appropriate, whereas wide-spread adaptation required to achieve an environmental impact will require more elaborate planning, coordination between public and private stakeholders, public awareness campaigns, investment in charging infrastructure, and the use of proven technologies. Each city will have to develop its own strategy based on its unique set of objectives connected with EVs and charging infrastructure.

On a more general note: Our interviews have also shown that there is also immense value from sharing lessons about what works and what doesn't in regard to charging, across cities, to overcome the information deficiencies discussed in earlier chapters. This is where networks like the C40 EVN have tremendous value in terms of information and best practice sharing across cities, with regard to regulation, PPP (Public Private Partnership) models, implementation challenges faced, etc.

2. **City governments have limited resources to mitigate up-front EV cost but can use other policy levers to affect TCO of EVs**

The upfront cost of EVs is the single biggest barrier to adaptation / deployment of EVs; however cities have limited means at their disposal (if any) to influence upfront EV cost, as cities typically have limited local tax resources and many spending needs. Current programs to reduce upfront cost for EVs are mainly sponsored on a federal level. However cities have other instruments at their disposal which affect the TCO of EVs and therefore enter into the overall value equation of an EV from a consumer's perspective. Potential instruments (as discussed in chapter 4) include waiving congestion charging & parking costs, providing free / discounted electricity for charging, preferred street access, etc. All these instruments can be used to reduce the cost of an EV over its life-time compared to a traditional ICE vehicle. These measures might not be as effective as direct upfront cost reductions because consumers often seem to struggle with the concept of TCOs, but the measures might be a second best option from a city perspective. These additional incentives are potentially especially valuable early in the life-cycle of the EV technology when scale effects have not yet set in and EVs therefore might seem less attractive. In this early phase these measures are also likely to impose only a limited burden on city finances because only few EVs will be sold during the initial years. Our research has shown that several cities have employed this approach - London and Los Angeles being prominent examples.

3. **Cities should use their regulatory influence smartly to create a conducive environment for private investors of charging infrastructure – and only provide subsidies under specific circumstances**

This report shows that there are several regulatory barriers to the deployment of EV charging infrastructure including permitting of charging infrastructure, the lack of a technical standard for charging infrastructure, policy uncertainty regarding sale of electricity, regulation regarding EV-related investment by utilities, etc. Cities which face these regulatory barriers should address them as early as possible by building political consensus and then mandating the relevant government agency to address each issue whether it be permitting, deciding a standard in consultation with OEMs, etc. As mentioned in Chapter 4, city governments hold a comparative advantage in zoning and building codes and permitting, and they should use those levers to good effect. Various city, state and federal governments have already been pro-active in the regulatory space – examples include San Francisco, Los Angeles (permitting), Singapore (EV charging standard), California (mandating the Public Utility Commission to address questions regarding sale of electricity, utility EV-related investments, etc), Berlin (mandating inter-operability between EV charging networks). Cities should use their regulatory influence smartly to remove / mitigate barriers to create a conducive environment for private investors.

This report has also shown in chapter 3 that per-se a direct subsidy to private infrastructure providers is not required because charging networks offer a viable business opportunity – the notable exemption being cities with large proportions of on-street residential parking where residents might be undersupplied with charging infrastructure as the economics under those conditions are less appealing.. It is in those cities that an extensive public and residential parking infrastructure becomes necessary because consumers can only rely on cheap home charging to a limited degree. If cities see the need to speed up adaptation in these areas, cities might be forced to either subsidize infrastructure or operate it themselves on a non-profit basis. Another circumstance where city investment might be necessary is the case of very high demand risk – under these circumstances cities can also consider running pilot projects or demonstration projects for proof of concept, which if proved economically viable, can then subsequently be sold to the private sector. This approach has for example been chosen by London.

4. If cities or city utilities do offer charging infrastructure services there is a strong case to be made for subscription fee based business models to gain consumer acceptance

Two key insights emerge from the analysis of the economics of public charging infrastructure. First, from a pay-per-use perspective, the mark-up required to make the infrastructure economically feasible might look prohibitively expensive to consumers. Second, annual subscription fees required to finance a network would be, even under conservative assumptions, appear modest and in line with amounts consumers are prepared to pay for other services. To make consumers accept public charging and allow for a profitable charging infrastructure business, there is a strong case to push for subscription fee models. Cities which run own the charging infrastructure themselves (or by city owned utilities) should therefore have subscription-fee based business models. Interviews with Better Place and RWE have shown that this is the direction the private sector is also taking.

5. Cities should be aware of technological uncertainties and not commit prematurely

As discussed in Chapter 3, there are significant technology barriers and uncertainties that also exist. EV battery swap technology, for example, has generated tremendous media attention and investor attention over the last few years. Our research and interviews show several concerns regarding this technology, including the constraints it places on EV design by OEMs, its costs, and the inverse relationship of its usefulness with advances in battery technology. Battery swap is therefore a good example why, we recommend that cities should not commit prematurely to specific technical solutions. The EV industry is still young and highly dynamic, and hence changes in technology while the industry matures are likely. That being said: for key components of charging infrastructure, like Level I, II and III charging, the norms have been set and one can expect with a high certainty that they are here to stay. It appears to be safe for cities to commit to these standards now. Waiting to gain additional information about the development of the smart grid is not recommended. Yes, the smart grid promises to be an important tool in the energy infrastructure of the future and there are a number of pilot projects and R&D efforts currently focused on the interplay of EVs as storage device and the electric grid. The uncertainties relating to the smart grid are still high though – there is uncertainty regarding what technical specifications it will have and what the impact on charging infrastructure and batteries will be. From today's perspective it is even uncertain whether the smart grid will ever rely in significant numbers on car batteries. Therefore slowing down EV adaptation based on this remote possibility does not make sense given the current dynamic of the sector. If a particular smart grid application in the future makes economic sense, it will generate economic returns that allow for the charging infrastructure to be updated. The argument that the smart grid is required for the charging infrastructure's economic viability is not supported by the analysis in this report – and also not by the reality of public and private sectors already investing in charging infrastructure without any smart grid component.

We believe that taking these five recommendations into consideration, cities can increase their likelihood of successful and rapid EV deployment. The research for this paper has proven, at least from our perspective, one thing beyond any reasonable doubt: the adaptation of EVs is a reality, during the next decades there will be a significant uptake of EVs on the streets around the world – OEMs are preparing the cars for this uptake, utilities, transport agencies and infrastructure providers are gearing up to build and operate the charging infrastructure and consulting firms are preparing to restructure whole value chains. Cities that want to actively steer this development have to act decisively and comprehensively. In the words of a senior city official of a C 40 city who said in an executive meeting early this year: "This is really happening! In 2020 we will have tens of thousands of electric cars on our streets. We better get ready!"

Appendix I: City Case Studies

Case Study 1: Singapore

Key government agencies involved in EV pilot program: Energy Market Authority (EMA), Land Transport Authority (LTA), Economic Development Board (EDB), Agency for Science, Technology and Research (A-STAR), Housing Development Board (HDB).

Budget for EV pilot program: $20M

Average trip length: 10 km (6.25 miles)

Summary: We traveled to Singapore to understand the city-state's EV pilot program announced in November 2009 and that is scheduled to run for 3 years, commencing in June 2010. A-STAR is taking the lead on finalizing the charging standard, which will then form part of an RFP for charging infrastructure providers that will the city plans to release in the first half of 2010. The key objective of the city government is for industry development – to attract technology companies to Singapore, attracting them with the prospect of using Singapore as an ideal EV pilot test-bed.

Description

On the outset Singapore is an unlikely candidate for a large EV market and an EV program because it has none of the characteristics which would imply a high demand for EVs. The city has an extremely low carbon-dioxide profile and no major transportation caused air-quality issues. Most of the electricity is generated not by renewable energy sources therefore making EVs less green than under other conditions. Furthermore it has no significant automotive industry which would justify investing in this technology early on.

On the other hand, Singapore has the characteristics that would make it an ideal place to set up a charging infrastructure. A very well developed current grid, a geographically clearly defined area with high population density, a highly effective regulatory environment and a supportive and stable government.

Currently Singapore has no significant numbers of EVs operating on its streets. Private investors tried to establish an infrastructure for motor-scooter, but had to stop their efforts after money run out after a testing phase. In regard to EVs and charging infrastructure Singapore therefore would have to start from scratch.

Approach

Acknowledging the missing experience with EV infrastructure and the low degree of knowledge publicly available about EV consumer behavior, Singapore has set up a 2 year test balloon. This test run is designed very ambitiously, Singapore wants to install and set-up a complete charging, closed EV and charging microcosm including charging stations, electric cars and backend solutions (billing, etc.). Currently it is planned to install 2-3 public charging stations and private charging outlets at the locations where the EVs that take part in this test-run are parked over night (mostly parking lots of multi-apartment buildings). After two years the data about usage patterns and consumer behavior obtained by this test run should be used for a social cost-benefit analysis based on which a mass roll-out will be determined.

The test run is organized and controlled by a multi-stakeholder commission that includes the local housing, electricity and transport agencies, as well as researchers and regulators. To facilitate the test run, Singapore is willing to invest significant resources. It offers tax credits for the purchase of EVs and was offering significant subsidies for installing the charging infrastructure. The EV taskforce has been working with Renault-Nissan, Mitsubishi and other auto manufacturers to secure a supply of EVs for Singapore. The city expects a first batch of up to 50 Mitsubishi i-MiEVs to arrive from September 2010.

Logic and reasoning

As mentioned, investing large scale in EV infrastructure and adaptation is not obvious for a country like Singapore. Interviews have supported that impression and uncovered a different underlying logic. Under this logic Singapore wants to leverage its nearly optimal starting conditions for installing a charging infrastructure to establish itself as premier testing ground for new charging technology. Furthermore the government hopes that based on the experience as testing ground opportunities for new technology ventures in the charging infrastructure realm might emerge. Singapore sees the efforts to establish a charging infrastructure therefore more as an investment in its industrial policy and development. Environmental considerations are only of secondary relevance.

Feedback of key stakeholders

The feedback of key stakeholders so far has been mixed. Singapore’s original plan was to use a private operator to set up the charging infrastructure. For this purpose Singapore negotiated with several international players, among them also Better Place. However, even given a direct subsidy of up to 50% of the infrastructure cost could not motivate private actors to invest in Singapore. According to Singapore officials the main reasons for this reluctance to invest is the limited size of the Singaporean market. Given the extremely small number of cars in Singapore, the number of EVs would stay sub-critical even given the most aggressive adaptation expectations. Also the long term business case for charging infrastructure in Singapore is grim – given the small size of the car fleet in Singapore the market will be permanently limited.

So far no other major feedback has been obtained – it is to be seen how the industry reacts to Singapore's plans.

Current status

The project has been kicked-off at the beginning of 2009 and is currently on time. The next major milestone is set for early 2010, when the tender process for the infrastructure starts.

Case Study 2: Bangalore

Key government agencies involved in EV pilot program: No formal municipal government program

Budget for EV pilot program: No formal municipal government program

Average trip length: Not available

Summary: Ronald visited Bangalore and met with local EV OEM REVA and some REVA customers and also did a test-drive on the REVA EV. The city has no formal EV program or incentives for EVs, and no public convenience EV charging infrastructure. In spite of this, the city has over a thousand REVA EVs on the roads, indicating that EV users driving and charging behavior might be tailored to the constraint of no public convenience charging infrastructure as well as relying on REVA's proprietary Revive battery reserve technology.

Description:

Bangalore offers a stark difference to other cities with organized EV pilots or EV programs. The city government has not actively encouraged the deployment of EVs through any incentives or pilot program, etc. Bangalore is a rapid-urbanizing city in India which has had a thousand REVA EVs on the road since 2001, when local EV OEM REVA released its first EV model. There is no public convenience charging infrastructure for EV users to charge their EVs. EV users charge almost entirely at home and in some cases, also at working places. This would indicate that EV users in Bangalore constrain their charging / driving behavior to the fact that there is no public availability of charging infrastructure. Another factor that mitigates EV users' range anxiety is REVA's proprietary Revive technology which is a special battery reserve, which can be released through a text message or call to a REVA call centre, when the main battery is running low. This service comes at a fee and hence users have an incentive to only use it in emergency situations. The REVA interviewee mentioned that this proprietary technology has helped alleviate users range anxiety.

The upfront cost of the EV is currently more than comparable ICE vehicles: The REVA EV is significantly – 30-40% - more expensive than a regular ICE vehicle of similar characteristics. The EV users interviewed mentioned though, that running costs were significantly lower than a regular ICE vehicle. One of the EV owners interviewed had bought a second REVA and cited driving comfort as an additional factor to low running costs, for his choice of the REVA EV over a regular ICE. The REVA EV is automatic (i.e. no gears) and that is an advantage over most ICE models in India which currently have gears. To reduce the upfront cost of the EV, REVA had run a battery leasing pilot, which reduced the upfront cost of the EV, which was well received by customers. The company is considering expanding battery leasing in the future, providing a monthly lease payment option to consumers, with maintenance for the duration of the lease done by REVA. On completion of the lease duration, consumers will have the option to continue with the same lease plan or upgrade to the latest battery packs available in the future. Another model that the company is considering for increased consumer awareness is making REVAs EVs available at big campuses and other central locations for use on a pay-per-use basis.

The company has incorporated user feedback on its earlier EVs in its design of its latest EVs. The first generation of REVA EVs was small cars, which users expressed safety concerns with. REVA's VP-Marketing mentioned that amongst consumers there was a perception that a larger car often lent an increased sense of safety on Indian roads and hence the second generation of REVA models – the REVA NXR and NVG - is larger and "more muscular".

India is currently not the major market for REVA's EVs. REVA expects most of its sales to come from Europe. It is already the highest selling EV OEM in the UK with its G-Wiz EV. It foresees a significant chunk of its revenues coming from technology licensing. It recently entered into a licensing agreement for its technology with GM in India[48]. REVA also recently signed a MoU with US-based Bannon Automotive to open a manufacturing facility in New York State in the US, where it will receive $3M in state grants & $3.76M in tax incentives and breaks for its new facility[49]. This is indicative of a global trend where large automobile OEMs can jump ahead on the EV technology curve by procuring technology from existing EV OEMs like REVA through licensing agreements / collaboration.

The REVA interviewee mentioned that they don't view extensive publicly available convenience charging infrastructure as a key concern for early-adopters. The company's target early-adopter market is families that will buy the REVA EV as a second car for use for short trips to the supermarket, to pick up children from school, etc. These trips are easily within the 100 mile range of the battery, which can be charged from a regular home charging plug. The new NXR model has two charge ports for both normal and fast charges. The company doesn't see the REVA EV being used for long-distance inter-city trips and believes consumers will use regular ICEs for that purpose for the mean time. However the company does believe that for mass adoption, there will be a requirement for battery charge stations in various locations across cities for top-up fast charging, which can be done while consumers shop / eat / drink.

The interviewee mentioned that government support would be useful for providing funding and incentives for local EV plants. Government fleets are also an opportunity for conversion to EVs in the future.

Case study 3: London

Key government agencies involved in EV program: Transport for London, Commissioner's Delivery Unit

Budget for EV pilot program: £ 17M

Average trip length: 90% of trips are below 10 miles

Summary: London has started implementation of an ambitious electric vehicle delivery plan, announced in May 2009. This involves building a comprehensive network of charge points across London, electrification of the public sector fleet and stimulating the wider EV market and a program of incentives, marketing & communications. The city government's transport agency – Transport for London - is taking the lead in building, owning and operating the charging infrastructure – 250 charging points as of Feb 2010, with a target of 25,000 in London by 2015. TfL is working closely with a consortium of EV OEMs, the main London utilities, rental car companies and the London boroughs in rolling out his plan.

Description:

London appears to be the leading city in terms of EV charging infrastructure roll-out thus far. In November 2008, Mayor Boris Johnson established the London Electric Vehicle Partnership[50]. The partnership includes representatives of the Greater London Authority, the motor and energy industries and London's boroughs, with the objective of working to share best practice, co-ordinate activity, and encourage greater funding of the technology. This was followed by the publication of an electric vehicle action plan in May 2009.

Key objectives and details of Delivery Plan

The Delivery Plan[51] set out key targets:

- 100,000 electric vehicles on the capital's streets as soon as possible.
- 25,000 charging spaces in London's workplaces, retail outlets, streets, public car parks and station car parks by 2015.
- At least 1,000 Greater London Authority fleet electric vehicles by 2015.

The Delivery plan is an elaborate strategy document that builds the context and rationale for deployment of EVs and EV charging infrastructure in London and which then lays out a three-pronged strategy which includes:

- **Infrastructure** – Working with boroughs and other partners to deliver 25,000 charge points across London by 2015 - 500 on-street, 2,000 in off-street public car parks, station car parks, 22,500 provided in partnership with businesses -to be located in employers' car parks and retail/leisure locations. London Plan policy –a requirement to provide charge points in all new developments.

- **Vehicles** – electrify public sector vehicle fleet and stimulate wider EV market by procuring at least 1,000 electric vehicles in the GLA fleet by 2015, extending active support to extend the number of EVs in the public sector vehicle fleets e.g. the boroughs and central Government and working with fleet users and companies to expand the use of EVs in business fleets.
- **Incentives, marketing & communications** – increasing and communicating customer benefits, providing a Congestion Charge discount worth up to £1,700 a year, working with boroughs to develop simplified range of parking incentives, encouraging uptake of electric vehicles in car clubs and working with the boroughs to develop a London-wide membership scheme for EV users –giving access to the charge point network and the congestion charging discount.

Current status

As of February 2010, there were over 250 charging points in London with 1,700 EVs currently registered [52]. An online database[53] contains a list of all publicly accessible EV recharging points in London, including on-street and off-street (typically located on dedicated bays within a car park). The parking fee for these charge points vary – for dedicated spots, an application is required and involves an annual parking fee ranging from £231 – 500, while for hourly parking spots, the fee can range from zero to £2.50 / hour. The charge fee at most spots is currently free.

In February 2010, London secured £17 million funding for its charging network - £9.3 million from the Department for Transport, £5.6m provided by Transport for London and £7.6m pledged from a range of leading organizations. The charging infrastructure is being rolled out by a consortium including TfL (lead) and Sainsbury's, Tesco, Siemens, Nissan and Hertz which aim to deliver 7500 charge points by 2013, with 1,600 charge points to be installed over the next twelve months. This will contribute to the delivery of the Mayor's target of 25,000 charge points in London by 2015, with the goal of having no Londoner more than a mile from a charging point by that time. The total of 7500 charging points are expected to deliver 6000 points at work places, 500 on-street, 330 in public car parks, 50 at Tube stations, 140 in supermarket car park and 120 for car clubs. The 7500 charge points to be installed by 2013 will be a mix of standard, fast and rapid charging points. Different types of charging points will be installed in different sorts of locations across the capital.

A consortium led by Transport for London of public and private partners including London Boroughs, major supermarkets, energy companies, car park operators, vehicle manufacturers, car club and car hire companies, had secured the grant funding from the UK Government's £30 million 'Plugged in Places' fund. The London consortium is comprised of EDF Energy, Enterprise rent-a-car, Europcar, Hertz, London boroughs, NCP, Nissan, Sainsbury's, Scottish & Southern Energy, Siemens, SMMT, Streetcar, Tesco, Transport for London and Zipcar.

Mayor Johnson has also announced that a single Londonwide brand for electric vehicles in the capital will be launched in 2010 so that Londoners will be able to clearly identify where a charging point is located. In terms of the procurement target of 1000 EV for the public fleet, Mayor Johnson is seeking funding from the government to help deliver this major introduction of electric vehicles.

Given government information that 90 per cent of car trips in London are less than 10 miles and more than 99 per cent of journeys are within the range of existing or near-market electric vehicles, TfL expects that a 25,000 strong network will be able to support tens of thousands more electric vehicles in London and help realise the vision of 100,000 electric vehicles in the capital by 2020.

Stakeholder feedback

In October 2009, we spoke with Mark Evers, Director of the Transport Commissioner’s Transport Unit, which was responsible at the time for London’s EV program. The unit takes issues of political significance to the Mayor and issues of strategic significance to the Transport Commissioner. We understand that responsibility for London’s EV program has now moved to within TfL.

Mr. Evers spoke about the roll-out of the program and how customers could use a single RFID card to access any charge point across London, despite the fact that there were multiple owners of the charge points. We asked Mr. Evers why the charging infrastructure was not being built, owned and operated by the private sector and he mentioned that there was room for selling the infrastructure network to the private sector in the future, once a critical mass of EVs had come on London’s roads.

Mr. Evers expects that most early adopters will have access to parking facilities and that most charging will happen at night at domestic charge points.

Case study 4: Berlin

Key government agencies involved in EV program: City of Berlin, various agencies on the federal level

Budget for EV pilot program: not disclosed, mainly private

Average trip length: not available

Summary:

In Berlin two simultaneous test cases have started, both with the main objective to gain a better understanding of how a potential charging and electric vehicle ecosystem could look like. Both test cases are initiated by the private sector and supported by a major German utility and car manufacturer respectively. The city of Berlin is taking a laissez-faire role. The city limited itself to supporting the private efforts administratively and mandating the interoperability of the two networks. The idea behind this strategy seems to be to leverage the benefits of the private sector by fostering competition while also preventing lock-in effects that could have a long term detrimental effect. Both test cases are currently well under way and the first cars are driving on Berlin's roads and are charged at public charging stations. All this is happening against the background of a major federal initiative to make Germany the main hub of electro-mobility technology.

The field studies:

Two major field studies for electric mobility and charging infrastructure are currently under way in Berlin. One has been initiated by RWE, one of Germany's largest utilities and Daimler a major OEM, the other one by Vattenfall, a Swedish utility with major operations in Germany, and BMW another large OEM. Both studies are similar in structure: In each the car manufacturers have developed battery powered versions of their smaller models (the Mini in the case of BMW and a car of Mercedes Smart brand) of which approx. 100 are permanently rented out to users in Berlin while the utility companies are installing the required charging infrastructure to supply these cars with electricity. In both cases the utilities are not only installing single charging stations but complete charging ecosystems including home-charging and convenience charging spots as well as billing systems and a centralized system architecture.[54] The stated goal of this test runs from a charging perspective is to learn more about user patterns and infrastructure requirements to prepare a larger scale role out. In the words of the project leader of BMW "We want to know, when and to which degree the vehicles are used" and then base the further roll out on the identified customer needs.[55] This all is happening against the background of a massive federal electro mobility program, which is also supporting the RWE/Daimler project with €6m. The federal government has developed a national development plan for electro mobility and pledged €500m until 2011 to jump start the EV industry in Germany.[56] How important these field studies are for the respective companies and the federal government can be easily seen by the cast present when RWE and Daimler announced their plans. Present were not only the CEO of Daimler and RWE, but also the head of the German Automobile Federation and the German chancellor.

Characteristics of infrastructure

Both field studies have decided to install a network based on Level II infrastructure, but designing the stations in a way that they can be easily upgraded to level III charging. Furthermore the stations already have vehicle-to-grid capability and therefore can be used for further smart-grid scenarios. The plan for both field studies is to provide a comprehensive coverage of Berlin. Most charging stations are installed on private premises like parking garages, parking lots of shopping malls or company parking lots. The goal of RWE is to have installed over 500 charging spots at the end of the test phase. Currently approx. 70 spots have been installed by RWE and around 30 by Vattenfall.[57] Both operators have set up a comprehensive backbone for the infrastructure including billing services, which rely on a subscription fee plus paying for the consumed electricity. The billing concept is akin to that of a mobile phone contract and it is not a coincidence when the CEO of RWE states in the official press statement to announce the cooperation that “The accounting system should be as simple and convenient as when using one’s mobile phone”.[58]

The regulatory environment

Our interviews and research has shown that Berlin’s potential influence on the charging network is relatively limited. Berlin has privatized its electricity utilities as well as most parking garages. The later allows it basically every provider to set up a comprehensive charging infrastructure without relying on any public real estate, thereby limiting the city government’s influence significantly. As steering and influencing charging infrastructure providers against this background anyways, Berlin seems to have decided to follow a laissez-faire approach of supporting every infrastructure provider who wants to set up a network equally instead of preferential treatment. What the city however was able to mandate to every infrastructure provider active was the interoperability provision. According to our interviews, RWE charging spots must be accessible for Vattenfall users and the other way around. This approach achieves several policy goals at once. First, it prevents early lock-in effects which might later once certain critical network sizes are reached might lead to regional monopolies. Second, it increases the accessibility and availability of charging infrastructure and therefore should help to support the EV adaptation rates. Third, it intensifies the competition between the different providers, which can already be seen in early pres statements in which for example the Daimler CEO teases Vattenfall/BMW about technological disadvantages they have and the resulting discomfort for users.[59]

First insights from the field studies

Whereas no initial results are available for the RWE test case so far, Vattenfall and BMW have published a preliminary summary of first insights.[60] During the first months of the field test they could observe that user of EV show almost no changes in their mobility behavior in comparison to using petrol powered vehicles. The test run so far also confirms that most charging is done at home and convenience charging is only used supplementary. When users use convenience charging, then they mainly rely on charging spots close to their work place, major shopping areas or transportation hubs such as the airport. These usage patterns support the notion that public level II charging will mainly be used if people are parking anyways for other reasons than charging – with the implication that public level II charging might best be set-up close to areas to which people travel by car and where they spend significant amount of time.

Appendix II: Policy levers for influencing deployment of EVs and EV charging infrastructure

This appendix expands on the list in 4.2.1, with descriptions of various policy levers for influencing deployment of EVs and EV charging infrastructure along with examples of some cities where these levers have been deployed.

Regulatory levers

- **Zoning and building codes:** These are city laws that dictate urban planning guidelines as well as what guidelines and specifications, new construction needs to meet. Some cities e.g. San Francisco & London, have mandated or committed to mandate, that their building codes will be modified to require all new buildings to have EV charging infrastructure.
- **Approval for technical standards for charging equipment:** Most countries have a national technical standards agency that either develops a standard or adopts a standard developed by an international technical agency, for use in the country. This approval process often involves consultation with various other government agencies that look after fire safety, electric grid, etc. A-STAR in Singapore has been mandated by the government with developing a standard for EV charging in consultation with OEMs, the local utility and other stakeholders.
- **Regulation whether EV-related investments get included in utility asset bases, etc:** In cities where city government wields considerable influence over utility regulation, it can take a regulatory decision regarding whether EV-related investments get included in utility asset bases, whether third-party organizations selling electricity for EV charging become regulated entities, etc. The California Senate has mandate that the CPUC set rules for EV-related investments by a specific timeline.
- **Permitting rules and guidelines:** Cities can streamline permitting processes for installation of charging infrastructure. Los Angeles has committed to streamlining its permitting processes for installation of EV charging equipment.

Monetary and non-monetary incentives

Monetary incentives

- **Subsidies / tax credits for EVs –** These can be employed to reduce the upfront cost of EVs. Examples include the US federal government tax credit of up to $7500 for the first 200,000 electric vehicles produced by an EV manufacturer.[61] Some cities also have additional incentives, e.g. the city of Austin, Texas provides incentives of up to $500 for electric vehicle purchases.

- **Discounts or waivers on registration / annual taxes on EVs:** Several countries have provided discounts or waived annual taxes on EVs including Norway and Denmark.
- **Subsidies for charging infrastructure –** City governments can provide subsidies for various types of charging equipment, and to various owners e.g. consumers for home charging equipment, supermarkets for public charging infrastructure, etc. For example, the City of Los Angeles, in December 2009, announced that it would provide a subsidy for home chargers of up to $2000 for the first 5000 residential customers.
- **Investment tax credits for charging infrastructure** – Similar to investment tax credits for renewable energy, investment tax credits can be used for investment in charging infrastructure.
- **Production tax credits for charging infrastructure** – Similar to production tax credits for renewable energy which provide tax credits based on the actual amount of renewable energy generated, production tax credits for EV charging infrastructure could provide incentives for each kWh of electricity sold from an EV charging station. A potential advantage over investment tax credits is that production tax credits reward actual charging.
- **Free parking for EVs** – Cities can provide designated free parking spots for EV users e.g. certain London burroughs have free parking for EVs. Supermarkets / malls / multiplexes can also offer designated EV parking spots to attract EV users.
- **Waiving congestion charges for EVs –** Cities that have congestion pricing schemes e.g. London, Singapore, etc – can potentially waive congestion charges for EVs. London has already done so, providing EV users with a discount up to GBP 1700 per year.
- **Electricity discounts for EV charging –** London already provides free electricity for EV charging.

Non-monetary incentives

- **Access to HOV lanes:** Cities that have separate lanes for High-Occupancy-Vehicles can potentially allow EVs to use the lane also. Research has shown (citation required) that access to HOV lanes significantly impacted adoption rates for hybrid cars.

Ownership of public garages & on-street space that can be used for charging infrastructure

City governments with significant control over on-street space / parking / housing in the city can give out concessions to private sector operators for provision of charging infrastructure on city-owned property e.g. Singapore can potentially give a concession for provision of home charging infrastructure in all government-owned condominiums regulating prices, etc through the concession contract.

Advocacy and public relations

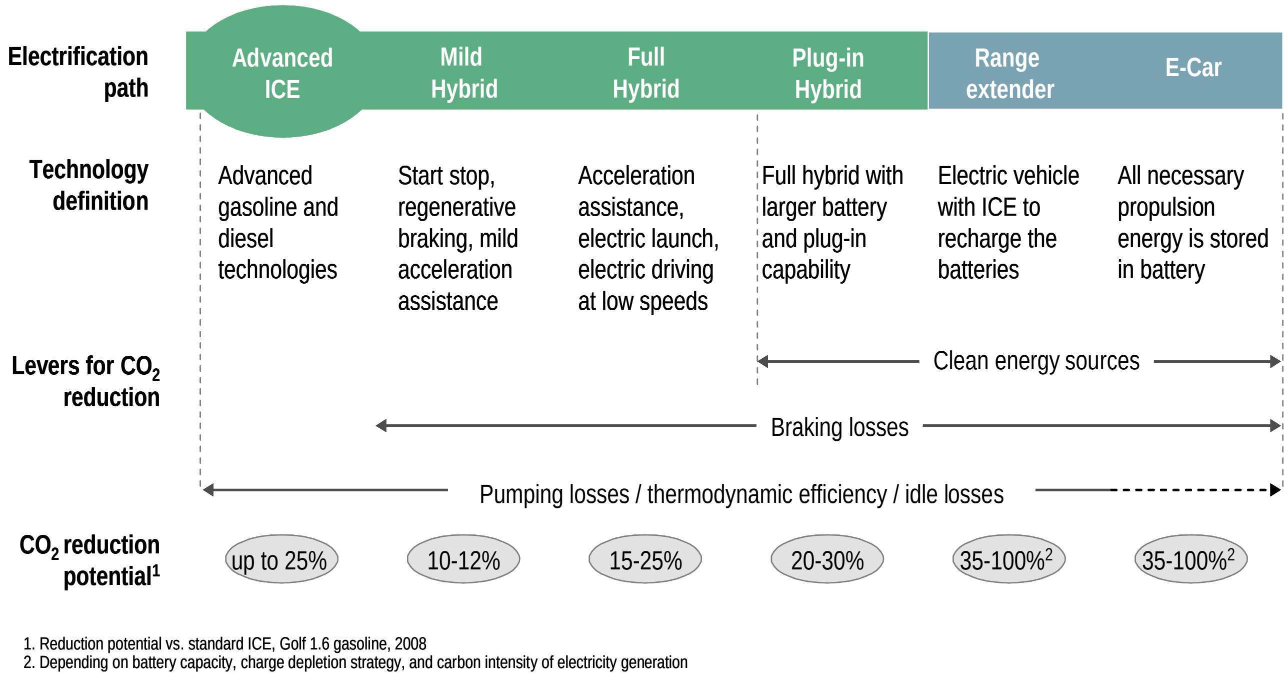
- **Demonstration projects:** City governments can get involved in demonstration projects with EV OEMs to obtain publicity and spread awareness about EVs e.g. Singapore pilot with Renault, etc.
- **Advocacy:** City government can get public figures – e.g. the Mayor, etc – to get involved in EV projects or drive EVs and engage in advocacy efforts for EV adoption.

Procurement for public fleets

- City governments can procure EVs for public fleets e.g. London has announced that it will procure 1000 EVs for its public fleet by 2015.

Appendix III: Figures and graphs

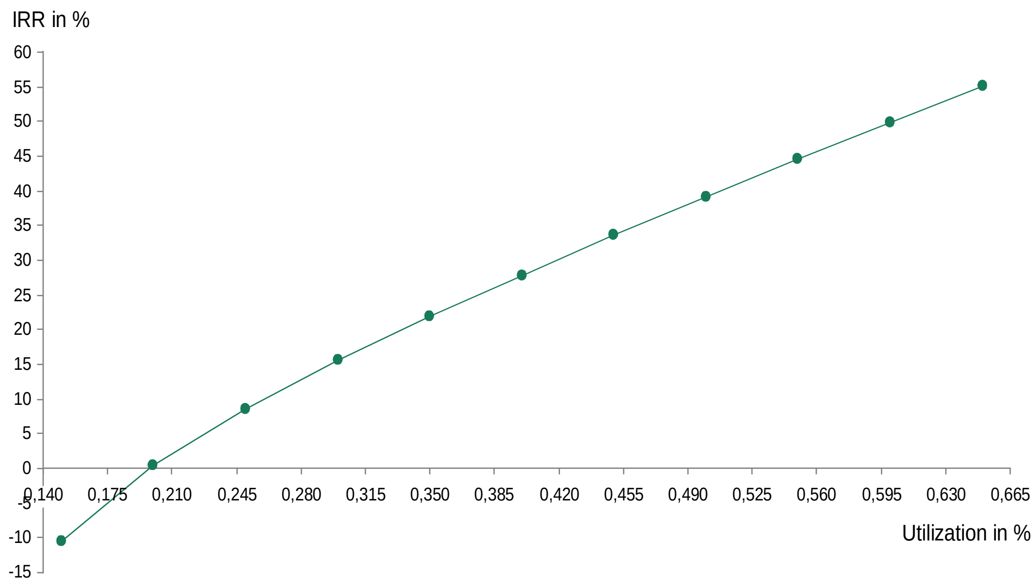
Figure 1: Continuum of different car propulsion technologies



Source: The Boston Consulting Group (2009), p. 2

Figure 2

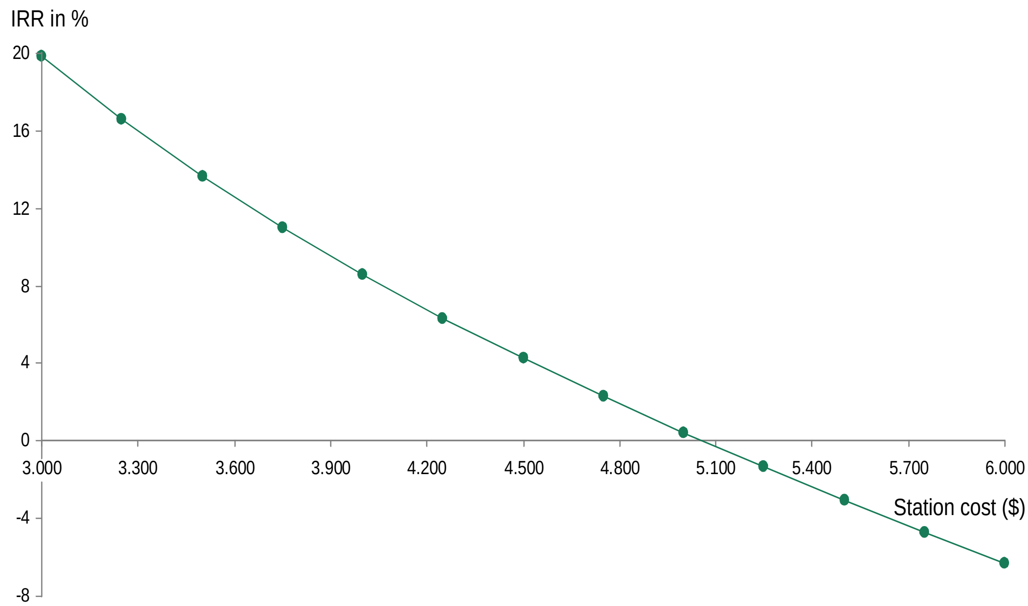
Rate of return based on varying utilization rates – Level II



Note: Mark-Up 7.5 cent; 10 years life time; 10% maintenance cost per year; $5,000 station and installation cost; 7.7kwH throughput
Source: Team analysis

Figure 3

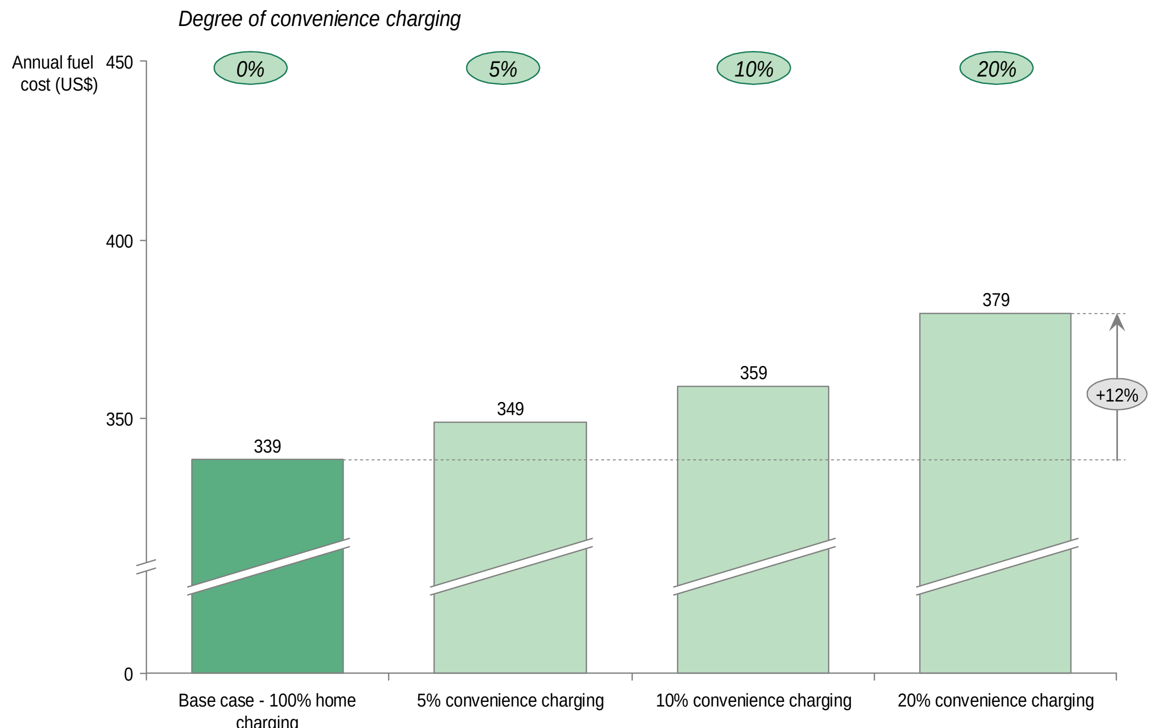
Return rate based on varying station prices – Level II



Note: Mark-Up 7.5 cent; 20% utilization; 10 years life time; 10% of station cost as maintenance cost per year; 7.7kwH throughput
Source: Team analysis

Figure 4

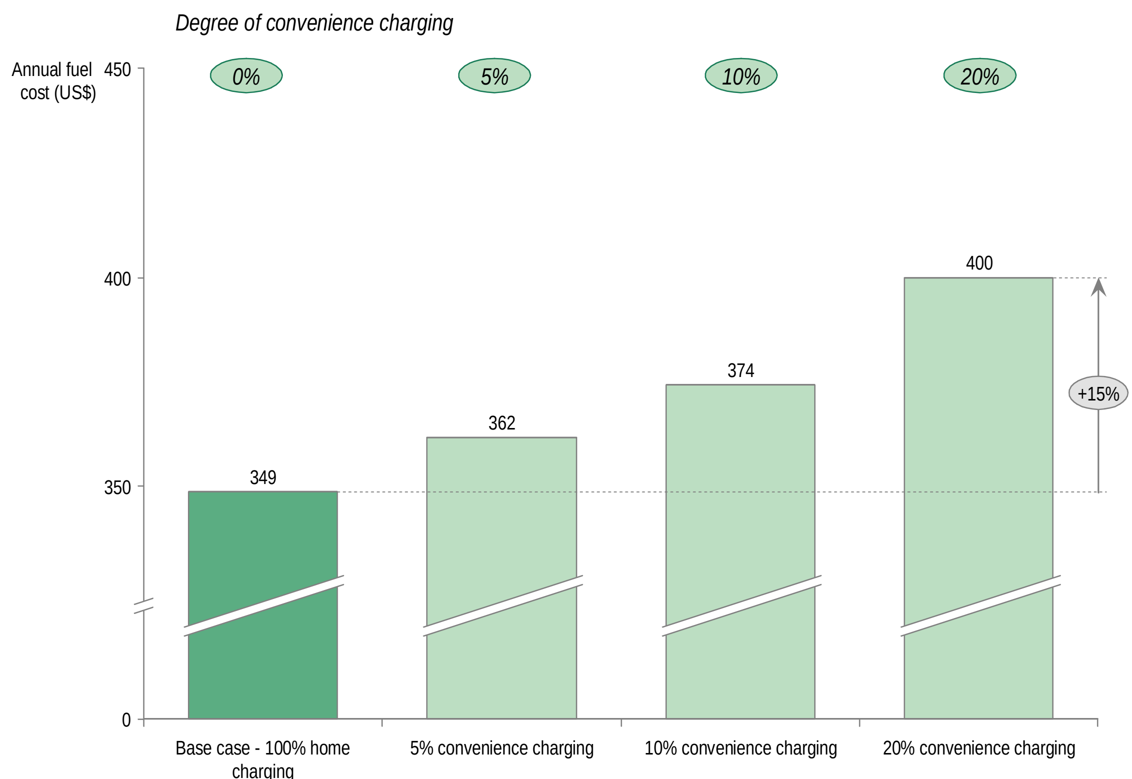
Impact of convenience charging on total fuel costs for consumers Level II charging – Example Berlin



Note: Based on electricity price of approx. 18 cent per kwH; 12.000km annual avg. travel distance; assumption of car efficiency of 16km per kwh
Source: German government; Team analysis

Figure 5

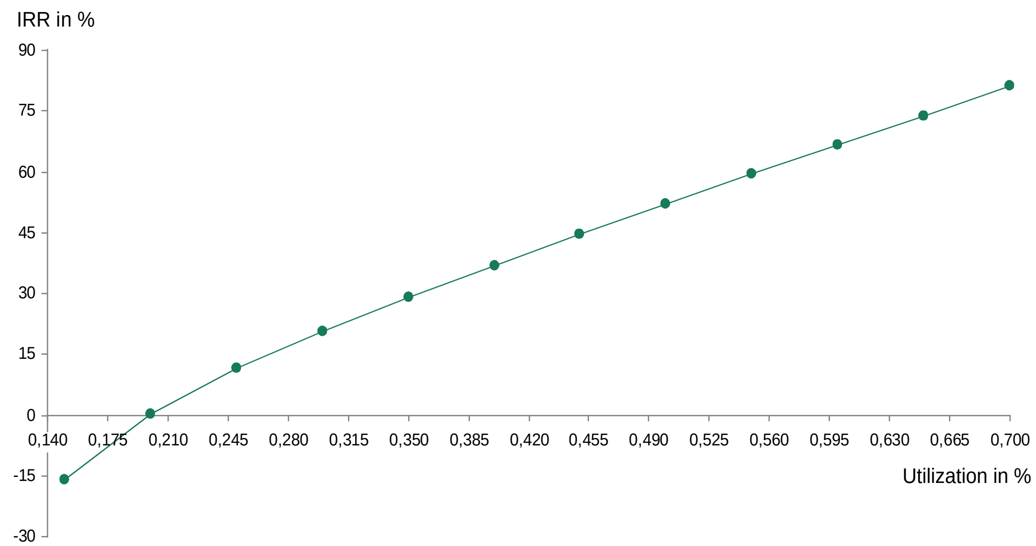
Impact of convenience charging on total fuel costs for consumers Level II charging – Example London



Note: Based on electricity price of approx. 15 cent per kwH; 15.000km annual avg. travel distance; assumption of car efficiency of 16km per kwh
Source: UK Government; Team analysis

Figure 6

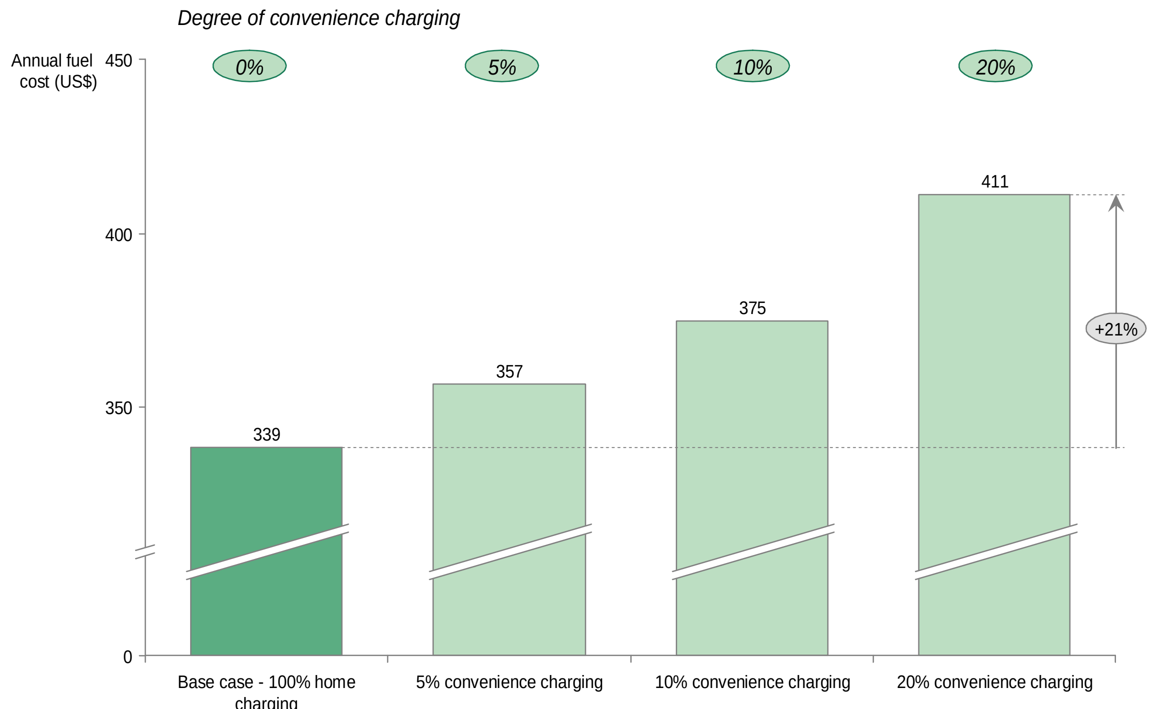
Rate of return based on varying utilization rates – Level III



Note: Mark-Up 7.0 cent; 10 years life time; 10% maintenance cost per year; 5000$ additional operation cost p.a.; 60000 station and installation cost; 50kwH throughput
Source: Team analysis

Figure 7

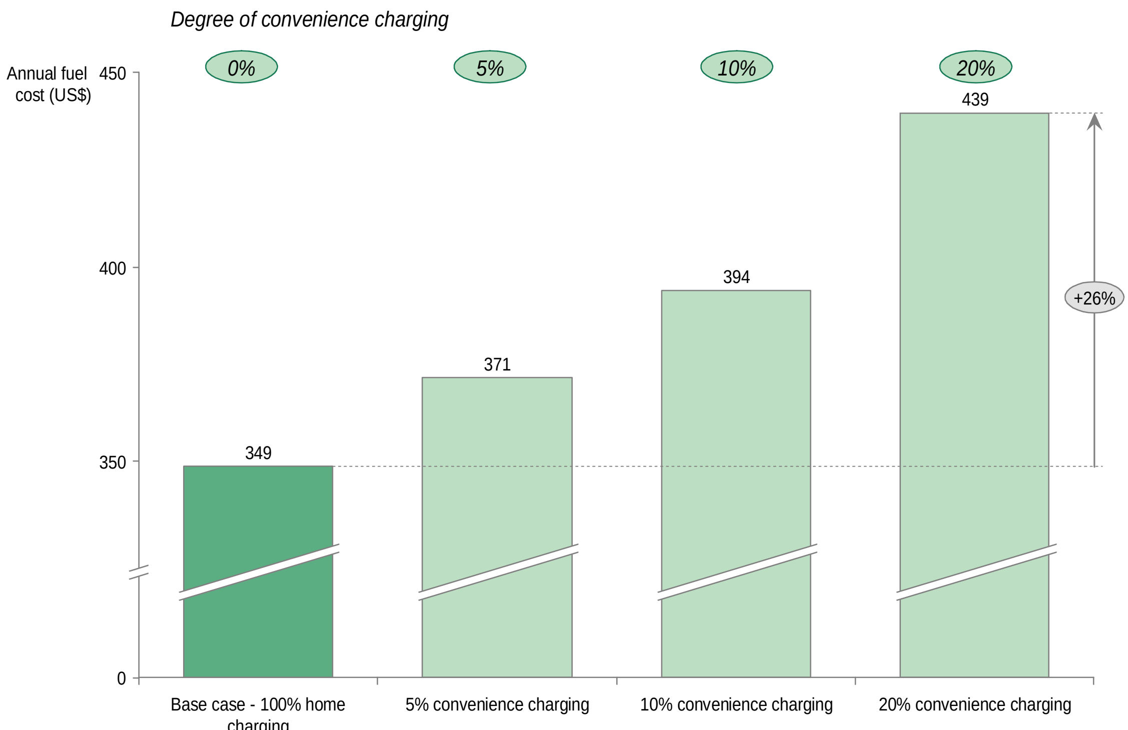
Impact of convenience charging on total fuel costs for consumers Level III charging – Example Berlin



Note: Based on electricity price of approx. 18 cent per kwH; 12.000km annual avg. travel distance; assumption of car efficiency of 16km per kwh
Source: German government; Team analysis

Figure 8

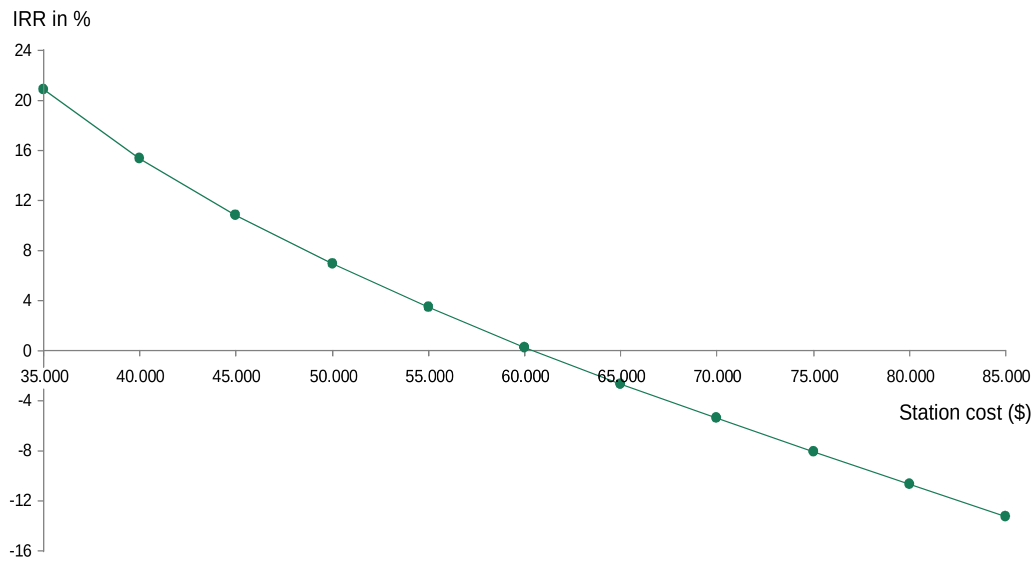
Impact of convenience charging on total fuel costs for consumers Level III charging – Example London



Note: Based on electricity price of approx. 15 cent per kwH; 15.000km annual avg. travel distance; assumption of car efficiency of 16km per kwh
Source: UK Government; Team analysis

Figure 9

Return rate based on varying station prices – Level III



Note: Mark-Up 19.5 cent; 20% utilization; 10 years life time; 10% of station cost as maintenance cost per year; 50kwH throughput
Source: Team analysis

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Appendix V: List of Interviews

Name	***Organisation***
Mark Evers	Transport Commissioner’s Delivery Unit, London
Marcus Groll	RWE, Berlin
Sean Arian	Mayor’s Office, Los Angeles
Adrian Garcia	Mayor’s Office, Los Angeles
Alex Fay	Mayor’s Office, Los Angeles
Alexander Morris	Southern California Edison
Sarah Potts	Clinton Foundation, Los Angeles
Gustavo Collantes	Government of Washington State
David Shlacter	Better Place, San Francisco
Miguel Brandao	Experimental Power Grid Centre, Singapore
Dr. Sanjay Kuttan	Energy Market Authority, Singapore
Dr. George Sun	Land Transport Authority, Singapore
Dr John Kua	Agency for Science, Technology & Research, Singapore
Ivy Ong	National Environmental Agency, Singapore
Jan Croeni	Eonlux, Singapore
R. Chandramouli	REVA, Bangalore

All these interviews took place over the period from October 2009 till February 2010. We have not listed exact interview dates as we had multiple interactions with most of the interviewees. Several interviewees asked to not be directly quoted in the report; therefore we have not referred to them by name in the report.

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[2] US department of Energy, "Electric vehicles"

[3] US Department of Energy, "Hybrid electric vehicles"

[4] US Department of Energy, "Plug-In hybrid electric vehicles"

[5] Participating C40 cities (40): Addis Ababa, Athens, Bangkok, Beijing, Berlin, Bogotá, Buenos Aires, Cairo, Caracas, Chicago, Delhi, Dhaka, Hanoi, Hong Kong, Houston, Istanbul, Jakarta, Johannesburg, Karachi, Lagos, Lima, London, Los Angeles, Madrid, Melbourne, Mexico City, Moscow, Mumbai, New York, Paris, Philadelphia, Rio de Janeiro, Rome, Sao Paulo, Seoul, Shanghai, Sydney, Toronto, Tokyo, and Warsaw. Affiliate cities (19): Amsterdam, Austin, Barcelona, Basel, Changwon, Copenhagen, Curitiba, Ho Chi Minh, Heidelberg, Milan, New Orleans, Portland, Rotterdam, Salt Lake City, San Francisco, Santiago, Seattle, Stockholm, Yokohama.

[6] These cities are Bogota, Buenos Aires, Chicago, Copenhagen, Delhi, Hong Kong, Houston, London, Los Angeles, Mexico City, Toronto, Sao Paulo, Seoul and Sydney.

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[18] See for example Valeo, "Zero Emission Vehicle"

[19] See McKinsey, "Electric Vehicles in Megacities" and BCG, "The Comeback of the Electric Car"

[20] See McKinsey, "Electric Vehicles in Megacities" and BCG, "The Comeback of the Electric Car" as well as BCG, "Batteries for Electric Cars"

[21] McKinsey, "Electric Vehicles in Megacities", p. 8.

[22] See for example Element Energy, "Electric Vehicles – Strategies for uptake and infrastructure implications", p. 1 and 10-17.

[23] For example - Element Energy, "Strategies for the uptake of electric vehicles and associated infrastructure implications", Oct 2009

[24] BCG, "The Comeback of the Electric Car", p. 8.

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[37] BCG, "The Comeback of the Electric Car", p. 7.

[38] Electrification Coalition, "Electrification Roadmap", p. 95.

[39] For a sensitivity analysis regarding utilization rates using a constant mark-up see Appendix III – Figure 2 and for varying station costs with utilization and mark-up rates hold constant see Appendix III – Figure 3.

[40] See London Fire Brigade, "Our Performance"

[41] Agassi, "Projecting the Future of Energy, Transportation, and the Environment", p. 4, from where also the following quotes are taken.

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[45] See Economist, “A Netscape moment?”, for a similar argument.

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[53] Newride London website,“Recharge points“

[54] Heise online, “E-Mobility Berlin: Elektroauto-Pilotprojekt gestartet”

[55] Tagesspiegel, “Einmal aufladen, bitte!”

56 For more details see Bundesregierung, “Nationaler Entwicklungsplan Elektromobilität der Bundesregierung“

[57] For a current overview of charging locations visit http://www.rwe-mobility.com/web/cms/de/240690/rwemobility/was-ist-elektromobilitaet/standorte-rwe-ladesaeulen/ or http://www.vattenfall.de/www/vf/vf_de/225583xberx/228797innov/228917wasse/1550203minix/1715944ladem/index.jsp

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