Where Should the Public Sector Invest in Alternative Modes of Transport?

A Comparative Study of Car Clubs and Electric Vehicles in London

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in conjunction with Arup

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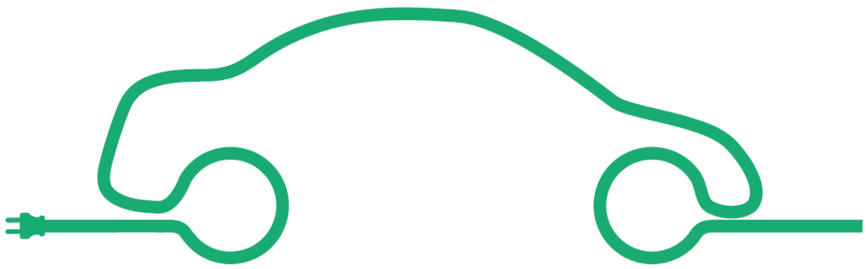

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Purpose of This Study

Arup is a global structural engineering, design and planning, and project management and consulting firm with a particular focus on public sector transportation and infrastructure projects. It is our hope that Arup, researchers, and the public sector can utilise this research and the associated cost benefit software models we construct to develop a more comprehensive framework with which to analyse the feasibility and opportunities inherent in the EV and car club industry in London over the next ten years, gaining valuable insights into the most critical factors influencing future demand.

In addition to making a conclusive recommendation on where to invest in infrastructure (car clubs, electric vehicles, or both), we offer concrete policy recommendations on how London can promote demand for each of these options. We hope these findings will help inform policymakers as to the important opportunities and costs, qualitative and quantitative, associated with each alternative, including how best to effectively integrate these transportation options with existing modes of transport and capitalise on potential synergies therein.

List of Acronyms

CAGR	Compounded annual growth rate
CBA	Cost benefit analysis
CO_2	Carbon dioxide
CPI	Consumer price index
CBI	Confederation of British Industry
DECC	Department for Energy and Climate Change
dB	Decibels
DEFRA	Department for Environment, Food and Rural Affairs
DOT	United Kingdom Department of Transportation
EVs	Electric vehicles
GLA	Greater London Authority
GVA	Gross value added
GDP	Gross domestic product
ICE	Internal combustion engine (i.e. non-electric)
IPCC	Intergovernmental Panel on Climate Change
NPV	Net present value
NSB	Net social benefit
SMMT	Society of Motor Manufacturers and Traders
PLC	Product life cycle
TfL	Transport for London
TRL	United Kingdom Transport Research Laboratory
UNDP	United Nations Development Programme

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Executive Summary

Objective of the Report

The objective of this report is to conduct a comprehensive cost-benefit analysis to identify which of two alternatives – car clubs or electric vehicles (EVs) – might provide the greatest overall return through 2021, and therefore merits priority within London's strategic considerations.

Key Findings

We ultimately conclude from our analysis that:

1. From the perspective of the public sector, car clubs provide a total social benefit that is four-times as great as that of EVs;

2. Much of this discrepancy in total social benefit stems from the reduction of CO_2 and improved air quality, which car clubs contribute to significantly more than EVs;

3. From the perspective of the individual consumer, car clubs appeal to consumers across a wider spectrum of income levels than do EVs;

4. EVs still represent a highly positive social investment and significant opportunities to integrate EVs with car clubs.

Policy Recommendations

From these findings, we recommend that London's policymakers focus primarily on promoting car clubs over EVs in the short term.

Specifically, they should: 1) increase their allocation of car club-designated parking spaces; 2) consider larger parking infrastructure projects for car club vehicles; 3) explore tax incentives for car club operators and consumers; and 4) help build consumer awareness of the benefits of car clubs outlined in this report by engaging in targeted marketing techniques, such as advertising throughout bus and tube networks.

Since our analysis reveals a significantly positive net present value for EVs as well, policymakers should: 1) continue subsidising EV-related costs and investing in London's charging network; 2) focus on finding ways to enable vehicle manufactures to reduce the price of EVs, such as subsidies on R&D, battery research or direct tax incentives; and 3) promote the integration of EVs into car clubs.

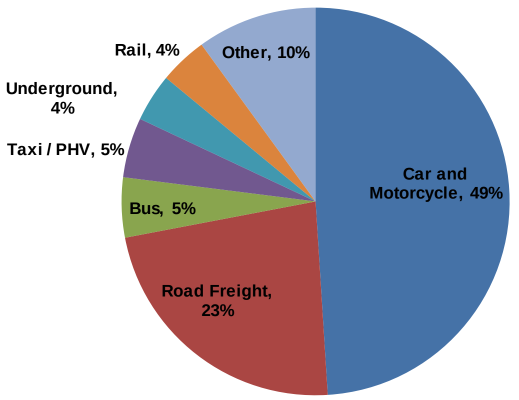
Part I: Introduction

London and CO_2 Reduction

Mayor Boris Johnson set an aggressive mandate for the City of London to reduce its greenhouse gas emissions by 60% from 1990 levels by 2025, and is currently spearheading a campaign to establish London as a global leader in carbon dioxide (CO_2) reduction over the next decade. Central to achieving these targets is a coordinated effort to reduce transportation and other road-based emissions, which currently account for more than 80% of London CO_2 emissions (Guidance for Implementation, 2009).

Transport for London (TfL) has been tasked with meeting the Mayor's goals by developing transportation based solutions. TfL has targeted automobile use as a critical component in reaching the goals.

Composition of CO_2 Emissions in London



Source: An Electric Vehicle Delivery Plan for London (2009)

Currently, TfL are focusing efforts on two main strategies for automobiles' emissions:

1. Spurring demand for EVs via the installation of charging points, the implementation of tax incentives, and increasing consumer awareness

2. Promoting greater membership in car sharing schemes by subsidising on-street parking spaces to be used exclusively by car club companies, and likewise increasing consumer awareness.

EVs and car clubs have the potential to provide London with many environmental benefits, most notably improved air quality through the reduction of CO_2. Pursuing either strategy will require the public sector to incur significant costs in the form of foregone revenues from tax incentives and relevant automobile-related fees, as well as the direct costs of constructing the charging infrastructure for EVs, building on-street parking bays for car clubs, and marketing these new initiatives to the public. Accurately quantifying each of these costs and benefits is critical in determining which strategy London should prioritise. However, one must also consider the decision of the individual consumer, which ultimately drives the feasibility of the policy.

From the consumer's standpoint, EVs and car clubs have many tangible and intangible costs and benefits. These include the higher cost of purchasing an EV as well as the membership fees required to join a car club scheme. Financial benefits are realised mainly in the form of cost savings from gasoline, tax incentives, and insurance.

Examples of less tangible costs include the hassle of having to recharge an EV or walk to a car club-designated parking bay to retrieve an available vehicle, while users of both schemes may benefit intrinsically from participating in such an environmentally-friendly program.

Our cost-benefit analysis incorporates all of these factors from both the public sector and private consumer's perspective. We also conducted sensitivity analyses to determine which assumptions are most important. A further contribution of this analysis is a synthesis of qualitative considerations London must consider, including how to incentivise and spur future demand for these initiatives and possible ways to integrate each of these industries with public sector transportation.

The following table represents a sampling of the interviews we conducted and key resources consulted throughout our analysis. We'd like to thank each of these individuals for their invaluable input and support.

Kate Gifford
Strategy and Business Manager, Carplus

Jack Husse
Member Services Executive, Zipcar

Keith Kelly
Strategy Unit, City Car Club

Joseph Rubin
Member Care Center Administrator, Hertz-on-Demand

Aaron Weeks
TfL – Borough Programme Officer
Better Routes and Places , Surface Transport

Peter Sadler
TfL – Electric Vehicles Strategy

Phillip Rode
Executive Director, LSE Cities and Senior Research Fellow at the London School of Economics

Rafael Hortala Vallve
Lecturer in Political Science and Public Policy Government Department at the London School of Economics

Overview of This Report

The remainder of this report will proceed as follows: first we provide a brief overview of the current status of EVs and car clubs in London, providing insights into key areas where policymakers might incentivise demand. Following this discussion, we will present the available survey data that was used to construct our "average" EV and car club consumers for whom we evaluate costs and benefits. We then outline the assumptions and data behind our market sizing in which we forecast demand for EVs and car clubs over our ten-year horizon. Next, we present our methodology and general approaches to cost benefit analysis, importantly including a discussion of some of the limitations of this type of analysis. Using our market projections and methodology, we then present our cost benefit analyses of EVs and car clubs, as well as implications for policymakers. Our study concludes by offering Arup and London's government officials sound policy recommendations as to the most effective personal transport strategy moving forward and specific potential action steps.

Where Are We Today? Car Clubs and EVs in London

The Car Club Industry in London

Through TfL, the UK has officially supported efforts to expand car clubs since 2003 when it initially provided 'pump priming' funding in support of the London Car Club Consortium.

Car clubs have since grown rapidly, with over 160,000 members in the UK as of January 31, 2011 (Carplus, 2012). Of these, 83%, or approximately 130,000 are London-based, where growth has been concentrated. To date, the extent of government support has been relatively minimal but sufficient to meet the limited borough demand. London-policymakers have begun building consumer awareness for car clubs by supporting the requisition process and providing the materials to paint in car club parking spaces.

London has further supported the expansion of car clubs via the piloting of research studies in partnership with boroughs. These studies include an examination of the future market potential (Camden & Islington), their feasibility in outer boroughs (various boroughs) and deprived areas (Greenwich) and their potential integration with EVs (Camden).

Borough Level Demand Analysis

Borough	Adult Population w Driving License	Current Car Club Members	% living within 400m of a Bay	Total Potential Members
Barking & Dagenham	78,454	257	5.7%	16,439
Barnet	165,276	947	6.3%	53,548
Bexley	110,440	79	1.0%	24,211
Brent	137,900	2,442	43.1%	33,516
Bromley	150,244	369	1.9%	39,137
Camden	127,338	5,912	94.9%	42,602
City of London	4,550	661	78.6%	2,139
Croydon	166,445	954	3.2%	40,916
Ealing	154,966	2,069	32.6%	47,928
Enfield	141,428	236	0.3%	34,824
Greenwich	111,421	2,359	23.0%	26,296
Hackney	101,402	5,489	82.7%	20,358
Hammersmith & Fulhan	91,522	4,505	82.0%	33,274
Haringey	119,989	3,032	36.7%	34,493
Harrow	107,524	213	2.9%	27,260
Havering	114,630	75	0.9%	25,219
Hillingdon	124,563	259	2.3%	28,751
Hounslow	109,449	1,669	20.9%	29,534
Islington	98,291	10,868	99.5%	27,148
Kensington & Chelsea	99,798	4,879	99.8%	42,103
Kingston	81,192	1,158	21.9%	26,303
Lambeth	140,362	8,222	5.9%	39,574
Lewisham	128,019	2,994	37.8%	30,461
Merton	102,234	2,360	41.5%	32,627
Newham	127,404	1,292	8.8%	23,868
Redbridge	124,378	620	10.9%	29,937
Richmond Upon Thame	91,881	2,954	66.4%	36,644
Southwark	147,070	5,865	56.3%	33,497
Sutton	92,431	745	22.4%	22,058
Tower Hamlets	113,690	6,558	92.1%	26,306
Waltham Forest	108,573	1,182	29.5%	23,963
Wandsworth	150,136	10,203	76.7%	57,544
Westminster	148,219	6,860	99.0%	58,421
Total	**3,871,219**	**98,287**	**36.7%**	**1,070,899**

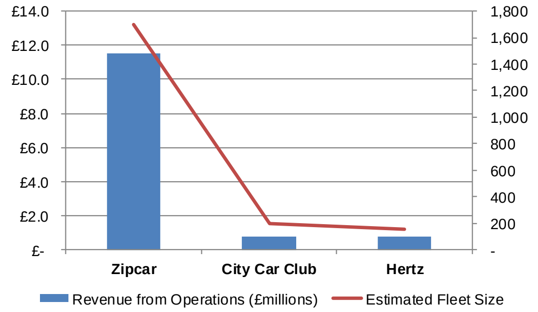
Source: Adapted from TfL Mosaic Report

London Car Club Companies

The market landscape for car clubs has undergone a drastic transformation since City Car Club established London's first car sharing scheme in 2000. Today, the market share for car clubs is divided amongst City Car Club and its three main competitors: Zipcar, Hertz on Demand, and Greenwheels, all of whom opened their London operations within the last five years.

London's two largest operators – City Car Club and Zipcar – have each recently expanded their capacity through major acquisitions of smaller car club operators. In August of 2009, City Car Club acquired Whizzgo, which expanded their fleet to roughly 500 vehicles, and within the next year, Zipcar acquired what was UK's largest operator Streetcar for $50 million. The acquisition combined Streetcar's fleet of over 1,400 vehicles with Zipcar's fleet of only 400, propelling the company to the largest car club operator currently in London.

London Car Club Operators' Revenue and Fleet Size



Source: London office of fair trading; interviews with company representatives

This recent market consolidation demonstrates the need for these operators to achieve economies of scale and gain access to limited on-street parking bays. City Car Club's CEO, James Finlayson, said following Zipcar's acquisition of Streetcar that the consolidation "is a land grab… and that what's important is prime on-street city centre locations" (Kavanagh and O'Doherty, 2009). This highlights the critical role that London's public sector can play in determining growth. The extent to which TfL continues subsidising the construction of new designated parking spaces as well as willingness to explore larger infrastructure projects for car club vehicles will be a significant factor in defining industry capacity in London.

Long-term Growth Prospects

As the only publicly-traded, pure car club operator in London, Zipcar's available financial statements provide the most insight into their business model as well as the risks facing the industry.

Zipcar has been operating at a loss of over $65 million since it was first established in 2000. The company has realised year-over-year revenue growth since 2005, and recorded its first profitable quarter in November of 2011. Despite its lack of sustained profitability, the market has embraced the growth potential for Zipcar and the car club industry, as the company's share price surged 60% immediately following its initial public offering in April 2011 (Struck, 2011).

Investors have remained optimistic about Zipcar's future prospects despite the inherent risks. As of the end of Q3 2011, the company held over $75 million of debt on their balance sheet, used mostly to finance the leases on their vehicle inventory (Zipcar financial statements). Zipcar typically leases each of its vehicles for two years before replacing. The company bears significant residual risk in reselling their vehicles as many factors influence their resale value, including depreciation and macro systematic risks that affect general market demand, such as the price of gasoline or an economic recession (Zipcar Inc, Form 424B4, 2011).

A key challenge influencing growth and profitability of the industry is reaching a critical mass in membership, fleet size, and parking infrastructure. Zipcar has stated that they require 50 members/vehicle in order for their model to be sustainable. Achieving this may require targeted marketing as well as expansion via partnerships with London universities and businesses (Zipcar-JPMorgan, 2011).

Car club operators must incur significant fixed costs to pay for vehicles and parking bays, and covering these costs will require operators to increase their vehicles' utilisation rate (Frost & Sullivan, 2010). Before capacity is achieved in London, operators must either reach their sustainable member-to-vehicle ratio or entice members to take separate trips with greater frequency. Shorter trips, charged on an hourly basis, provide higher profit than flat-rate daily reservations, while also increasing availability of vehicles for others (Zipcar-JPMorgan, 2011). A major factor in incentivising shorter trips for users is the availability of on-street parking spaces in convenient locations, such as supermarkets, movie theatres, and other places of interest where people typically spend small amounts of time.

The car club industry in London over the next decade will significantly depend on the level of competition from new operators. As demand grows, new entrants are expected to enter in the market in the form of traditional car rental companies (e.g. Hertz) as well as from vehicle manufacturers directly. Furthermore, selected boroughs have already promoted competition amongst the current operators by allowing multiple operators to service their constituents, whereas other boroughs have granted exclusive contracts to individual operators. With such high demand for limited on-street parking bays, the decision at the borough level to use a single versus multi-operator system will be a critical factor.

EVs in London

Current Status of EVs in London

In early 2011, the UK government launched the Plug-In Car Grant, a £230 million plan to incentivise EV demand. Under the scheme, buyers can receive a 25% rebate (up to £5,000) on their EV purchases. Although only 55 EVs were purchased in the UK in 2009, the Plug-In Car Grant spurred 680 new orders in its first six months (Vaughn, 2011).

In addition to the grant, the government launched the £30 million Plugged-In Places scheme, a programme designed to increase the number of charging points in eight pilot regions throughout the UK (Charging Point, 2011). The government sees EVs both as a way to rebuild the UK's automotive industry and improve the environment (Bhatti, 2011). The Committee on Climate Change estimates the UK will need 1.7 million EVs by 2020 in order to meet its targets (Business Green, 2011). London leads the UK in EV infrastructure and will be the driving force behind meeting the Committee's targets in the future.

Since spring 2011, Mayor Boris Johnson has been strongly committed to making London the EV capital of Europe (TfL, 2011). London is an ideal location for EVs because Londoners tend to make short car trips: on average, 95% of London motorists travel fewer than 75 km per day, well within the typical 160 km EV range (Vaughn, 2011).

In order to make EVs more appealing, Mayor Johnson launched Source London in May 2011, the UK's first citywide charging point network and membership scheme. Johnson hopes to install 1,300 new charging points across the city by the end of 2013 (TfL, 2011). "One of the biggest hurdles to greater use of EVs has been a lack of charging points," says Johnson, "But now Londoners will see Source London points popping up in locations all over the capital. By giving increasing numbers of drivers the confidence in EV technology we will make a considerable contribution to improving our air quality and cutting carbon emissions" (Mayor of London, 2009).

The figure below shows the current layout of Source London's charging points throughout the city, which are predominantly focused around central London:

Source London Charging Points

Source: Source London (2012)

In addition to this initiative, London has secured an additional £17 million for further EV infrastructure improvements. This additional funding from DoT, TfL, and others will be used primarily for installing more charging points at work places (Bhatti, 2011). Furthermore, Mayor Johnson has pledged to introduce 1,000 EVs into the Greater London Authority car fleet by 2015 (The Automotive Council, 2010).

While 2011 was a breakthrough year, the future of EVs in London remains uncertain. On February 1, 2012, the London Assembly Environment Committee published *Charging Ahead*, an overview of the city's progress on implementing the Mayor's 2009 EV delivery plans. There are currently 2,313 EVs registered in London, representing only 0.08% of London's total car fleet (London Assembly Environment Committee, 2012). In addition, London currently has only 400 charging points throughout the city, of which 263 are part of the Source London network. Although TfL officials remain confident Source London will provide 1,300 points by 2013, the current outlay of points seems well below initial estimations (London Assembly Environment Committee, 2012).

The Environment Committee's report highlights that charging facilities, information about EVs, and the vehicles themselves are the most substantial barriers to market growth. The report also underscores that despite a slow start, EV demand is increasing in London and government support for low-emission vehicles remains strong. Furthermore, almost every major car company has announced plans to produce an EV by the end of this year. A larger EV market with more competition should boost consumption. The mayor hopes to make London the "epicentre of electric driving in Europe," (Vaughn, 2011) and 2012 will provide important insight into the prospects of meeting such ambitions.

The EV Industry

There are currently three types of EVs on the market in London: the Nissan LEAF, Mitsubishi i-Miev, and Renault Fluence ZE. Each of these manufacturers is aggressively pursuing strategies to increase future UK EV sales. In 2013, Nissan is planning to start producing the LEAF at its plant in Sunderland, England. The LEAF was the first mass-market EV available in the UK in 2011, and Nissan currently projects the Sunderland plant will initially produce 50,000 LEAFs per year (Nissan, 2010).

The Mitsubishi i-MiEV hit the UK market after the LEAF in 2011 but has only been available at select locations. Mitsubishi is starting a training program to get the i-MiEV into all franchised UK dealerships by March 2012 (My Electric Car Forums, 2012). Finally, in December 2011, Renault announced that the first wave of Fluence ZEs would become available throughout the UK, including at the Renault dealership in west London. At £17,850 (including the Plug-In Car Grant deduction), the Fluence ZE is by far the least expensive EV available in the UK. In addition to the Fluence, Renault is also planning to release three other ZE series EVs throughout 2012 (The Charging Point, 2011).

Citroen and Peugeot also make EVs currently only available to rent. Smaller manufacturers offer other variants, but many of these, like the G-Whiz, are classified as quadricycles rather than cars. Over the next 18 months, around 29 new EVs, from manufacturers such as BMW, Ford, and Volvo, are expected to go on sale in the UK (plugincars, 2012). However, currently only four of these qualify for the Plug-In Car Grant. The DoT's updated list of qualifying vehicles and market delivery dates is shown in the table below.

In London specifically, BMW will likely receive particular attention after pledging to use 200 of their new EVs for the 2012 Olympic Games (plugincars, 2012). In addition, the Nissan LEAF, which was the first mass-market EV available in the UK in 2011, has also received attention after an announcement in February 2012 that Europecar will be adding several new LEAFs to their London rental fleet (Business Green, 2011). Nissan has also partnered with Source London to offer LEAF buyers a one-year free charging membership (Source London, 2012). According to a recent survey from Chargemaster, 81% of London respondents who are planning to buy a new car said that they would consider "going electric" (What Car, 2012). This heightened consumer interest, coupled with more vehicle options and increased brand awareness throughout the city, could make 2012 a critical year for EV demand in London.

Comparison of EVs on the Market in London or Coming Soon

Make	Model	Availability	Price (Base)	Currency	Price (Base) in GBP
	Chevrolet Volt	2012	31,645	USD	£19,853
	Citroen Czero	Now (Rental Only)	25,000	GBP	£25,000
	Mia	May 2012	19,500	EUR	£16,283
	Mitsubishi I-MiEV	Now	28,990	GBP	£28,990
	Nissan Leaf	Now	25,990	GBP	£25,990
	Peugot iON	Now (Rental Only)	33,155	GBP	£33,155
	Renault Fluence ZE	Now	22,850	GBP	£22,850
	Tata Vista	To Be Confirmed	NA	NA	NA
	Vauxhall Ampera	2012	29,995	GBP	£29,995
				Median	**£25,495**
				Mean	**£25,264**

Source: Department for Transport (2012), manufacturer data (2012)

Part II: Methodology and Market Analyses

Analysing the Consumers of Car Clubs and EVs: Finding the 'Average' Consumer

In order to properly analyse costs and benefits, we first work to define the 'average consumer' for car clubs. This is designed to act as a representative mean consumer for whom we then calculate public and private costs and benefits. This is an important step of our analysis and critical to keep in mind as one considers the results of the study. Running CBAs for all potential types of consumers is neither feasible nor wise – capturing an 'average' consumer is much more relevant in terms of making policy and analysing the overall investment decision at both the consumer and public sector levels.

Car Club Consumers

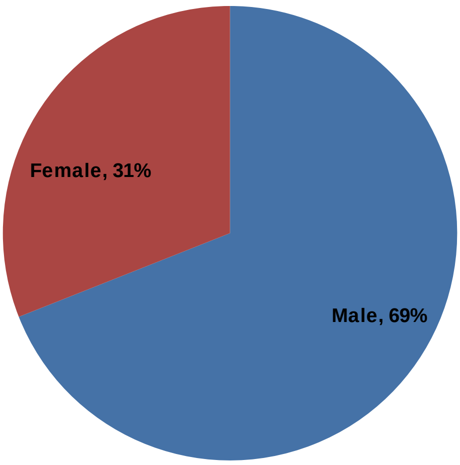
City Car Club defines three categories of consumers:

1. those who currently don't own a vehicle but could benefit from having access to one;
2. those who are currently paying for a private vehicle without getting much use out of it; and
3. those that occasionally need access to an additional vehicle (citycarclub.co.uk).

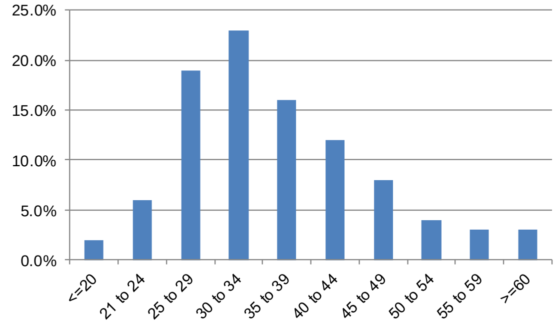
Across all these, we would expect a large variance in car club members' driving behaviour prior to joining a car club.

Data pooled from by Carplus from the five largest car club operators in the UK shows that the average car club member is a male between the ages of 25-34 and drove a private vehicle on average 2,301 miles annually before joining a car club (Carplus, 2012). The primary uses of their car club membership are short weekend trips to recreational destinations (e.g. mall, cinema, etc.) and longer extended day trips (Zipcar.com).

Car Clubs Users: Gender Distribution



Car Club Users: Age Distribution

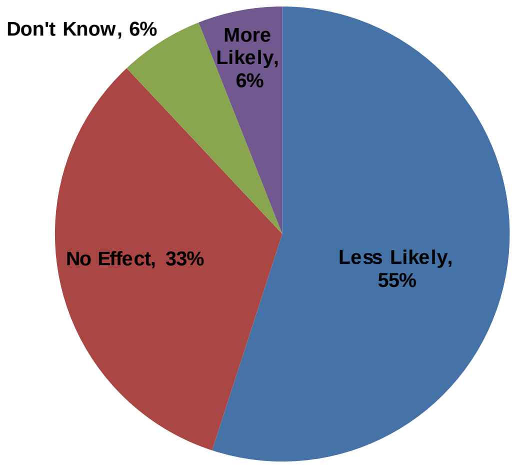


Source: 2010-2011 Carplus Annual Survey

The survey distinguishes individuals who have been car club members more than six months from those that recently joined. While this sample of new joiners consists of only 700-observations, it does provide the most current and revealing insight into the previous driving behaviour of individuals before joining. As with any self-reported survey data, there exists a possibility of random and systematic measurement error that could contaminate the data set and any conclusions we make from them. However, we see no material factors that would make this error systematic, and we concluded that any effects it may have on the data would likely be insignificant. Carplus provide by far the most comprehensive and scientific approach, however we highly recommend policymakers undertake more rigorous empirics to better understand car club use. With this information, we construct an 'average' new car club consumer for which we forecast costs and benefits realised had they joined a car club kept using their membership for the next ten years. Data from Carplus reveals that the "average new joiner" of car clubs drove 2,300-miles in a privately-owned vehicle in the year prior to joining the car club. A difficult yet critical conclusion to draw from the available data is what motivated our average consumer to join the car club, and specifically how their new membership influenced what they did with their previous private vehicle, if they owned one.

Various organisations have attempted to figure out how many private cars each club car replaces. Private cars are removed both by the sale of existing vehicles and by the deferral or cancellation of future car purchases. Carplus, the industry-leading advocate, estimates that each club car replaces an average of 25 cars (Carplus, 2012). NextGreenCar (2012), another independent research organisation, cites studies which estimate the range from 6 to 20. The City of Westminster (2012) aims for each of its club cars to remove 15 to 20 cars from the road. Of the available research, however, Carplus again offers both the most comprehensive and scientific analysis. As the following diagrams illustrate, there is considerable variation across new joiners in the change in private vehicle ownership after joining a car club.

Survey Question: "Has joining a car club made it more or less likely that you will buy your own car in the next few years?



Source: Carplus 2010-2011 Annual Survey

Derived Change in Number of Cars per Household

Change in number of cars owned	Frequency	%
-5	0	0.0%
-4	0	0.0%
-3	1	0.1%
-2	42	3.7%
-1	259	22.8%
0	804	70.8%
1	24	2.1%
2	6	0.5%
Wtd. Avg. Change in Number of Cars		**-0.270**

Total responses *1,136*

Note: Only for households with at least 1 new joiner

Source: Carplus 2010-2011 Annual Survey

As this data was taken at the household level, it is possible that there could be more than one new car club joiner in the same household, thereby biasing our estimate for vehicles removed per new car club member. Based on interviews with private car club members regarding the average number of households with more than two new joiners, Carplus recommended scaling down the estimate by 5% to account for potential double counting. A further concern in the Carplus survey data is that there were a small percentage of respondents who reported both a decrease in the number of private vehicles owned in their household AND that they would've purchased a private vehicle had they not joined the car club. Intuitively, it is reasonable to assume that this was made in error on the part of the respondent, and thus we also scaled down the data to avoid over-counting.

Derived Net Average Vehicle Reduction

	Reduction in Privately-Owned Vehicles	
	Reduction in private owned cars per joiner	-0.270
(A)	Scale down by 5% to avoid double counting of shared addresses	-0.257
	People who would otherwise have bought car	
	% of joiners reporting they would've otherwise bought a car	28.6%
	Implied reduction in cars per joiner	-0.286
(B)	Scale down by 5% to avoid double counting from shared addresses	-0.272
(A) + (B)	Implied total additional reduction in cars per joiner	-0.529
	Downscaling results to allow for potential overlap in answers	
	% who reduced household car ownership and would've otherwise bought a car	11.5%
	Implied double counting in cars per joiner	-0.115
(C)	Scale down by 5% to avoid double counting from shared addresses	-0.109
(A) + (B) - (C)	**Implied total reduction in cars per joiner**	**-0.419**

Data source: Carplus 2010-2011 Annual Survey

Driving Behaviour Before and After Joining

The three major operators in London provided Carplus with data on the average trip length in hours and mileage, as well as the number of trips their typical customer makes annually. From this data, we were able to construct three different scenarios – low, base, and high – to represent the average consumer who uses their car club membership minimally, moderately, and frequently each year.

Observed Driving Behaviour Before and After Joining a Car Club

	Low	Base	High
Length Of Average Trip (Miles)	30.3	37.3	44.4
Trips/Year	8.4	9.7	14.4
Length Of Average Trip (Hours)	5.4	6.8	9.0
Implied Annual Mileage	**254.5**	**361.8**	**639.4**
Implied Annual Hours	**45.6**	**66.0**	**130.0**
Average annual mileage before joining	2,070.9	2,301.0	2,531.1
Implied average annual mileage for new members after joining	254.5	361.8	639.4
Difference (%)	**-87.7%**	**-84.3%**	**-74.7%**

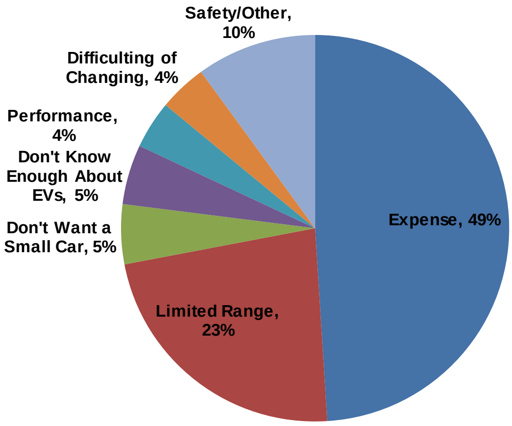
Source: Derived from 2010-2011 Carplus Annual Survey

These figures, along with the aforementioned assumptions about the driving behaviour of the typical car club joiner prior to joining and their private vehicle displacement, are the critical drivers of the costs and benefits that a new car club member will realise.

EVs

For EV users, one of the key benefits of owning a low-emission vehicle is some form of life-style impact. Although life-style benefits are inherently difficult to estimate, considering what type of person might be interested in an EV is crucial for better understanding the market. Deloitte completed a comprehensive analysis of early EV adopters, surveying 2,000 current EV owners as well as leaders of EV manufacturers. They found 'early adopters' to be young, high-income individuals, who already own one or more vehicles. These individuals are also politically active and highly sensitive to environmental matters (Deloitte, 2010). In addition to early adopters, the study also categorised potential consumers into an 'early majority' profile. These people typically have above average incomes, access to garage space for overnight charging, and drive ~600 miles per week. The early majority will likely make their EV purchases once prices become more competitive. In fact, in the table below, Deloitte found the high purchase price of EVs to be the top factor preventing respondents from purchasing EVs.

Survey Question: "What is the Top Factor That Would Prevent You from Purchasing an EV?"



Source: Deloitte (2010)

In addition to the Deloitte study, Nissan completed a similar survey in preparation for the debut of the Nissan Leaf in 2011. By researching income, age, and current cars of everyone who pre-ordered a Leaf, Nissan found similar results to the Deloitte study: on average, buyers are young Baby Boomers (around 45 years old) making salaries of £80,000 per year (Green Car Reports, 2010). They also noted that buyers tend to drive less than 50 miles a day and have adequate garage space for charging at night.

Overall, the consumer reports highlight that early EV adopters represent a very particular group in society. This is important when considering the social inclusion impact of a given policy. In many cases, these buyers are also already knowledgeable about low-emission vehicles. Nissan found that many of the people who pre-ordered a Leaf were planning to update from a previously owned hybrid (Green Car Reports 2010). The challenge for future EVs in London will be to reach past these early adopters and inform a broader audience about the substantial opportunities and benefits of electric driving.

Key Traits of the Typical EV User

Early Adopters

Young Baby Boomers (ages 40-44)
High income (HHI) (>£127K)
Already own one or more cars
Educated, politically active/environmentally conscious

Early Majority

Higher than average HHI (>£72K)
Drive around 160 km/week

Non-Adopters

Price sensitive
Low income (£35K)
Drive around 1,000 km/week
Tend to drive larger vehicles (SUV/Trucks)
Rarely politically active

Source: Deloitte, Nissan.

Market Sizing

Now that we have a better idea of who the typical EV and car club consumers are, we turn to how these individuals will grow into markets. Sizing the market is an important exercise because it ultimately drives the relative scale of costs and benefits and informs as to the economic significance of each measure.

Ultimately, the precise number of users is not as important as capturing the reasonable window of outcomes and taking consistent approaches for both EVs and car clubs, since comparability between EVs and car clubs is our primary concern.

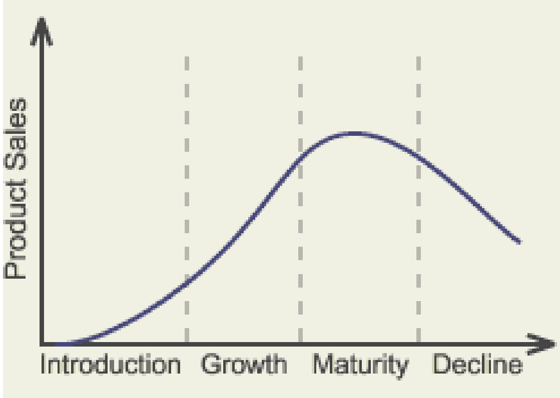
The Product Life Cycle

An applied discussion of the concept of the product life cycle (PLC) is helpful in investigating the future prospects for car clubs and EVs in London. The PLC outlines four broad stages of a product: introduction, growth, maturity and decline (Day, 1981). During the introduction phase, companies introduce a new product to the market in a high cost environment but with little competition, as competitors have yet to enter. At this early stage demand must be created from the ground up. As the customer base grows and demand reaches a critical point, other competitors begin to enter the market and compete for business. At this point, companies also begin to streamline their product and exploit economies of scale, leading to more efficient practices and often better relative profitability vis-à-vis the introduction phase (the growth phase).

In the next phase, maturity, more competitors enter the market, pushing prices (revenues per unit) lower and increasing pressure on suppliers to compete for business. At this point, substitute goods (competing products) begin to enter the market and may 'cannibalise' market share. While producers have now mastered their processes, the cost savings may no longer be enough to offset the reduced prices their products now demand.

In the final phase, decline, the market has become completely saturated and profits are squeezed even lower. This is consistent with widely accepted economic theory which states that in the long run, perfectly competitive markets result in zero profits.

The Product Life Cycle



Source: Day, 1981

Application to Car Clubs and EVs

Applying these theories to the car club and EV industries reveals some interesting insights. First, a cursory glance at car clubs and EVs would indicate that both are still in the introduction or perhaps early growth phase of the PLC.

While early growth rates and demand characteristics of EVs and car clubs have been consistent with an early product life cycle, competitive market pressures in car clubs are more consistent with the late phases of the process. Competition has reached a dangerous level while demand has yet to reach the critical mass which would typically trigger this level of competition. Already we are seeing significant threats from substitute products such as those contemplated by DaimlerChrysler (Car2go) and BMW (BMW Drive).

While the product life cycle is apt at describing the life cycles of new products, other items are harder to characterise, particularly service based offerings like car clubs. Raw products like EVs must be sourced from research and development, technologies, materials and industrial processes. Car clubs can be considered more of a bundling of pre-existing assets and services, as each of the inputs (cars, people, rental processes, and pricing structures) come from already mature markets (car manufacturers, car rental companies, and labour markets). So while car clubs are certainly a new innovation, barriers to entry are uncharacteristically low and the threat of new entrants is particularly strong.

Ultimately, car club membership can only proliferate into a true staple of London transport with the long-run success of the private car club operators. It remains to be seen to what extent these companies will be able to capitalise on best practices and economies of scale in order to create consistent and dependable long-run value. This is a major risk factor we identified when projecting the future growth of car club participation.

Similar to car clubs, we assume EVs to be at the early growth stage of the product life cycle and therefore we move from a high to low growth rate over time. However, one must consider further that EVs in London are an even more nascent industry than car clubs. Because these early stages in the life cycle are crucial in determining future growth, developments in the near future could have a major impact on future growth prospects. Thus, EVs are at a much more sensitive stage of the cycle than are car clubs. Several risk factors could negatively impact the future growth of this industry including but not limited to increases in resources prices (especially battery components like lithium ion), troubles in advancing research and development, continued macroeconomic downturn, and changes in consumer preferences.

Market Projections

Car Clubs

We considered a wide range of factors in creating our base, high and low scenarios for car club market uptake in London. We identified three critical factors that will significantly influence the future growth of car clubs in London:

1) car club operators' ability to maintain profitable growth
2) support for car clubs by London's policymakers
3) user behaviour, which can largely be influenced by the prior two factors.

Our aim in sizing the market is to develop a reasonable window of possibilities for future demand in order to determine the potential scale of the costs and benefits we analyse. This is prudent given the wide range of factors that may largely impact market over our 10-year time horizon.

The wide range of car club growth estimates currently offered by well-established professionals demonstrates the difficulty of projecting the future growth of car club membership in London. Transportation consulting firm Frost & Sullivan projects its base compound annual growth rate (CAGR) at about 42% through 2016, where Carplus estimates 1 million users by 2020, implying a CAGR of roughly 22%. In the near term, our base case approximately reflects a midpoint between these estimates. In building the rest of our scenarios, we use these starting points to construct three curves that demonstrate increasing and then decreasing marginal growth in order to capture the acceleration and deceleration exemplified at the growth stage of the PLC.

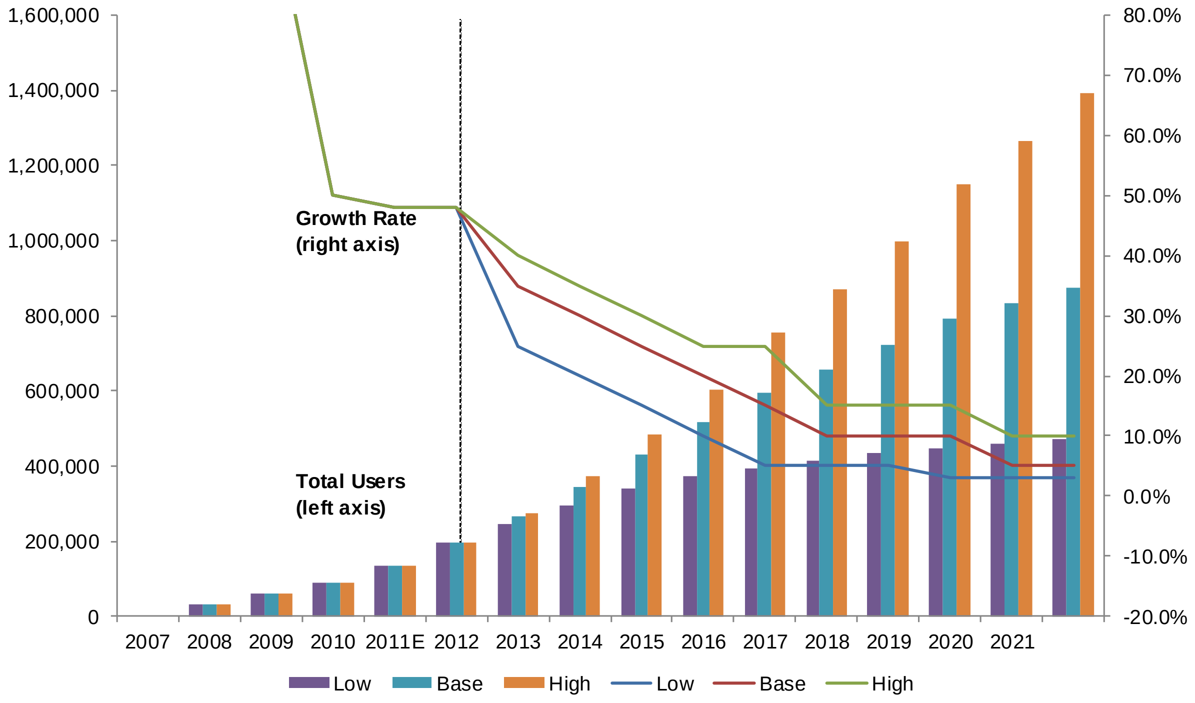
As a second check, we consider what each growth scenario would imply in terms of a penetration rate (users divided by total potential users, which we consider to be the population in London with a driver's permit). Industry experts widely concur that a 30% penetration rate by 2021, while possible, would be a very optimistic scenario (Interviews with TfL and Carplus, 2012). Thus we use this 30% penetration rate as our high case. Conversely, we use a 5% penetration rate as our low case. Based on our research and previous trends, we believe 20% penetration is a reasonable baseline expectation, and thus we build our base case growth scenario to meet this penetration rate by 2021.

EVs

We approach the sizing of the EV market in a similar fashion to our approach for car clubs. The most important factor of which to remain aware is that EVs are by and large a much less developed market in London than car clubs, so predicting the future market based on historical figures is less relevant than focusing on broader targets and indicators. To fit our growth curves at the base case, we relied primarily on three sources. First, Mayor Boris Johnson has stated publicly that his goal is to have 100,000 EVs on the road in London 'as soon as possible' – which we interpret as roughly within the next 5-10 years. Second, the UK Committee on Climate Change forecasts a figure of 1.7 million EVs in the UK by 2020. Assuming 9% of these are in London, based on historical splits of vehicle density, we come to a figure of 153,000.

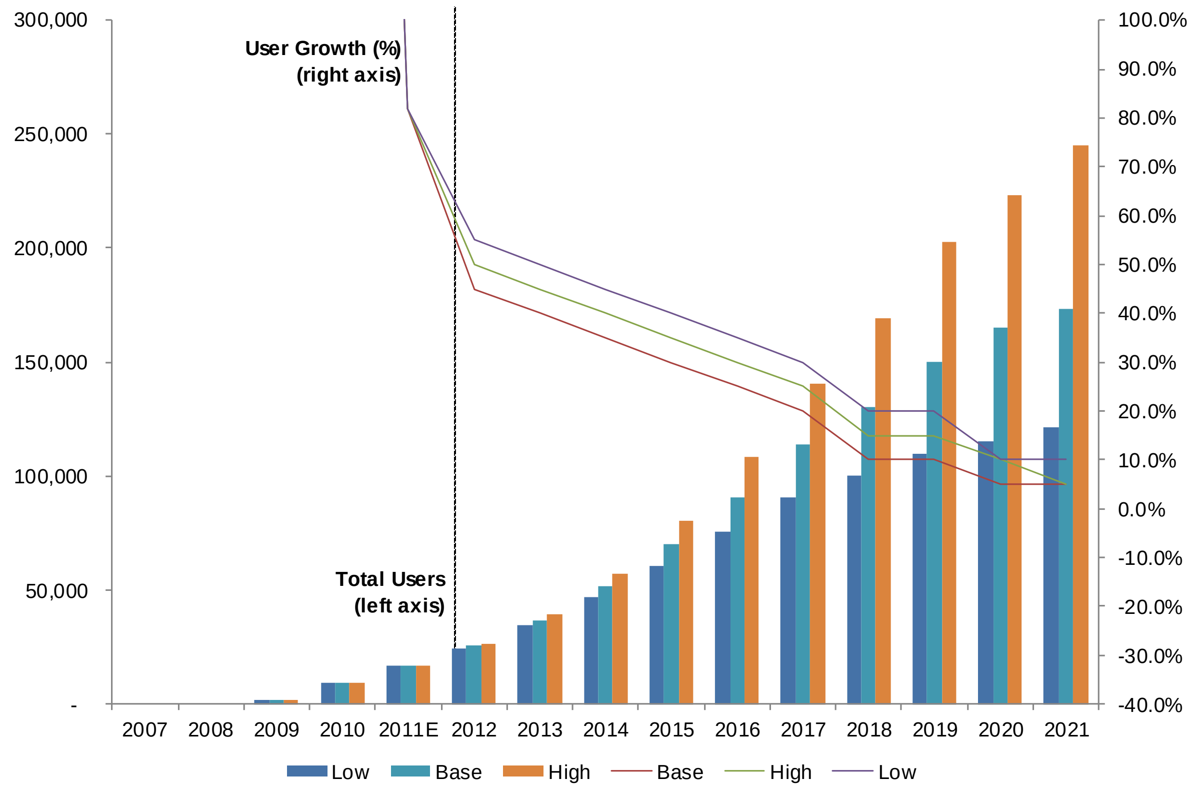
As a third external check, we compared historical and projected EV uptake in comparable cities (Paris, Berlin, Amsterdam, San Francisco, Tokyo, Seoul and Beijing). This exercise serves two important purposes, first to expand beyond the government projections and second to incorporate much more actual historical data as EVs have penetrated some of these cities to a far greater extent than exists in London currently. Using these cities' per capita projected EVs in 2020 we come to a figure of 236,000 EVs in London by 2020. Our base case assumes a number slightly lower than the mean between this figure and the UK Committee on Climate Change forecast of 153,000. We select a base case slightly below the mean of these two figures in order to make our assumption more conservative.

Market Projections for Car Clubs, 2007 to 2021



Sources: Analysis adapted from various sources (see above)

Market Projections for EVs, 2007 to 2021



Sources: Analysis adapted from various sources (see above)

Cost Benefit Analysis: a Theoretical Framework

Cost benefit analysis (CBA) is a policy assessment method that attempts to quantify the values of all consequences of a policy to all members of society in monetary terms. Generally, CBA is used to evaluate policies, programs, regulations, demonstrations and other government interventions. The aggregated value of a policy to society is measured by its net social benefits (NSB), calculated by the social benefits (B) minus the social costs(C); NSB= B-C (Atkinson, 2012).

In short, CBA begins from listing out the benefits and costs associated with a proposed project or a policy. It then quantifies the costs and benefits, placing a monetary value on each. The final stage is to recommend a policy with largest NSB by calculating net benefit and net cost.

The basic steps of CBA are broken down into nine steps shown below (Boardman et al, 2011).

Steps in Cost Benefit Analysis

1. Specify the set of alternative projects
2. Decide whose benefits and costs count
3. Catalogue the impacts and select measurement indicators
4. Predict the impacts and select measurement indicators
5. Monetise all impacts
6. Discount benefits and costs to obtain present values
7. Compute the net present value of each alternative
8. Perform sensitivity analysis
9. Make a recommendation

Source: Boardeman et al, 2010

Two types of disagreements exist within the relevant academic literature on CBA. The first is a social critique, which disputes CBA on the grounds that it is merely a sum of individual utilities and thus cannot measure trade-offs between them (Boardman et al, 2011). That is, CBA cannot make trade-offs between one individual's benefits and another's costs. Furthermore, some researchers (Turner, 2007) criticise the efficacy of CBA, suggesting that it's is too abstract to adopt in the public policy-making process, as we cannot predict 'what impacts will actually occur over time', 'how to monetise' and 'how to make trade-offs between the present and future'.

However, CBA is still useful for social decision-making as its objective is 'to facilitate more efficient allocation of society's resources'. When perfect markets exist, individuals who constantly maximise their utility help ensure the efficient allocation of resources. Where markets fail, however, there is a rationale for government intervention. Any government policy induces a 'market failure'; however, we can demonstrate the efficiency of a particular intervention relative to the alternatives (including the status quo) by using CBA. Because of this function, some governments mandate the general use of CBA when implementing major regulatory initiatives. A key limitation is that CBA is not conclusive, but indicative of a policy's efficacy; it should be considered as one of several measures and never relied on solely for decision-making.

Social Discounting and Relevant Academic Debates

A major area of debate in the literature on social cost-benefit analyses relates to identifying the appropriate discount rate to use when calculating the present values of social and private costs and benefits. This was a main area of contention following the publication of the Stern Review on the Economics of Climate Change, in which economist Nicholas Stern conducts a comprehensive analysis of the effect of climate change on future international economic growth. Stern (2006) specifically highlights the on-going debate on the use of discounting in evaluating environmental projects, stating (p.45):

> "Discounting and discount rates have been controversial in environmental economics and the economics of climate change, because a high rate of discounting of the future will favour avoiding the costs of reducing emissions now, since the gains from a safer and better climate in the future are a long way off and heavily discounted (and vice versa for low discount rates."

For the purposes of this report, we call upon the theoretical framework put forward by Ramsey (1928) to identify the most critical determinants of an appropriate discount rate in cost-benefit analysis. As we demonstrate in our sensitivity analyses, as we are discounting over a ten-year period, even small absolute changes in our rate of discount has significant implications for our analysis. The Ramsey formula for deriving the social discount rate is shown below:

$$r = P + \eta * g$$

where:

r = social discount rate

P = time preference rate, used to discount utility

η = elasticity of marginal utility of consumption
g = growth rate of consumption per capita

Under this theoretical framework, the social discount rate is determined by individual preferences towards current and future consumption. The time preference rate, *P*, is assumed to be positive as individuals will always value deriving utility more today than in the future. In the specific context of our cost-benefit analysis, *P* measures the extent to which London policymakers in 2012 value the utility they gain today from promoting the welfare of future generations through sustainable personal transport solutions, i.e. EVs and car clubs. A zero-value would imply that the welfare of London's population in 2020 is valued equally to the welfare of Londoners today, whereas the extent to which current policymakers discount the utility of those citizens in 2020 is positively increasing in *P*.

The second variable in Ramsey's formula is η, the elasticity of marginal utility with respect to consumption, which determines how the growth rate of consumption per capita, g (1.2%), will be scaled. The UNDP (2007) offers three possible interpretations of η:

1. Personal risk aversion towards future consumption fluctuations;

2. Aversion towards inter-generational inequality: if the current population in London favours the redistribution of current public resources to policies that promote the utility of citizens in 2020, a low value of η is appropriate. If, however, policymakers today prefer to smooth inter-generational consumption and thus are less willing to sacrifice public resources for the sake of future generations, a higher value of η should be used.
3. Aversion towards intra-generational inequality

To simplify our analysis, we assign values to each of these variables in line with those used in the Stern Review: The Economics of Climate Change (i.e. P = 0.1% instead of zero to account for the remote possibility of human extinction, which Stern argues is the only ethical reason to discount the welfare of future generations; η = 1, g = 1.2%) to derive a social discount factor under our base scenario of r = 1.3%.. As we acknowledge that there are many criticisms regarding the validity of this discount rate based on the inherent ethicality and subjectivity required to derive its determinant variables, we put our findings under exhaustive sensitivity analyses using a more conservative discount rate of 3% (Nordhouse, 2006) and a rate of social discount based solely on the assumed future growth of per capita consumption (1.2 %), which implies that the welfare of future generations should be given the same weight as current ones.

For our consumer cost benefit analyses, we use the average yield on the U.S. 10-year Treasury Bill from 2001-2011 (3.90%, derived from Bloomberg data) as our consumer discount factor under our base scenario. For the typical EV and car club consumer, this represents the opportunity cost of the money they spent to join a car club or purchase an EV. We also subject our findings to multiple sensitivity analyses using a more conservative and liberal private discount factor.

Limitations of the Methodology, Scope and Key Caveats

Readers should be aware of several key traits and limitations of this type of analysis. CBA must be viewed as just one way of viewing a policy; it alone cannot serve as conclusive evidence that a policy is the proper choice. Our key goal here is only to compare car clubs and EVs on their relative merits, not to compare these policies to any other particular policy. CBA provides rough approximations at best, and several assumptions are very subjective by nature (measuring the value of clean air, the value of congestion reduction, etc.) and as such we attempt to provide sensitivity analysis of the relevant ranges.

Excel Based Modelling

We chose to construct our entire model in Excel, which enables live dynamic updating of key assumptions and enables stress testing of key assumptions. We have provided this model to Arup as a key deliverable of this project. All CBA outputs you see here are outputs of this comprehensive Excel model. Excel further allows the individual switching of every key input; should you desire to see the outputs run at any other assumption, please contact the authors. We provide some further snapshots of the Excel model in the appendix.

Part III:
Cost Benefit Analyses

Cost Benefit Analysis 1:
Car Clubs at the Individual Consumer Level

The most critical factor influencing demand for car clubs over our time horizon is at the micro-level, where individual consumers must decide if car club membership offers a cost-efficient option for their current lifestyle. We identified the following costs and benefits that will most greatly influence this choice by the consumer:

List of Benefits and Costs Analysed

Benefits
- Value of Foregone Vehicle Purchase
- Annual Standing Costs (£ / annum)
  - Insurance
  - Depreciation
  - Breakdown Cover
  - VED Road Tax
  - Cost of Capital / Leasing Cost
- Annual Running Costs (Variable by Miles)
  - Savings on Fuel Costs
  - Service / Labour/ Parts / Tyres Costs
  - Parking
  - Congestion Charging

Costs
- Total Average Annual Membership Cost
- Total Convenience Cost / Year

Source: Arup, own analysis

Rather than conduct several cost benefit analyses to capture all potential users, we conduct a single CBA to capture average car club user individual behaviour. Modelling the CBA this way presents many unique challenges, of which a key goal is to identify the 'average' car club member. The magnitude of costs and benefits associated with car club membership is then a direct function of the average consumer's driving behaviour, both before and after joining. Thus, our methodology is grounded on the construction of a typical consumer based on annual mileage travelled before and after joining a car club. In general, we attempt to construct conservative (i.e. high cost/low benefit) assumptions throughout our CBA.

We priced fixed annual fees of joining a car club and variable costs based on the number of trips taken, length of trips, and miles travelled by our average consumer. We collected this pricing data from each of three largest car club operators in central London – Zipcar, City Car Club, and Hertz-on-Demand, segmented by vehicle type and frequency of use. We were thus able to deduce a comprehensive average annual membership cost for each of our scenarios. We also explored the intangible costs of car club membership, such as time lost from having to walk to a parking bay and the risk of not having access to an available car club vehicle when needed, as well as the lack of diversity amongst the fleets of the various operators.

Measuring the benefits of car club membership for the typical consumer requires we make several assumptions that have not been fully validated empirically, as the industry is still relatively new and data is scarce. Theoretically, the greatest benefit obtained from joining a car club is the reduced need for car ownership. While survey data supports this notion, it is unclear whether the typical car club member abandons car ownership altogether after joining a car club, or if they merely supplement their current vehicle-use by renting car club vehicles for specific purposes. These preferences may also shift over time.

To determine annual savings for the typical consumer of car clubs, we call primarily upon survey data from the Carplus annual survey to estimate the average number of vehicles the typical consumer replaces when joining a car club, and used this to estimate the weighted average of cost savings that the consumer will realise from the decreased need for private vehicle ownership.

We then aggregate each of the aforementioned costs and benefits, using our three different definitions of the average car club member (based on pre and post-joining behaviour), to derive the net annual benefits of car club membership per consumer. We can then determine the present values of the all of the costs and benefits that a consumer who joins a car club scheme in our base year will realise throughout our ten-year horizon.

Quantifying the Costs of Car Clubs at the Individual Consumer Level

Annual Cost of Membership

In calculating the comprehensive annual membership cost for our average new car club consumer, we use pricing data from the three largest car club operators in London as well as information we gathered from interviews with representatives of these operators to determine typical vehicle usage patterns. To derive the total annual cost to the consumer, we multiply their average annual driving behaviour after joining a car club in each of our three different scenarios, in terms of mileage (above the average free mileage provided by the operators) and hourly usage, by the respective average fees across the three main operators. Adding the average fixed annual membership fee yields the total average annual costs for the typical consumer who uses their car club membership minimally, moderately, and frequently.

Vehicle Costs by Provider

	Annual Fee	Variable Mileage Fee	Free Miles	Hourly Vehicle Costs and Usage (%) Small (15%)	Mid-Sized (65%)	Sedan (15%)	Van (5%)
Zipcar	£59.50	£0.25	40	£5.00	£6.00	£7.00	£9.00
City Car Club	£50.00	£0.22	-	£5.20	£6.20	£7.20	£8.20
Hertz on Demand	£0.00	£0.25	20	£4.50	£5.50	£7.50	£14.00
Average	**£54.75**	**£0.24**	**20**	**£4.90**	**£5.90**	**£7.23**	**£10.40**
				Avg Hourly Wtd by Usage			**£6.18**

Source: Adapted from Company reports

Notes:

** Usage % represents how often the average car club member rents each type of vehicle. Estimates are from interviews with representatives of the car club operators*

***Excludes annual membership fee for Hertz-On-Demand; as the company isn't a pure car club operator, we don't foresee competitive operators as being able to not charge an annual fee over the next ten years*

The remaining costs we considered fall under the category of consumer "inconvenience costs," which include the need to walk to an available car club bay, assuming the risk of not having a car club vehicle available when needed, and having to select from a limited inventory of vehicle types.

Inconvenience Cost – Walking to the nearest available car club vehicle

One of the disadvantages of car clubs as opposed to private vehicle ownership is that the consumer has to walk some distance to get to the nearest available car club car. Assuming that the private vehicle owner is able to park their car nearby their residence or office, walking to the nearest car club bay can be a significant time imposition for the consumer.

One of Zipcar's stated objectives is to ensure that all of their customers will be within a half-mile walk of the nearest available car (Zipcar-JPMorgan, 2011). We believe it is reasonable to assume as the industry matures and more vehicles are made available to consumers, most car club operators will have to maintain this standard in order to remain competitive. Thus, we quantified this added imposition cost to the consumer by multiplying the average half-mile walking time (10-minutes) by the average value of non-working time as put forward by Transport for London (£4.46 per hour). Doubling this value gave us a monetary value of £1.49 per round-trip in a car club vehicle. Again, we multiplied this value by the average annual number of trips that our typical consumer makes under our different scenarios.

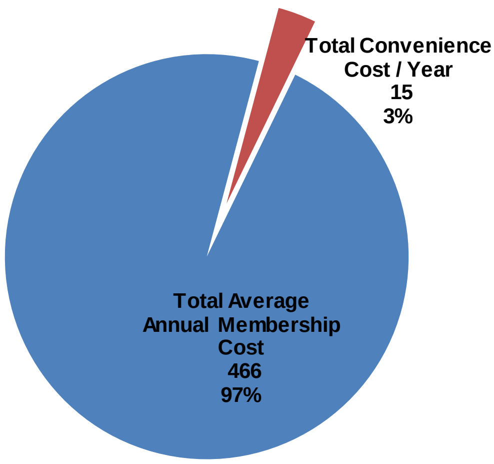
Inconvenience Cost – Vehicle Availability and Lack of Diversity of Inventory

Based on our interviews with representatives from the major car club operators in London, we were able to conclude that any imposition put on the consumer from the risk of not having an available vehicle or from not having a diverse fleet of vehicles to choose from is insignificant for the purposes of our analysis. Each of the representatives reported no problems with not having enough car club vehicles nearby to fulfil consumer demand, and that expect this to be even less of a problem over the next ten years as they continually expand their fleet. Furthermore, Zipcar prioritises inventory management and has representatives available 24/7 to ensure that their customers will have access to a vehicle if needed (Hussey, 2012).

Zipcar's initial public offering documents provided us with valuable insight into their business model. Zipcar uses debt financing to lease their vehicles, which they typically hold for 2-3 years before trying to re-sell them in the open market. This allows them to constantly adapt to shifting demand for different types of automobiles, thus ensuring that their limited inventory is as representative of their consumers' preferences as possible. Thus, we concluded that any lack of diversity in the operators' inventory provides an insignificant cost to our average consumer over our ten-year period.

The figure below represents our estimate of base year (2012) costs to the car club consumer.

2012E Cost Breakdown, Car Club Individual Consumer
in £ and % of 2012E Total – Base Case



Source: Own analysis

Quantifying the Benefits of Car Clubs at the Individual Consumer Level

The most significant benefits to the average new car club consumer are cost savings realised from decreased dependence on private vehicles. As previously discussed, we are assuming that every new car club consumer uses their membership to replace 0.42 of their privately-owned cars. Thus, in order to quantify the benefits to the consumer, we used data from the UK Automobile Association and Carplus to derive the average annual fixed and variable costs that our typical new car club member would've incurred had they not joined a car club.

Value of Foregone Vehicle Purchase

We derived the average number of private-vehicles that were displaced for every new car member using survey data that included respondents who said that they would've purchased a private vehicle had they not joined the car club. Thus, we included in our analysis the cost savings for the consumer who would have otherwise purchased a private vehicle in year 0, multiplied by 0.28 to account for the 28% of consumers who stated in the Carplus annual survey that they would've otherwise purchased a private vehicle had they not joined their car club.

Under our base scenario, we assume that the average car club joiner would've purchased a new Honda Civic SE valued at £17,195, which was the most popular vehicle purchased in the UK in 2011 (UK DOT, 2011). This results in a one-time savings of £4,814.60 in year 0 for our average car club joiner.

Savings on Annual Standing Costs

Our typical car club joiner saves 42% annually on what they would've otherwise spent to cover the fixed costs associated private vehicle ownership. We define the following components of car ownership into average annual standing costs: insurance, depreciation, breakdown cover, VED Road Tax, and the cost of capital/leasing costs. These cost the typical driver in London £1,765 annually (Automobile Association, 2011), resulting in an annual savings of £737.70 for our typical car club joiner (£1,765 x 0.42-cars displaced).

Savings on Annual Running/Variable Costs

We define yearly costs that a private vehicle driver must incur which vary by mileage as annual running costs. These include fuel costs and service, labour, parts, and tyres expenses, which the UK Automobile Association lists on a per mile basis. Thus, we multiply each of these costs by the average annual mileage that our typical car club joiner drove prior to joining the car club (2,301-miles) to derive annual savings from running costs per vehicle. We then multiply each of these figures by 0.42 to account for the fact that our typical car club joiner is only displacing 0.42 privately-owned vehicles. This equates to an annual savings of £176.90 on running costs.

Savings on Parking and Congestion Charging

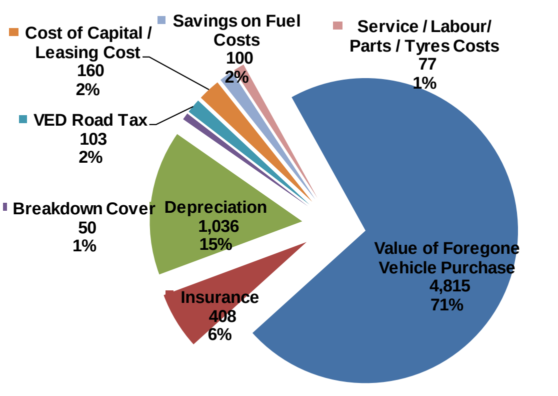
All three of the largest car club operators in London cover the congestion charge for their customers when applicable. However, as we assume that the our typical car club joiner uses their membership predominantly for recreational activities closer to their homes (outside of the congestion zone) and weekend trips, any savings they would realise from the congestion charge would be insignificant for our analysis.

Furthermore, as car club users assume full responsibility of the car club vehicle once it's rented, they must incur any parking fees at their point of destination. For those car club consumers who use their membership in lieu of purchasing their own private vehicle, any parking fees they incur would represent a marginal cost of their membership. However, as we assume that the typical car club user rents a vehicle for shorter recreational trips to locations where parking fees are not usually imposed (i.e. malls, cinemas, etc.), as well as for longer weekend trips outside of London, we assume that any additional parking fees would be sporadic and therefore insignificant for the purposes of our analysis.

If the public sector in London does support car clubs in the future by providing on-street, designated car club parking bays in congested areas where parking fees are typically imposed, this would represent a significant benefit to the car club consumer. We will explore this possibility, as well as other mechanisms by which the public sector can similarly increase the benefits for the typical car club consumer in our section on policy recommendations.

The chart below presents a detailed breakdown of our CBA model's projected 2012 total benefit to the car club individual consumer.

2012E Benefit Breakdown, Car Club Individual Consumer
in £ and % of 2012E Total – Base Case



Source: Own Analysis

Key Outputs and Results of the Consumer Car Club Cost Benefit Analysis

There are several important implications from our cost benefit analysis of car clubs at the consumer level.

First, our base case implies that the average car club joiner can expect to benefit by approximately £17,000 over the course of 10 years. This is a very positive result and implies that the public sector does not need to subsidise at the consumer level to make car clubs an attractive investment.

Second, our sensitivity analysis implies that even in the absence of the primary benefit of costs saved from the value of the foregone vehicle purchase, the total decision remains positive. This means that even in the case a user was provided a free car, or in the case that a user is just supplementing an existing car, the decision remains positive.

Finally, the positivity of the analysis is robust to several assumption changes (see sensitivity analysis below), including significant changes in the discount rate assumed, membership costs, and other assumptions. The centre bolded number of each of the four blocks represents the £17,000 base figure we arrive at.

Cost Benefit Analysis 1: Car Clubs, Consumer Level

	PROJECTED									
	Year ending 31 December									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Benefits										
Cost Savings										
Value of Foregone Vehicle Purchase	4,815									
Annual Standing Costs (£ / annum)										
Insurance	408	408	408	408	408	408	408	408	408	408
Depreciation	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036
Breakdown Cover	50	50	50	50	50	50	50	50	50	50
VED Road Tax	103	103	103	103	103	103	103	103	103	103
Cost of Capital / Leasing Cost	160	160	160	160	160	160	160	160	160	160
Annual Running Costs (Variable by Miles)										
Savings on Fuel Costs	100	100	100	100	100	100	100	100	100	100
Service / Labour/ Parts / Tyres Costs	77	77	77	77	77	77	77	77	77	77
Parking	-	-	-	-	-	-	-	-	-	-
Congestion Charging	-	-	-	-	-	-	-	-	-	-
Total Benefits	**6,748**	**1,933**	**1,933**	**1,933**	**1,933**	**1,933**	**1,933**	**1,933**	**1,933**	**1,933**
Discounted @ Consumer Discount Rate	**6,748**	**1,861**	**1,791**	**1,724**	**1,659**	**1,597**	**1,537**	**1,479**	**1,424**	**1,370**
Costs										
Total Average Annual Membership Cost	466	466	466	466	466	466	466	466	466	466
Total Convenience Cost / Year	15	15	15	15	15	15	15	15	15	15
Total Costs	**481**	**481**	**481**	**481**	**481**	**481**	**481**	**481**	**481**	**481**
Discounted @ Consumer Discount Rate	**481**	**463**	**446**	**429**	**413**	**397**	**382**	**368**	**354**	**341**
NET BENEFIT / (COST)	**6,267**	**1,452**	**1,452**	**1,452**	**1,452**	**1,452**	**1,452**	**1,452**	**1,452**	**1,452**
Discounted @ Consumer Discount Rate	**6,267**	**1,398**	**1,345**	**1,295**	**1,246**	**1,199**	**1,154**	**1,111**	**1,069**	**1,029**

Valuation	
Selected Consumer Discount Rate	3.9%
Sum of Future Discounted Net Benefits / (Costs)	**17,115**

Sensitivity Analysis: Car Clubs, Consumer Level

Savings from Foregone Vehicle Purchase (£)

	Average Miles/Year Before Joining						
	0	500	1,500	2,301	3,000	5,000	10,000
0.0	10,803	11,128	11,779	12,301	12,756	14,057	17,312
2,000.0	12,803	13,128	13,779	14,301	14,756	16,057	19,312
4,000.0	14,803	15,128	15,779	16,301	16,756	18,057	21,312
4,814.6	15,617	15,943	16,594	**17,115**	17,570	18,872	22,127
5,500.0	16,303	16,628	17,279	17,801	18,256	19,557	22,812
7,500.0	18,303	18,628	19,279	19,801	20,256	21,557	24,812
8,000.0	18,803	19,128	19,779	20,301	20,756	22,057	25,312

- ✓ The more one saves by deferring a purchase, the larger the benefit
- ✓ However even if the savings are 0 (e.g. a free car) one would still benefit more from joining a car club due to the secondary costs avoided (maintenance, taxes, etc.)

Total Average Membership Cost (£ per Annum)

	Average Miles/Year Before Joining						
	50	500	1,500	2,301	3,000	5,000	10,000
0.0	19,598	19,891	20,542	21,064	21,519	22,820	26,075
150.0	18,328	18,621	19,272	19,793	20,248	21,550	24,805
300.0	17,058	17,350	18,001	18,523	18,978	20,280	23,534
466.2	15,650	15,943	16,594	**17,115**	17,570	18,872	22,127
500.0	15,364	15,657	16,308	16,829	17,284	18,586	21,841
700.0	13,670	13,963	14,614	15,135	15,590	16,892	20,147
1,000.0	11,129	11,422	12,073	12,594	13,049	14,351	17,606

- ✓ Membership costs are a key area of sensitivity
- ✓ If membership costs were to increase from £466 to £700 per year, this decreases the total benefit by approximately £2,000

Fuel Cost per Mile (£)

	Average Miles/Year Before Joining						
	50	500	1,500	2,301	3,000	5,000	10,000
0.025	15,636	15,804	16,178	16,477	16,738	17,485	19,352
0.050	15,640	15,849	16,311	16,681	17,005	17,929	20,242
0.075	15,645	15,893	16,444	16,886	17,271	18,374	21,131
0.103	15,650	15,943	16,594	**17,115**	17,570	18,872	22,127
0.150	15,658	16,026	16,845	17,500	18,072	19,708	23,799
0.250	15,676	16,204	17,378	18,318	19,139	21,487	27,356
0.500	15,720	16,649	18,712	20,365	21,807	25,933	36,249

- ✓ Fuel costs are not a key driver of value

Discount Rate

	Average Miles/Year Before Joining						
	0	500	1,500	2,301	3,000	5,000	10,000
1.0%	17,016	17,384	18,119	18,708	19,222	20,692	24,369
2.5%	16,257	16,602	17,291	17,844	18,326	19,704	23,152
4.5%	15,362	15,679	16,315	16,824	17,268	18,539	21,717
5.0%	15,156	15,468	16,091	**16,590**	17,026	18,272	21,388
5.5%	14,958	15,263	15,875	16,364	16,791	18,014	21,070
7.5%	14,226	14,510	15,077	15,531	15,928	17,062	19,898
9.0%	13,737	14,006	14,544	14,974	15,350	16,425	19,114

- ✓ Decision is largely unaffected by discount rate selected

Cost Benefit Analysis 2: Car Clubs at the Public Sector Level

In conjunction with Arup we decided on the following list of final costs and benefits to analyse at the level of the public sector. It is important to remember that this analysis is performed at the London authority level – as such, national initiatives are not included at this level.

List of Benefits and Costs Analysed

Benefits
- Value of CO_2 Reduction (£ annual)
- Value of Clean Air / Health Benefits
- Noise Reduction
- Reduced Congestion
- Public Perception

Costs
- Construction of Spaces / Requisition Process
- Lost Congestion Charge Revenue
- Lost Vehicle Registrations Revenue
- Lost Parking Revenue
- Research Studies
- Advertising and Marketing

Source: Arup, own analysis

Quantifying the Costs of Car Clubs at the Public Sector Level

Parking Bays/Requisition Process

Constructing a car club space requires two primary steps, requisition and physical construction. Requisition is the more labour-intensive and expensive of the two steps. This process consists of locating spaces and completing the necessary procedural elements (documentation, purchase, etc.), including a mandatory period to notify community members via newspaper of the space acquisition. The physical construction of the space (painting the pavement) represents only a small fraction of the total expense (interview with TfL, 2011).

To estimate the total annual cost of parking spaces and requisitions, we divided the estimated portion of the total annual historical support by the number of spaces constructed to get a per space amount, which we use as a base case of public sector support per space. We assume conservatively (i.e. high cost) that London will support all parking spaces to this same extent as historically supported, and thus multiply the per space amount by the total number of spaces required to support the car club member population, assuming that each bay can support 50 members, which is the consensus long term profitable target per our interviews with representatives of the big three London operators.

Lost Congestion Charge Revenue

This cost represents foregone public revenues from those car club members who are no longer paying congestion charges, as car club cars that are utilised exclusively within the congestion zone are exempt from this charge. To estimate this cost, we use the rate for a full-year congestion charge pass (£2,278) and assume that 10% of car club joiners were previously paying a rate similar to this. We believe this represents a conservative estimate because very few car club joiners would hold such a pass as most car club trips happen within the congestion zone and many car club members would ride the tube or bus (when the congestion charge would be applicable) in absence of the car club. This figure was confirmed via our interviews. Thus, this cost estimate accounts for those car club members who would've otherwise driven into the congestion zone, but now rather use public transportation to enter the zone and utilise a car club vehicle when travelling within it. To find the total cost we multiply the full-year congestion charge pass by 10% and again by the number of car club users. This cost grows with the growth of members as more people avoid the congestion charge year after year.

Lost Vehicle Registrations and Taxes

This cost represents lost revenues from vehicle registration, which is currently £155 (www.direct.gov.uk) per vehicle. This is a one-time expense and driven by the number of vehicles foregone which we derive based on the aforementioned assumptions on vehicle displacement. This cost does not accumulate over time.

Lost parking revenue

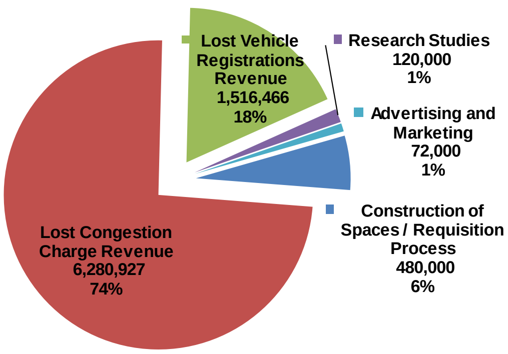
This cost would represent public profits forgone as fewer people park in public spaces. As a conservative assumption we use the rate of £155 per year which is the average annual rate for on street parking in the boroughs (Southwark Council Annual Report, 2011). However, this cost is primarily administrative in nature and not profit generating, so we assume that any profit forgone would be zero.

Research Studies and Marketing

We assume research studies and marketing expenses will grow proportionally with market demand. We estimate this cost in a similar fashion to the parking bays/requisition support: we divide the estimated portion of annual support by the number of spaces required to calculate a per space support figure. This estimate is conservative (high) because it is more likely that as car clubs become more widely-adopted, fewer research studies and marketing efforts will be required. Further, as research studies reach beyond the initial capital-intensive phases, the costs to update them should decrease over time.

The chart below provides a detailed breakdown of the estimated 2012 costs of car clubs for the public sector per the output of our base case CBA model.

2012E Costs Breakdown, Car Clubs, Public Sector
£ and % of 2012E Total



Source: Own analysis

Quantifying the Benefits of Car Clubs at the Public Sector Level

Value of CO_2 Reduction and Value of Clean Air

We value CO_2 reduction from two sources: first from the differential reduction of number of cars on the road and second from the fact that club cars are on average more fuel efficient than traditional private cars. As a base case, we assume that each club car net takes 20 traditional cars off the road, based on Carplus survey data (Carplus, 2011). Assuming each club car can serve 50 users, we multiply are displacement factor of 0.42 by 50 to get 21 cars, and reduce this by 1 to account for the club car. This is consistent with other reports, thus we believe this to be both an accurate and prudent/conservative estimate as it largely agrees with the existing empirical body of research.

Traditional private cars emit approximately 5.2 tons of CO_2 annually on average (www.erasecarbonfootprint.com). To calculate the amount of carbon reduced from private car displacement, we multiply the reduction in cars by this factor. In order to capture the efficiency difference, we consider two primary drivers: first, the increased efficiency of the club cars as opposed to traditional private vehicles, and second, the fact that club car drivers on average drive considerably less annually after joining a car club. To calculate these savings we first consider what a traditional car and user would emit over one year and what the car club car and user would emit, with the difference representing the savings from efficiencies.

Summing these two figures provides us with a total CO_2 savings in tons for each year. To monetise these benefits, we utilise a forecast published by the DEFRA, which projects the EU carbon emissions trading costs per ton. These are the official figures DEFRA uses in all of its carbon related project modelling. DEFRA provides base, high and low figures for each year through 2025, as shown below.

DEFRA Costs of Carbon per Ton CO_2

Year	Low	Base	High
2011	£106.03	£212.07	£318.09
2012	£107.63	£215.24	£322.87
2013	£109.24	£218.47	£327.72
2014	£110.87	£221.76	£332.63
2015	£112.54	£225.08	£337.62
2016	£114.22	£228.46	£342.68
2017	£115.94	£231.88	£347.82
2018	£117.68	£235.36	£353.04
2019	£119.44	£238.90	£358.34
2020	£121.23	£242.47	£363.71
2021	£123.26	£246.52	£369.78

Sources: Adapted from DEFRA and CPI projections

Noise Reduction

One approach to valuing noise reduction is to examine the impact of noise on measurable transaction values, known within cost-benefit methodology as the 'hedonic' method (Lake et al, 2001). For example, if one could examine homes with a known noise level (as measured in decibels) and likewise examine homes with a different noise level but that are otherwise similar, one can derive the impact of the noise levels by analysing the differences in the prices of the two homes.

The most salient literature for our purposes is work conducted by Lake et al (2001) which examines the impact of noise reduction on UK home values. The key result of this study is that each decibel increase in noise is associated with a 0.20% decrease in price. This result is significant at the 95% level, and building a 95% confidence interval (two standard deviations) around the mean of 0.20% provides a range of 0.046% to 0.36%. We employ a one standard deviation range as our low and high assumptions (standard deviation = 0.08%). In order to apply this to our cost benefit analysis of London, we first had to derive the noise reduction associated with the development of car clubs, which is a function of both the number of cars and the type of cars used. To simplify our analysis and provide a more conservative estimate of this benefit, we assume that car club cars are the same type as existing private cars and thus the only driver of noise reduction is the reduction in the total number of the cars.

To apply a monetary value to this noise reduction, we take the median home price in Greater London (£340,000) (GLA, 2012) and use 0.20% (Lake et al, 2001) of that as the base case value of noise reduction per decibel. This results in a base case value of £680 per decibel of noise reduced per home. In order to derive the total benefit, we must make an assumption about the noise reduction per car removed from the road, and account for the total number of homes in London (3.3 million) (GLA, 2012). Taking £680 per decibel per home, multiplied by 3.3 million results in a value of £2.24 billion per decibel of noise reduction.

Decibels are measured logarithmically (exponentially). Thus, the smallest possible audible sound is 0 dB, and a sound 10 times more powerful is 10 db. For reference, 60 dB is about the noise level of a normal conversation, and a car horn is approximately 110 dB. Heavy city traffic is rated around 85 dB (www.hyperacusis.net). To derive the noise reduction implied by the removal a car, we must first know the current level of noise in decibels in London. Studies in London (2004) indicate that the daily average level of noise is approximately 60.2 decibels in Inner London and 54.8 decibels in Outer London.

In order to correctly factor the number of dB for our valuation, we develop the following methodology. First, we assume noise comes from 90 cars producing (nine groups of ten, with each group producing 51 dB), thus together creating noise of approximately matching the 60.2 decibels estimated for Inner London noise levels. Combining noise sources increases the level of noise gradually but at diminishing effects. The chart below, demonstrates the relations between reducing the number of cars and noise reduction.

Relationship between # of Cars and Noise in dB

(I) Cars (#) at 51 dB per 10 cars	(II) % reduction in cars	(III) dB	(IV) Delta dB	(V) Cumulative Delta dB
90	0.0%	60.30	-	-
88	2.2%	60.25	(0.05)	(0.05)
85	5.6%	60.15	(0.10)	(0.15)
83	7.8%	59.95	(0.20)	(0.35)
80	11.1%	59.80	(0.50)	(0.85)
70	22.2%	59.20	(0.60)	(1.45)
60	33.3%	58.60	(0.60)	(2.05)
50	44.4%	57.80	(0.80)	(2.85)
40	55.6%	56.90	(0.90)	(3.75)
30	66.7%	55.70	(1.20)	(4.95)
20	77.8%	54.00	(1.70)	(6.65)
10	88.9%	51.00	(3.00)	(9.65)
0	100.0%	0.00	(51.00)	(60.65)

Source: Adapted from http://sphere.sourceforge.net/flik/misc/db.html

In order to calculate the total decibel reduction, we divide the total number of cars removed due to car clubs by the total number of cars in London to calculate a percent reduction in cars, which we can then associate with a change in dB and apply to our baseline noise reduction value of £2.24 billion per decibel. We assume any noise reduction lower than 0.5 to be insignificant for the purposes of our analysis. Finally, we scale our results only to include central London.

Reduced Congestion

Various estimates contend that the UK loses approximately £20 billion of productivity (GDP) each year due to traffic congestion (CBI, Goodwin 2004). Congestion is defined as time spent in a full stoppage of traffic. While London-specific congestion data is not available, we use this figure and the fact that London accounts for approximately ¼ of the UK's GDP to estimate London's annual loss from congestion at £5,000,000. Studies of congestion show that in high traffic times, congestion reduces roughly in a linear fashion with the number of cars (Kerner, 2009). While this is a simplifying assumption, we do believe it safe to assume for approximating our CB analysis. Thus we use the overall reduction in cars (%) as a proxy for the reduction in congestion as a result of car clubs.

Estimates of the UK Cost of Congestion
£ billion per Annum

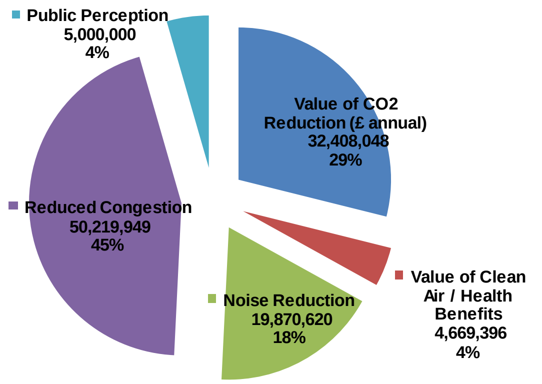
Source	Estimate
Glanville and Smeed (1958)	£0.2
British Road Federation (1988)	£15.0
CBI (1989)	£15.0
Newbery (1993)	£19.1
Dodgson & Lane (1997)	£7.0
Mumford (2000)	£18.0
Smith Group (1999)	£20.0

Source: Goodwin, 2004

Public Perception/Role as Tech Leader

This benefit measures the extent to which London benefits from improving its image as a global leader in clean technology. While this is at best a subjective measure, one can attempt to place a value on this benefit. Through interviews with TfL and industry experts, we found that this figure would be valued at no more than £5,000,000 per year, so we use this as our base case. Public perception does not shift the analysis significantly as the total benefits are in the magnitude of billions of pounds.

2012E Benefits Breakdown, Car Clubs, Public Sector
£ and % of 2012E Total



Source: Own analysis

Key Findings and Takeaways from the Car Club Public Sector Cost Benefit Analysis

Our public sector cost benefit analysis of car clubs reveals several important factors regarding the adoption and expansion of car clubs.

First, car clubs appear to be a greatly positive social investment, providing approximately £2.9 billion of net benefit at our base case assumptions. The primary benefits are in the form of reduced congestion, CO_2 and clean air benefits, and noise reduction.

Second, the costs related to supporting these benefits are relatively minimal. The primary cost associated with supporting car clubs is the foregone congestion charging revenue, however we recommend ways to curtail this loss in our recommendations section. Physical construction of the spaces represents only a small portion of the overall cost of car clubs.

Last, the positivity of the cost benefit analysis is again robust to significant changes in the values of key assumptions. This is of particular importance because many of the benefits are intangible by nature (e.g. noise reduction).

Cost Benefit Analysis 2: Car Clubs, Public Sector Level

In £	PROJECTED Year ending 31 December 2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Benefits										
Cumulative Reduction in CO2 Emissions (tons CO2)	150,564	325,816	517,229	710,979	888,858	1,030,606	1,186,529	1,358,045	1,463,107	1,573,423
Value of CO2 Reduction per ton CO2	215.2	218.5	221.8	225.1	228.5	231.9	235.4	238.9	242.5	246.5
Value of CO2 Reduction (£ annual)	32,408,048	71,182,344	114,699,674	160,028,382	203,067,659	238,973,126	279,261,796	324,433,564	354,766,856	387,879,488
Value of Clean Air / Health Benefits	4,669,396	10,104,406	16,040,640	22,049,336	27,565,853	31,961,844	36,797,433	42,116,582	45,374,851	48,796,034
Noise Reduction	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620	19,870,620
Reduced Congestion	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949	50,219,949
Public Perception	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Total Benefits	**112,168,013**	**156,377,318**	**205,830,883**	**257,168,287**	**305,724,082**	**346,025,539**	**391,149,798**	**441,640,715**	**475,232,276**	**511,766,092**
Adjusted for Inflation	**112,168,013**	**161,068,638**	**218,365,984**	**281,014,731**	**344,095,147**	**401,138,437**	**467,053,315**	**543,162,374**	**602,010,029**	**667,738,673**
Discounted @ Social Discount Rate	**112,168,013**	**159,001,617**	**212,797,292**	**270,334,049**	**326,768,938**	**376,051,262**	**432,224,904**	**496,207,770**	**542,910,403**	**594,458,473**
Costs										
Construction of Spaces / Requisition Process	480,000	478,573	518,454	518,454	466,609	357,733	393,507	432,857	238,072	249,975
Implied Spending per New Bay	*348*	*300*	*300*	*300*	*300*	*300*	*300*	*300*	*300*	*300*
Lost Congestion Charge Revenue	6,280,927	7,267,930	7,873,590	7,873,590	7,086,231	5,432,777	5,976,055	6,573,661	3,615,513	3,796,289
Lost Vehicle Registrations Revenue	1,516,466	1,754,768	1,900,999	1,900,999	1,710,899	1,311,689	1,442,858	1,587,144	872,929	916,575
Research Studies	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Advertising and Marketing	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
Total Costs	**8,469,393**	**9,693,271**	**10,485,043**	**10,485,043**	**9,455,739**	**7,294,200**	**8,004,420**	**8,785,662**	**4,918,514**	**5,154,840**
Adjusted for Inflation	**8,469,393**	**9,984,069**	**11,123,582**	**11,457,290**	**10,642,517**	**8,455,977**	**9,557,696**	**10,805,256**	**6,230,626**	**6,725,896**
Discounted @ Social Discount Rate	**8,469,393**	**9,855,941**	**10,839,913**	**11,021,826**	**10,106,635**	**7,927,140**	**8,844,973**	**9,871,177**	**5,618,963**	**5,987,771**
NET BENEFIT / (COST)	**103,698,621**	**146,684,048**	**195,345,840**	**246,683,244**	**296,268,343**	**338,731,340**	**383,145,378**	**432,855,054**	**470,313,762**	**506,611,252**
Discounted @ Social Discount Rate	**103,698,621**	**144,801,627**	**190,364,199**	**237,307,418**	**281,350,355**	**317,547,102**	**354,574,027**	**395,436,155**	**424,142,825**	**451,013,793**
Valuation										
Selected Social Discount Rate	1.3%									
Sum of Future Discounted Net Benefits / (Costs)	**2,900,236,120**									

Sensitivity Analyses – Car Clubs, Public Sector Level

London Annual Cost of Congestion (£)

	Net Car Differential per Club Car 5.0	10.0	15.0	20.0	25.0	35.0	50.0
500,000,000	767,011,273	1,282,231,399	1,851,055,835	2,473,484,578	3,256,726,246	4,287,166,500	6,154,452,730
2,000,000,000	802,573,901	1,353,356,657	1,957,743,720	2,615,735,092	3,434,539,389	4,536,104,899	6,510,079,015
4,000,000,000	849,990,739	1,448,190,333	2,099,994,234	2,805,402,444	3,671,623,579	4,868,022,766	6,984,247,396
5,000,000,000	873,699,158	1,495,607,171	2,171,119,491	**2,900,236,120**	3,790,165,674	5,033,981,699	7,221,331,586
6,000,000,000	897,407,577	1,543,024,009	2,242,244,749	2,995,069,796	3,908,707,769	5,199,940,632	7,458,415,776
7,500,000,000	932,970,206	1,614,149,266	2,348,932,634	3,137,320,311	4,086,520,912	5,448,879,032	7,814,042,062
9,000,000,000	968,532,834	1,685,274,523	2,455,620,520	3,279,570,825	4,264,334,055	5,697,817,432	8,169,668,347

- ✓ Figure remains positive even when each club car is only assumed to replace 5 cars and cost of congestion is assumed to be 1/10 of base case estimate

% Impact of Noise Reduction on Value, per Decibel

	Net Car Differential per Club Car 5.0	10.0	15.0	20.0	25.0	35.0	50.0
0.050%	853,597,543	1,475,505,555	2,110,814,645	2,759,524,811	3,448,438,209	4,692,254,234	6,638,384,734
0.100%	860,298,081	1,482,206,094	2,130,916,260	2,806,428,581	3,562,347,364	4,806,163,389	6,832,700,351
0.150%	866,998,620	1,488,906,632	2,151,017,876	2,853,332,351	3,676,256,519	4,920,072,544	7,027,015,969
0.200%	873,699,158	1,495,607,171	2,171,119,491	**2,900,236,120**	3,790,165,674	5,033,981,699	7,221,331,586
0.250%	880,399,697	1,502,307,709	2,191,221,107	2,947,139,890	3,904,074,829	5,147,890,854	7,415,647,203
0.500%	913,902,389	1,535,810,402	2,291,729,185	3,181,658,739	4,473,620,604	5,717,436,629	8,387,225,290
1.000%	980,907,775	1,602,815,787	2,492,745,341	3,650,696,436	5,612,712,154	6,856,528,179	10,330,381,463

- ✓ Highly subjective but important measure
- ✓ Net benefit remains positive even when impact is assumed to quintuple, or is cut by a factor of four

Value of Clean Air per Ton CO2 Removed (£)

	Net Car Differential per Club Car 5.0	10.0	15.0	20.0	25.0	35.0	50.0
0.0	791,636,291	1,352,725,824	1,967,419,664	2,635,717,814	3,464,828,887	4,587,007,953	6,591,902,400
12.0	823,389,596	1,408,012,157	2,046,239,026	2,738,070,203	3,590,714,305	4,759,959,427	6,835,452,958
25.0	857,789,010	1,467,905,685	2,131,626,668	2,848,951,959	3,727,090,175	4,947,323,524	7,099,299,397
31.0	873,699,158	1,495,607,171	2,171,119,491	**2,900,236,120**	3,790,165,674	5,033,981,699	7,221,331,586
35.0	884,250,098	1,513,977,630	2,197,309,469	2,934,245,617	3,831,994,689	5,091,449,752	7,302,258,195
50.0	923,941,730	1,583,085,547	2,295,833,671	3,062,186,104	3,989,351,462	5,307,639,095	7,606,696,393
75.0	990,094,450	1,698,265,408	2,460,040,675	3,275,420,249	4,251,612,749	5,667,954,666	8,114,093,390

- ✓ The value of clean air is highly subjective
- ✓ Increasing the value of clean air from £31 to £75 per ton CO2 removed increases the net benefit by approximately £375 mm over 10 years

Discount Rate

	Net Car Differential per Club Car 5.0	10.0	15.0	20.0	25.0	35.0	50.0
0.0%	941,404,050	1,610,941,794	2,337,252,738	3,120,336,882	4,073,740,626	5,412,816,114	7,762,068,547
0.8%	901,500,914	1,542,971,850	2,239,351,419	2,990,639,623	3,906,653,730	5,189,595,601	7,443,460,212
1.0%	888,715,275	1,521,190,323	2,207,974,714	2,949,068,448	3,853,090,211	5,118,040,307	7,341,321,509
1.3%	873,699,158	1,495,607,171	2,171,119,491	**2,900,236,120**	3,790,165,674	5,033,981,699	7,221,331,586
1.8%	851,822,830	1,458,332,615	2,117,417,189	2,829,076,552	3,698,460,285	4,911,479,853	7,046,457,944
2.5%	817,012,303	1,399,010,702	2,031,939,576	2,715,798,923	3,552,449,694	4,716,446,492	6,768,024,534
5.0%	714,313,832	1,223,927,176	1,779,571,219	2,381,245,960	3,121,012,796	4,140,239,485	5,945,263,708

- ✓ Theories vary widely as to what the appropriate discount rate for social projects is – this confirms that even at very high and low discount rates, the outcome is positive

Cost Benefit Analysis 3: EVs at the Individual Consumer Level

Similar to car club memberships, the most crucial factor for potential EV consumers is whether or not EVs are cost effective. In order to conduct this analysis, we aggregate each of the below costs and benefits, specifically evaluating the marginal costs/benefits of using an EV instead of a comparable ICE. We then use our market-forecasting model to derive the net present value of using an EV over the ten-year timeframe.

We again worked with Arup to develop the following list of costs and benefits.

List of Benefits and Costs Analysed

Benefits
- Reduced Maintenance
- Cost Savings
  - Plug-In Car Grant
  - Vehicle Excise Tax Exemption
  - Showroom Tax (first year only)
  - Congestion Charge
  - Fuel Costs Avoided

Costs
- EV Cost Relative to Traditional ICE Purchase (EV r
- Garage Charger Installation
- Charging Time
- Charging Network Membership

Source: Arup, own analysis

Quantifying the Costs of EVs at the Individual Consumer Level

Incremental Purchase Price Over ICE Cars

Although the number of EV models that receive certification from London is increasing (Source London, 2011), EV prices are still higher than that of ICEs. According to the 2011 Society of Motor Manufacturers and Traders (SMMT) Electric Car Guide, the average price of an EV is £29,300 while that of ICE is £19,650, which gives £9,650 price difference between the two cars (SMMT, 2011). It is precisely this incremental cost that we are interested in, as we are assuming that our average consumer is planning to purchase an ICE or an EV in year 0.

Garage Installation

Installation of home/office chargers are strongly recommended by SMMT for both safety and economic reasons. If consumers have a charger, it enables them to recharge their EVs in a state of stopping the EV's circuit. Also, they can get benefit from off-peak electricity tariffs if they turn on the switch late at night. The installation fee depends on where users want to install it, but standard 13 A 3-pin sockets of 'slow' charging point cost around £250-£1000 (nextgreencar.com/electric-cars). We use an average of this for our base case.

Time

Charging duration of EVs is one of key obstacles for potential EV consumers because it takes six to eight hours to achieve full charge if consumers use normal chargers, which are mostly provided in London (SMMT, 2011). Additionally, the charging frequency should be taken into consideration. EVs run approximately 100-miles, while current ICEs can drive over 300-miles on average (SMMT, 2011). This implies that EV users must "charge" their vehicle three times more than current users.

The monetary value of time is provided by the UK Department of Transport below. It depicts three categories of time (i.e. Work, Commuting and Other) and the trip proportion of each made by an average driver.

Categories and Values of Time

	Work	Commuting	Other
Value of Time per Vehicle per Hour	£40.30	£7.70	£11.00
Proportion of Travel by Car	13.10%	25.30%	61.60%

Source: DOT

As 90% of EV-users are expected to charge their batteries at night in their home or office (DoT, 2011), assuming that all battery charging time represents a cost to the average consumer would significantly bias our results. Furthermore, the average trip range of a Londoner is only 25 miles per day which is shorter than maximum EV range (SMMT, 2011). Thus, we assume the proportion of EV-users who need to charge their vehicle during a day is 10 per cent, which means 0.7 hours per day are lost by charging (average charging time (7 hours) times 10%). However, ICEs also require time to fill up with gas, which we assume to take 10-minutes on average. Under these assumptions, our model yields cost of time at £1,363 per annum.

Charging Network Membership

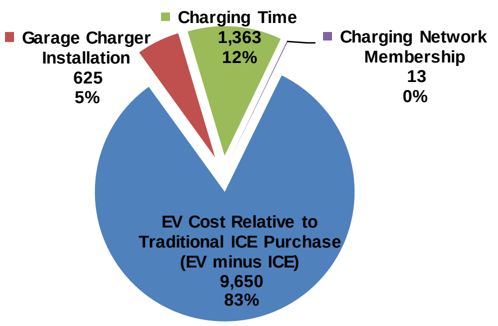
This is a membership scheme that gives its members unlimited access to London's charging stations if they pay an annual fee of £100. In order to count it as a consumer cost, we need to first estimate the number of members of the scheme. We assume that the proportion of membership is the same as the proportion of people who need to charge on road, which is 10%. Thus, the average cost per vehicle by this membership becomes £10.

Other / Incentives to Explore

Additional costs to explore are how consumers price any 'inconvenience costs' of using an EV. As EVs have not fully penetrated the market in London, certain services are only available on a limited basis. For example, if an EV suddenly breaks down, there is limited customer service staff available with the requisite experience or knowledge to fix these issues. Additionally, with limited charging infrastructure currently in place, EV-users must always be cognizant of their battery life. This "range anxiety" could represent a significant cost to the consumer, who may be more hesitant to use certain battery-depleting utilities such as air conditioning.

The chart below represents the base case output of cost detail from our EV CBA model.

2012E Costs Breakdown, EVs, Individual Consumer
£ and % of 2012E Total



Source: Own analysis

Quantifying the Benefits of EVs at the Individual Consumer Level

Plug-in Car Grant

Since 2011, the UK government has made a strong effort to jumpstart demand for EVs with public funding. The most notable grant to promote EV-ownership is the Plug-In Car Grant, which gives buyers a 25% rebate (up to £5,000) on their EV purchases (DoT, 2012). For potential EV-buyers, high purchase prices are one of the main deterrents. While the Plug-In Car Grant does not fully recuperate the price disparity between EVs and ICEs, it makes EVs a more reasonable option for consumers. Although the grant is currently scheduled to run until March 31, 2014, only the first year of funding (£43 million or 8,600 cars) is guaranteed (Vaughn, 2011). The UK government plans to review the scheme again in early 2012 (London Assembly Environment Committee, 2012).

Although government support for EVs has been strong thus far, there is precedent for discontinued funding. In 2005, a similar £1,000 purchase subsidy was prescribed during the launch of G-Whiz EVs. The subsidy disappeared two weeks later, though, due to lack of demand (Vaughn, 2011). This type of uncertainty related to public sector funding could become a major obstacle for EVs in London if the Plug-In Car Grant is not renewed.

Vehicle Tax Exemption / One-time Showroom Tax Exemption

In addition to the Plug-In Car Grant, the UK government has also tried to induce demand through tax incentives. Starting in April of 2010, Londoners who purchase a new vehicle have to pay a one-time showroom tax and an annual vehicle tax. EVs are exempt from both of these payments, each of which cost £155 (Mayor of London, 2009).

Amount Saved from London Congestion Charge Exemption

In addition to the UK-wide tax exemptions, EV drivers in London are also exempt from paying the annual £2,278 London Congestion Charge fee.

Amount Saved on Total Fuel Costs Compared to ICE

EV buyers are also exempt from making fuel duty payments (which currently represent 49% of petrol prices in the UK) on the electricity that they use. Taking fuel duty savings into account, SMMT notes that EVs save £618.75 annually on total fuel costs compared to ICEs (SMMT, 2011).

Savings on Maintenance and Service Costs Compared to ICE

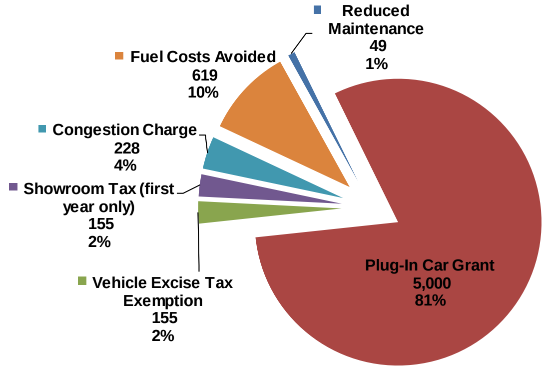
Another area of benefits for EV users is savings on maintenance and repair. Because EVs have fewer complex engine parts, most of their running costs centre on maintenance and replacement of the battery pack. As a result, SMMT project that EVs will save nearly £50 annually (£49.30 per year) on service fees compared to traditional ICE counterparts (SMMT, 2011).

Other / Incentives to Explore

In addition to highlighting the major quantifiable benefits for EV consumers, there are several other less well-defined benefits to consider as well. For example, some London boroughs have begun to offer subsidised parking for EVs. The Mayor's 2009 Electric Vehicle Delivery Plan notes that parking at public car parks in Westminster is free for EVs. Similarly, other boroughs, like Richmond, have established emissions-based on-street parking, which allows EV drivers to obtain parking permits free of charge (Mayor of London, 2009). Unfortunately, these types of parking subsidies are not consistent throughout all boroughs. In order to further incentivise EV demand in the future, the GLA should focus on creating a more unified subsidy structure.

Two other possible future benefits for EV consumers are cheaper insurance premiums and higher residual values. Several insurance companies offer "greener" car insurance policies to UK drivers; however, these policies, like parking subsidies, are not consistent (Electric Car Site, 2008). In addition, alternatively-fuelled vehicles currently on the market have set a strong precedent for relatively higher residual values compared to ICEs (SMMT, 2011). Although this seems like a promising trend for EV consumers, the EV re-sale market is still too young to accurately assess.

2012E Benefits Breakdown, EVs, Individual Consumer
£ and % of 2012E Total



Key Findings and Takeaways from the EV Consumer Cost Benefit Analysis

Our cost benefit analysis of EVs at the consumer level has several important implications for the future of EVs in general, potential EV users and policymakers.

First, EVs are highly negative under our base case assumptions. This owes primarily to the extremely high cost of EVs, as the average excess cost of an EV over a comparable ICE is approximately £9,650. Reducing this cost is a key barrier to wider expansion of EVs in London, and we recommend ways to achieve this in our recommendations section.

Second, this high cost explains in large part both why EVs have not taken off in a big way yet in London and why only wealthy individuals are using EVs. Currently EVs are so expensive that they are essentially a luxury item. Our sensitivity analysis suggests reducing the price of EVs in conjunction with an increase in the Plug-In Car Grant can shift the investment decision positive.

Finally, the investment decision is not largely affected by the cost of the garage charger installation or by the discount rate selected.

Cost Benefit Analysis 3: EVs, Individual Consumer Level

	PROJECTED									
	Year ending 31 December									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Benefits (similar to Public Sector Costs)										
Reduced Maintenance	49	49	49	49	49	49	49	49	49	49
Cost Savings										
Plug-In Car Grant	5,000	-	-	-	-	-	-	-	-	-
Vehicle Excise Tax Exemption	155	-	-	-	-	-	-	-	-	-
Showroom Tax (first year only)	155	-	-	-	-	-	-	-	-	-
Congestion Charge	228	228	228	228	228	228	228	228	228	228
Fuel Costs Avoided	619	619	619	619	619	619	619	619	619	619
Total Benefits	**6,206**	**896**	**896**	**896**	**896**	**896**	**896**	**896**	**896**	**896**
Discounted @ Consumer Discount Rate	**6,206**	**862**	**830**	**799**	**769**	**740**	**712**	**685**	**660**	**635**
Costs										
EV Cost Relative to Traditional ICE Purchase (EV minus ICE)	9,650	-	-	-	-	-	-	-	-	-
Garage Charger Installation	625	-	-	-	-	-	-	-	-	-
Charging Time	1,363	1,363	1,363	1,363	1,363	1,363	1,363	1,363	1,363	1,363
Charging Network Membership	13	13	13	13	13	13	13	13	13	13
Total Costs	**11,651**	**1,376**	**1,376**	**1,376**	**1,376**	**1,376**	**1,376**	**1,376**	**1,376**	**1,376**
Discounted @ Consumer Discount Rate	**11,651**	**1,324**	**1,275**	**1,227**	**1,181**	**1,137**	**1,094**	**1,053**	**1,013**	**975**
NET BENEFIT / (COST)	**(5,445)**	**(480)**	**(480)**	**(480)**	**(480)**	**(480)**	**(480)**	**(480)**	**(480)**	**(480)**
Discounted @ Consumer Discount Rate	**(5,445)**	**(462)**	**(445)**	**(428)**	**(412)**	**(397)**	**(382)**	**(367)**	**(354)**	**(340)**
Valuation										
Selected Consumer Discount Rate	3.9%									
Sum of Future Discounted Net Benefits / (Costs)	**(9,032)**									

Sensitivity Analysis: EVs, Individual Consumer Level

EV Cost over Traditional Car (£)

	Plug In Car Grant						
	0.0	1,500.0	3,500.0	5,000.0	5,500.0	6,500.0	7,500.0
3,000	-7,382	-5,882	-3,882	-2,382	-1,882	-882	118
5,000	-9,382	-7,882	-5,882	-4,382	-3,882	-2,882	-1,882
8,000	-12,382	-10,882	-8,882	-7,382	-6,882	-5,882	-4,882
9,650	-14,032	-12,532	-10,532	**-9,032**	-8,532	-7,532	-6,532
10,000	-14,382	-12,882	-10,882	-9,382	-8,882	-7,882	-6,882
12,000	-16,382	-14,882	-12,882	-11,382	-10,882	-9,882	-8,882
15,000	-19,382	-17,882	-15,882	-14,382	-13,882	-12,882	-11,882

- ✓ Key area of sensitivity
- ✓ Decreasing the cost differential to £3,000 and increasing the Plug-In Car Grant has the potential to shift the decision to neutral (see top right of table)

Charging Time Value per Year (£)

	Plug In Car Grant						
	0.0	1,500.0	3,500.0	5,000.0	5,500.0	6,500.0	7,500.0
300	-5,029	-3,529	-1,529	-29	471	1,471	2,471
750	-8,841	-7,341	-5,341	-3,841	-3,341	-2,341	-1,341
1,000	-10,958	-9,458	-7,458	-5,958	-5,458	-4,458	-3,458
1,363	-14,032	-12,532	-10,532	**-9,032**	-8,532	-7,532	-6,532
1,500	-15,193	-13,693	-11,693	-10,193	-9,693	-8,693	-7,693
2,000	-19,427	-17,927	-15,927	-14,427	-13,927	-12,927	-11,927
3,000	-27,897	-26,397	-24,397	-22,897	-22,397	-21,397	-20,397

- ✓ Eliminating this time shifts the investment decision positive (see top right of table)
- ✓ Government should consider ways to reduce the cost of charging time

Cost of Garage Installation (£)

	Plug In Car Grant						
	0.0	1,500.0	3,500.0	5,000.0	5,500.0	6,500.0	7,500.0
200	-13,607	-12,107	-10,107	-8,607	-8,107	-7,107	-6,107
400	-13,807	-12,307	-10,307	-8,807	-8,307	-7,307	-6,307
500	-13,907	-12,407	-10,407	-8,907	-8,407	-7,407	-6,407
625	-14,032	-12,532	-10,532	**-9,032**	-8,532	-7,532	-6,532
750	-14,157	-12,657	-10,657	-9,157	-8,657	-7,657	-6,657
1,200	-14,607	-13,107	-11,107	-9,607	-9,107	-8,107	-7,107
2,000	-15,407	-13,907	-11,907	-10,407	-9,907	-8,907	-7,907

- ✓ Cost of garage installation does not appear to be a prohibitive expense – not a large cost in relation to other costs

Discount Rate

	Plug In Car Grant						
	0.0	1,500.0	3,500.0	5,000.0	5,500.0	6,500.0	7,500.0
1.0%	-14,559	-13,059	-11,059	-9,559	-9,059	-8,059	-7,059
2.5%	-14,273	-12,773	-10,773	-9,273	-8,773	-7,773	-6,773
4.5%	-13,936	-12,436	-10,436	-8,936	-8,436	-7,436	-6,436
5.0%	-13,859	-12,359	-10,359	**-8,859**	-8,359	-7,359	-6,359
5.5%	-13,784	-12,284	-10,284	-8,784	-8,284	-7,284	-6,284
7.5%	-13,509	-12,009	-10,009	-8,509	-8,009	-7,009	-6,009
9.0%	-13,324	-11,824	-9,824	-8,324	-7,824	-6,824	-5,824

- ✓ Shifting discount factors does not change the overall negative outcome of the cost benefit analysis, even when increasing the value of the Plug-In Car Grant by 50%

Cost Benefit Analysis 4: EVs at the Public Sector Level

The most difficult aspect of measuring the costs and benefits of EVs to London's public sector is identifying which of these values are directly realised by the Greater London Authority, and therefore should be included in our analysis. For example, the UK's two most notable public sector expenditures towards EV development are the 2011 Plug-In Car and Plugged-In Places Grants. Although Londoners who own EVs can benefit from both grants, the grants themselves are not costs to the GLA directly, but rather to the UK government as a whole. With these kinds of considerations in mind, we compiled the following public sector costs and benefits of EVs:

List of Benefits and Costs Analysed

Benefits

- Value of CO2 Reduction (£ annual)
- Value of Clean Air
- Car Sharing Network Memberships
- Other Social Effects
  - Gross Value Added from EV Industry
  - Noise Reduction
  - Public Perception

Costs

- TfL Support for Source London
- Lost Parking Space Revenue
- Lost Congestion Charges

Source: Arup, own analysis

Quantifying the Costs of EVs at the Public Sector Level

Charging Infrastructure

The GLA's main EV expenditure to date has been a £6.6 million investment in 2010 to help launch London's first integrated charging network, Source London (London Assembly Environment Committee 2012). Transport for London, which is a subsidiary of the GLA, is currently leading a group of public and private partners in an effort to expand Source London and meet Mayor Johnson's ambitious charging network goals (Source London, 2012).

Lost Revenues from Using Parking Spaces as Charging Points

In addition to the upfront costs for Source London, developing a network of EV charging points offers another inherent cost as well: foregone revenue from parking fees. Because each charging station uses an on-street parking space, where drivers would otherwise have to pay to park, charging stations represent a public sector cost to the London government. As there is not an average annual on-street parking fee throughout London, in order to calculate a charging station cost value we used the average price of an Annual Resident Permit as stated by the Southwark Council (£154.75 in 2012) (Southwark, 2012). The reason for using this number is that residents who purchase annual permits are allowed to use on-street, pay-and-display parking spaces, which are the specific types of spaces taken by Source London charge points. According to the Mayor's 2009 Electric Vehicle Delivery Plan, only 8% of the new charging points through 2015 will be in public car parks (Mayor of London, 2009). The majority of charging points will be placed in workplace parking lots, which would not otherwise incur a general public parking fee.

Lost Revenues from Congestion Charge Exemption

Finally, in addition to costs related to Source London, Londoners who own qualified EVs are exempt from the London Congestion Charge. As a result, the London government currently foregoes £2,278 of revenue per year for every EV driver on the road (SMMT, 2011).

Others / Incentives to Explore

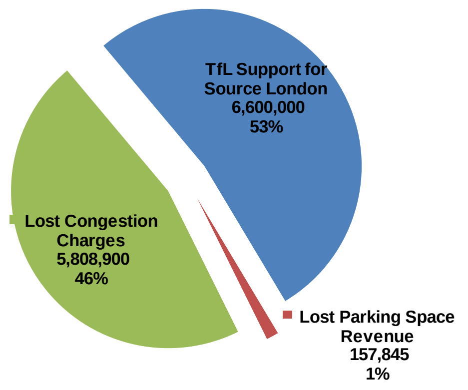
In addition to developing Source London and incentivising demand through the congestion charge exemption, the GLA has also begun to invest in its own EVs. In 2010, in an effort to spur EV awareness, Mayor Johnson announced a plan to introduce 1,000 new EVs into the GLA fleet by 2015 (Transport for London, 2010). This comprehensive procurement plan shows the government's commitment to lead by example in order to make London the EV capital of Europe. Although this procurement will be costly for the GLA, it represents a private investment decision rather than an explicit public sector cost. It will therefore not be factored into our cost-benefit analysis.

A second area for consideration, which will not be factored into our analysis but is important to consider qualitatively, is potential future public sector costs. As EVs continue to grow throughout London, one of these potential costs may be future GLA research investments as different issues arise. For example, in 2011, the UK's Transport Research Laboratory conducted a study to investigate the potentially negative impact of quiet EV engines on vision-impaired pedestrians (TRL, 2011). While the study concluded that the scale of the problem is still very small, the study in itself cost time and resources. The GLA will likely have to conduct similar types of studies in order to successfully incorporate EVs into its transportation regime.

In addition, Charging Ahead notes that one of the main barriers to EV growth in London is public information about EVs (London Assembly Environment Committee, 2012). The report specifically cites that potential consumers lack information on updated EV range capabilities and maintenance costs. It also mentions that the GLA needs to better educate the public on the national and local EV incentive schemes (London Assembly Environment Committee, 2012). If London takes these recommendations to heart, the GLA could also incur future costs related to EV publicity and awareness.

Another potential future cost deals with electricity demand and the structure of London's charging network. As EVs become more prevalent, some observers question whether or not the National Grid will be able to cope with heightened electricity demand. According to the Society of Motor Manufacturers and Traders, electricity demand is not expected to exceed 0.3% of total electricity consumption by 2020, even under the most optimistic EV growth scenarios (Source London, 2011). It is important to keep in mind the infancy of London's EV program—the Mayor's goal to put 100,000 new EVs on the road as soon as possible would only represent about 3% of the total vehicle population in London (Source London, 2011). Although energy demand is not currently a major concern, electricity companies are indeed working with EV manufacturers to prepare for future issues. In the short-term, electricity suppliers are offering cheaper overnight rates to encourage EV users to charge in off-peak hours. In the long-term, the Source London website notes that electricity demand will be managed through smarter metering systems which can automatically choose the most efficient charging times (Source London, 2011).

2012E Cost Breakdown, EVs, Public Sector
£ and % of 2012E Total]



Source: Own analysis

Quantifying the Benefits of EVs at the Public Sector Level

CO_2 Reduction and Clean Air
As shown in the following, CO_2 reduction weight depends on which stage we include in our model (SMMT, 2011). In this report, we used 'well to wheel method' because it is most appropriate to think of total CO_2 reduction in a global sense. Londoner's average travel range is 25 miles per day (SMMT, 2011). If using the same CO_2 price as car clubs, an average benefit of CO_2 reduction becomes £240-280 per vehicle, per annum. Calculating from the midpoint ICE well to wheel range and the EV well to wheel measure we find that EVs are approximately 50% more carbon efficient than comparable ICEs.

CO_2 Efficiency of EVs versus ICEs

- Pure-EV 'tank to wheel' average = 0g CO_2 /km
- Pure-EV 'well to tank' average = 77g CO_2 /km
- Pure-EV 'well to wheel' average = 77g CO_2 /km

- ICE 'tank to wheel' average = 132.3g CO_2 /km
- ICE 'well to tank' average = 14.7g to 29.0g CO_2 /km
- ICE 'well to wheel' average = 147.0g to 161.3g CO_2 /km

Source: Nissan, 2011

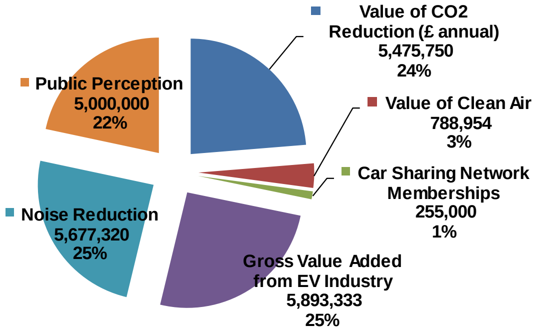
Air Quality
We follow a substantially identical approach for measure air quality benefits as followed in the car club public sector CBA. We simply apply the same £ rate per ton CO_2 removed and

apply that to the number of tons of CO_2 removed on account of EVs.

Noise Reduction
Nissan (2010) reports that EVs are generally 5-10dB quieter compared to ICEs because of their silent electric motor. However, EVs also generate 35-60dB of noise while they accelerate, as they are still subject to the road and wind noise that affects all vehicles. Therefore, we assume that current ICEs generate 55dB, while EVs incur 48dB on average. To value noise reduction, we again follow a substantially identical approach to that used in our car club public sector CBA.

Economic Impact – Gross Value Added (GVA) by the EV Industry
Ernst & Young (2009) estimates the social benefit of London's carbon reduction plans using a "bottom-up approach." According to the report, London's EV plan requires £284M of direct investment, which in turn creates £48M of gross value added (Ernst & Young, 2009). By removing the spill over effect to outside of London, annual GVA becomes £34M. However, London has not invested in EVs to this extent, and has reduced the planned number of EV charging points for 2013 from 7,500 to 1,300 (City of London, 2012). Thus, we reduced the estimated GVA to the same level, which results in a total value of £5.9M.

2012E Benefits Breakdown, EVs, Public Sector
£ and % of 2012E Total



Source: Own analysis

Key Findings and Takeaways from the EV Public Sector Cost Benefit Analysis

Our cost benefit analysis of EVs from the public sector level has several important implications for policymakers.

First, overall the adoption of EVs in London appears to be an extremely positive benefit, however not to the same degree as car clubs. This owes mainly to the facts that EVs are not as widely used and that EVs do not remove as many cars as car clubs do.

Second, EVs do have a great deal of benefit from an environmental standpoint but again not to the same degree as car clubs. While EVs are a great deal more efficient than ICEs, it is better to remove ICEs than to replace them with EVs.

Last, our results are robust to significant changes in our assumptions. As stated in our analysis of car clubs, this is important because many of these benefits are intangible and difficult to measure precisely.

Cost Benefit Analysis 4: EVs, Public Sector Level

	PROJECTED									
	Year ending 31 December									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Benefits										
Cumulative Reduction in CO2 Emissions (tons CO2)	25,440	59,783	104,048	158,273	221,019	288,994	339,975	398,603	443,551	468,273
Value of CO2 Reduction per ton CO2	215.2	218.5	221.8	225.1	228.5	231.9	235.4	238.9	242.5	246.5
Value of CO2 Reduction (£ annual)	5,475,750	13,061,134	23,073,597	35,624,446	50,493,810	67,010,782	80,016,515	95,225,238	107,550,014	115,438,333
Value of Clean Air	788,954	1,854,041	3,226,821	4,908,475	6,854,390	8,962,464	10,543,520	12,361,734	13,755,699	14,522,379
Car Sharing Network Memberships	255,000	369,750	517,650	698,828	908,476	1,135,595	1,305,934	1,501,824	1,652,006	1,734,607
Other Social Effects										
Gross Value Added from EV Industry	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333	5,893,333
Noise Reduction	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320	5,677,320
Public Perception	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Total Benefits	**23,090,357**	**31,855,578**	**43,388,721**	**57,802,402**	**74,827,329**	**93,679,495**	**108,436,623**	**125,659,449**	**139,528,372**	**148,265,972**
Adjusted for Inflation	**23,090,357**	**32,811,245**	**46,031,094**	**63,162,245**	**84,218,818**	**108,600,209**	**129,478,998**	**154,545,273**	**176,750,368**	**193,453,464**
Discounted @ Social Discount Rate	**23,090,357**	**32,390,173**	**44,857,225**	**60,761,603**	**79,978,151**	**101,808,359**	**119,823,681**	**141,185,341**	**159,398,695**	**172,223,140**
Costs										
TfL Support for Source London	6,600,000									
Lost Revenues										
Lost Parking Space Revenue	157,845	228,875	320,425	432,574	562,346	702,933	808,373	929,629	1,022,592	1,073,722
Lost Congestion Charges	5,808,900	8,422,905	-	-	-	-	-	-	-	-
Total Costs	**12,566,745**	**8,651,780**	**320,425**	**432,574**	**562,346**	**702,933**	**808,373**	**929,629**	**1,022,592**	**1,073,722**
Adjusted for Inflation	**12,566,745**	**8,911,334**	**339,939**	**472,686**	**632,926**	**814,892**	**965,240**	**1,143,326**	**1,295,389**	**1,400,963**
Discounted @ Social Discount Rate	**12,566,745**	**8,796,973**	**331,270**	**454,720**	**601,056**	**763,929**	**893,261**	**1,044,490**	**1,168,220**	**1,247,216**
NET BENEFIT / (COST)	**10,523,612**	**23,203,798**	**43,068,295**	**57,369,828**	**74,264,983**	**92,976,561**	**107,628,249**	**124,729,820**	**138,505,780**	**147,192,251**
Discounted @ Social Discount Rate	**10,523,612**	**22,906,019**	**41,969,983**	**55,189,341**	**70,525,521**	**87,161,813**	**99,602,354**	**113,947,337**	**124,908,599**	**131,038,809**
Valuation										
Selected Social Discount Rate	1.3%									
Sum of Future Discounted Net Benefits / (Costs)	**757,773,388**									

Sensitivity Analysis: EVs, Public Sector Level

Value of Clean Air per Ton CO2 Removed (£)

	Percent reduction in CO2 (EV versus ICE)						
	10%	25%	45%	50%	55%	65%	85%
5.0	250,837,801	418,157,019	641,249,310	697,022,383	752,795,456	864,341,601	1,087,433,892
15.0	255,462,454	429,718,652	662,060,249	720,145,648	778,231,047	894,401,846	1,126,743,443
25.0	260,087,107	441,280,284	682,871,187	743,268,913	803,666,639	924,462,090	1,166,052,993
31.0	262,867,753	448,231,899	695,384,093	**757,172,142**	818,960,191	942,536,288	1,189,688,483
35.0	264,711,760	452,841,917	703,682,126	766,392,178	829,102,230	954,522,335	1,205,362,544
50.0	271,648,739	470,184,365	734,898,534	801,077,076	867,255,618	999,612,702	1,264,326,870
75.0	283,210,372	499,088,447	786,925,880	858,885,238	930,844,596	1,074,763,313	1,362,600,746

- ✓ Increasing CO2 efficiency of EVs over ICE by 5% points increases net benefit by approximately £50 million over 10 years
- ✓ Value of clean air is subjective; increasing assumption from £31 to £75 per ton increases net benefit by about £90 million over 10 years

% Impact of Noise on Value of Homes (per Decibel)

	Percent reduction in CO2 (EV versus ICE)						
	10%	25%	45%	50%	55%	65%	85%
0.050%	222,664,522	408,028,668	655,180,862	716,968,911	778,756,959	902,333,057	1,149,485,251
0.100%	236,065,599	421,429,745	668,581,939	730,369,988	792,158,037	915,734,134	1,162,886,328
0.150%	249,466,676	434,830,822	681,983,016	743,771,065	805,559,114	929,135,211	1,176,287,406
0.200%	262,867,753	448,231,899	695,384,093	**757,172,142**	818,960,191	942,536,288	1,189,688,483
0.250%	276,268,830	461,632,976	708,785,170	770,573,219	832,361,268	955,937,365	1,203,089,560
0.500%	343,274,215	528,638,361	775,790,556	837,578,604	899,366,653	1,022,942,750	1,270,094,945
1.000%	477,284,986	662,649,132	909,801,326	971,589,375	1,033,377,424	1,156,953,521	1,404,105,715

- ✓ Highly subjective but important measure
- ✓ Net benefit remains positive even when impact is assumed to quintuple, or is cut by a factor of four

Gross Value Added from EV Job Sector

	Percent reduction in CO2 (EV versus ICE)						
	10%	25%	45%	50%	55%	65%	85%
1,000,000	216,665,716	402,029,862	649,182,056	710,970,105	772,758,154	896,334,251	1,143,486,446
2,500,000	230,828,466	416,192,612	663,344,806	725,132,855	786,920,903	910,497,001	1,157,649,195
4,500,000	249,712,132	435,076,278	682,228,472	744,016,521	805,804,570	929,380,667	1,176,532,862
5,893,333	262,867,753	448,231,899	695,384,093	**757,172,142**	818,960,191	942,536,288	1,189,688,483
7,500,000	278,037,631	463,401,777	710,553,972	772,342,021	834,130,069	957,706,167	1,204,858,361
10,000,000	301,642,214	487,006,360	734,158,555	795,946,603	857,734,652	981,310,749	1,228,462,944
15,000,000	348,851,380	534,215,526	781,367,721	843,155,769	904,943,818	1,028,519,915	1,275,672,110

- ✓ Job creation from EVs in London is derived from installation of infrastructure and related services (maintenance, etc.)
- ✓ Roughly equivalent benefit in magnitude to noise reduction

Discount Rate

	Percent reduction in CO2 (EV versus ICE)						
	10%	25%	45%	50%	55%	65%	85%
0.0%	282,734,290	483,763,102	751,801,518	818,811,122	885,820,726	1,019,839,934	1,287,878,350
0.8%	271,030,745	462,823,092	718,546,221	782,477,004	846,407,786	974,269,351	1,229,992,480
1.0%	267,277,619	456,112,974	707,893,447	770,838,566	833,783,684	959,673,921	1,211,454,394
1.3%	262,867,753	448,231,899	695,384,093	**757,172,142**	818,960,191	942,536,288	1,189,688,483
1.8%	256,439,232	436,749,590	677,163,401	737,266,854	797,370,307	917,577,212	1,157,991,023
2.5%	246,199,764	418,476,704	648,179,291	705,604,938	763,030,585	877,881,878	1,107,584,465
5.0%	215,911,081	364,555,021	562,746,941	612,294,921	661,842,900	760,938,860	959,130,780

- ✓ Valuing discount rate can for public sector projects can be rather subjective
- ✓ Project remains positive return even at very different discount rates

Summary Output of All 4 Cost Benefit Analyses Run at Base Case

	Car Clubs	Electric Vehicles
Total Users (London) - 2011E	196,944	17,000
Total Users (London) - 2021E	874,913	173,461
Public Sector Cost Benefit (in £)		
Net Discounted Benefits through 2021	3,522,922,722	935,516,726
Net Discounted Costs through 2021	88,543,732	27,867,880
Benefits - Costs	**2,900,236,120**	**757,773,388**
Consumer Cost Benefit (in £)		
Net Discounted Benefits through 2021	21,188	12,897
Net Discounted Costs through 2021	4,073	21,930
Benefits - Costs	**17,115**	**(9,032)**

Part IV: Key Findings and Recommendations

Key Findings

Summary of Key CBA Outputs

	Electric Vehicles	Car Clubs
Users in 2021, Base Case	173,461	874,913
Public Sector NPV, Base Case	£757,773,388	£2,900,236,120
Consumer NPV, Base Case	-£9,032	£17,115
Major Assumptions	Future cost of EVs Technological advances	Private vehicle displacement Driving behavior pre/post-joining Value of reduced congestion/noise
Risk Factors	Lack of competition Lack of technological advancements Public awareness Availability of charging networks Macroeconomic risks	Continued success/profitability of operators Competition from other alternatives (BMWdrive, e.g.) Borough level decisions/availability of parking
Incentives to Consider	Tax incentives/grants Home charging Vehicle purchase Public parking grants Charging network grant Battery grants Incorporating EVs in public fleets Increased charging infrastructure Higher proportion of quick chargers Trade-in programs	Free parking Joining with public sector transport Congestion zone exemption

Source: Own analysis

Finding 1: Car clubs' total public sector benefit is far greater than that of EVs

The results of our cost benefit analysis show that car clubs provide approximately four times the total net benefit that EVs would provide under our base case scenario (£2.9 billion versus £758 million). This is due primarily to two factors, first that car clubs are a much more developed market appealing to a far broader demographic than EVs and second that car clubs result in far greater carbon benefits since each club car removes so many cars from the road. Both car clubs and EVs provide net social benefit, however car clubs appear to be a larger and more cost effective opportunity for delivering value and carbon reduction; in 2012 for example we project approximately £37 million of CO_2 and clean air benefit from car clubs, where the same figure for EVs is approximately £6 million.

Finding 2: EVs are currently negative at the consumer level while car clubs are positive

EVs currently represent a highly negative investment decision at the individual consumer level (approximately -£9,000 over the course of 10 years), which explains in large part why EVs are currently only purchased by wealthy individuals and why EVs do not yet constitute a major segment of London transport. The main barrier preventing widespread EV uptake is the significant difference in the price of EVs over traditional ICE cars.

Car clubs on the other hand represent an extremely positive investment decision at the individual consumer level, and individuals are unlikely to require much if any subsidy to encourage future uptake. Car clubs appeal to a much broader demographic than EVs and thus are much more appealing in terms of social inclusion.

Finding 3: Car club gains are highly robust to changes in key assumptions

Our sensitivity analysis of car clubs remains highly positive even when significantly changing several key assumptions. A key figure that may move in the future is net cars displaced per club car, which we assume at 20 for the base case. Shifting this figure all the way down to 5 cars we still observe a significant and positive benefit for car clubs. This fact is important because a key concern of car clubs is that it will simply induce demand for cars, i.e. attract users who would otherwise not drive. While these users do make up a significant portion of car club joiners, they are not a major issue because first there are plenty of non-induced demand joiners to make up for them and second because shifting these induced joiners away from public transport (which currently makes losses in London) and toward private modes of transport may not necessarily be a bad outcome.

High Level Recommendations

Recommendation 1: Focus at present on promoting infrastructure for car clubs over EVs and pursue EVs at a later time

Because our findings strongly suggest that car clubs are both a higher impact, more cost effective, and more socially inclusive way of reducing carbon emissions and congestion, we recommend London focus first on developing this infrastructure. Since the individual consumer investment decision is highly positive, London's efforts should focus primarily on building awareness and educating the population as to the significant benefits inherent in car clubs. While EVs are not as beneficial as car clubs, they still represent a highly positive and economically significant way to reduce carbon emissions in London. As such, we recommend London continue to invest accordingly to develop the young EV market (see below).

Recommendation 2: Promote ways to increase the individual cost effectiveness of EVs and reduce the price gap between traditional cars and EVs

The primary barrier preventing rapid EV expansion in London is the high cost of EVs. As such we recommend London continue to support the Plug-In Car Grant and consider supporting research and development to improve EV production processes and lower the price of the final output. Battery technology is a key area of potential improvement in cost. Because a great deal of the cost to the individual EV user is in the value of time spent charging, installing night-time charging points presents a large benefit to EV users as they can charge their vehicles during non-work hours. Further, increasing the number of available charging points will work to alleviate any concerns of range anxiety, another key barrier preventing many potential buyers from purchasing EVs.

Recommendation 3: Focus on integration of EVs into car clubs

Supporting the inclusion of EVs in car club fleets presents a major synergistic opportunity for London to develop both EV and car club infrastructures. Since most car club users use club cars for short trips within a small zone, using EVs in car clubs makes good sense. Promoting uptake within car clubs of EVs will also increase the image of EVs in London in general, and further allow potential EV purchasers a low cost way of testing the vehicles before purchasing.

Specific Recommendations and Key Lessons from Other Cities

As part of our final analysis we examined the EV and car club programmes of leading cities throughout the world. Further detail of these programmes appears in the appendix.

1. We recommend London consider the following specific actions in the near term to promote car club and EV use

2. Increase allocation of car club-designated parking spaces in popular areas throughout Central London

3. Consider large scale car club-only parking infrastructure projects

4. Explore the feasibility of direct tax incentives for car club operators and consumers

5. Engage in targeted marketing of car clubs, e.g. advertising throughout London's bus and tube networks

6. Support Carplus with funding and/or provision of public forums

7. Continue investing in the development of London's charging network, when economically feasible and not to detriment of the development of car clubs

8. Consider ways to help reduce EV prices, e.g. continue Plug-In Car Grant, subsidising R&D on battery research, or granting tax incentives for EV production

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Appendix

Appendix A.
Terms of Reference

Arup provided these initial terms of reference at the commencement of the project in October 2011:

1. Prepare a literature review on the policy drivers and incentives that can be provided to support each type of infrastructure. Students should look at London and international examples that Arup will provide from the C40 Cities stakeholder list.

2. Construct a cost -benefit analysis over a 10 year period on the implementation of EV infrastructure and car-clubs in London from a 1) public sector perspective and 2) consumer perspective. Students should consider the infrastructure required to serve 100,000 residents and results can be extrapolated across the population.

3. Undertake scenario testing on how different incentives/incentive levels could change the cost-benefit analysis.

4. Provide a concluding argument on whether the public sector should invest more in electric vehicles or car clubs (or a mixture of both)

These goals stayed substantially the same throughout the project, with the exception of the extrapolation mentioned in point 2. We found that such an extrapolation would lack validity given the extremely diverse nature of the boroughs in London, and therefore focused on a city wide approach.

Appendix B.
Comparison Cities EV and Car Club Programmes

Car Club Comparison Cities (U.S.)

San Francisco, California

The introduction of car clubs in the United States can be traced back to 1983 in San Francisco, California, with the establishment of the Short-Term Auto Rental Service (STAR). This STAR project was funded by a private firm and only served residents of large apartment complexes near San Francisco State University. The idea behind the project was that these residents had transportation needs that could only be met by owning a private vehicle, but because of the high fixed cost of purchasing the vehicle, car owners actually drove more than they would have if costs were based on a per-mile driving basis. While the project succeeded in reducing private-vehicle use by its participants, the 16-month experiment failed to achieve profitability because of vehicle unreliability and a failure to collect the necessary payments from users.

Despite the results of the STAR Project, the City of San Francisco has fully embraced car sharing. Over the last decade, City CarShare, a local non-profit agency, has grown from a fleet of 12-Volkswagon Beetles to the largest car club scheme in the San Francisco Bay Area. By relying on funding from private donors, as well as coordinated partnerships with local transportation agencies and other community groups, City Carshare is able to offer low fees while continually reinvesting all of its earnings back into expanding the scheme. Having a similar non-profit organization compete in the private car club industry in London is an additional possibility for policymakers to explore.

Austin, Texas

While one of the main drawbacks of car club schemes is the requirement to return the vehicle to its original parking bay upon completion of the trip, Car2go in Austin, Texas and other U.S. cities has introduced a scheme that allows customers to park their car club vehicle at any available public parking space within a specified area. The vehicle is rented in a “Parkspot:” a designated parking space in heavily congested areas – and must returned at any available legal public parking place within a several-mile radius surrounding downtown Austin . By charging competitive hourly rates, users do not have to specify a timeframe beforehand and instead can drive for as long as they want. Car2go, which is a subsidiary of Daimler, originated in Ulm, Germany and brought a fleet of 200 Smart cars to Austin in 2009.

San Diego, California

In November 2011, San Diego became the second North American outlet for Car2go, but the first U.S. city to provide fully electric Car2go fleets. The combination of car sharing and EVs is undoubtedly one of the most exciting new possibilities for low-emission transportation. Throughout the world, notable programs like Car2go, Autolib in Paris, and e-Mobility in Berlin, are taking advantage of this concept and designing smart solutions for the future. In November 2011, Murad Qureshi, chairman of the London Assembly Environment Committee, visited Paris to look for ways in which London can replicate the Autolib system. Without question, such a program, designed with an eye towards the efficient car-sharing model in San Diego, could also quickly improve London’s EV take-up.

Car Club Comparison Cities (Europe)

Switzerland

Switzerland has over 20 years’ experience in car clubs. Switzerland’s leading car club operator, Mobility, which as of 2011 has over 100,000 members, resulting in an estimated reduction of 20,000 private cars. In addition to standard private car sharing services, Switzerland has focused heavily on corporate and academic clients to expand membership. Business car sharing has exhibited very strong historical growth. To encourage growth on campuses, students and employees of certain universities are able to use their employee or student cards to rent vehicles.

From a public sector perspective, Switzerland has partnered with Hertz to promote its car sharing schemes, and Hertz in turn provides comprehensive information services for potential users. City maps in Switzerland are now integrated to show public transport routes, pedestrian, cycle and car club bay locations in the same map. Last, club cars are provided at major rail stations and car club members are able to book train tickets and club cars at the same time. Each of these practices are certainly replicable in London, and represent significant opportunities for London to expand its user base and deliver better car club services to its citizens.

Germany

Germany is highly focused on car clubs and specifically on integrating car clubs with the public sector. In 2002, they announced plans to introduce car sharing in all cities with more than 250,000 people, aiming to develop the fleet of shared cars to supplement public transport. Germany combined packages of public transport with reduced prices for car club membership, a strategy supported by all brands used. In Berlin, members receive an electronically readable sticker to place on their driver's licenses, which works with all car clubs in the city. This interchangeability is a key feature in order to simplify the car location and rental process. Germany notes in particular that car clubs represent a potentially large value shift in consumers, especially among young people. Where once car ownership represented affluence and freedom, young people now see cars largely as an expensive and unnecessary item. This is especially true in large cities, due to the expense and lack of practicality in owning a car.

A more recent development in Germany is the entry of vehicle manufacturers such as BMW's DriveNow program. This program could impact uptake in London in one of two ways, either by entering the London market directly or by encouraging local British or other auto manufacturers to begin their own car sharing programs.

Italy

The Italian Ministry of the Environment has been working with car clubs since 1998, and in 2000 Italy created the ICS (Iniziativa Car Sharing) with Euro 9 mm of funding. Car sharing has been instituted in 12 cities and a national organisation oversees the standards of service and development of car sharing, ensuring a high quality of service. This oversight has been cited as a key factor in the strong growth in car clubs in Italy.

ICS guarantees several factors designed to promote healthy expansion of car club use. The first of these is interoperability, meaning each user must be able to access the car in the same way, no matter where they are in the country. Similarly, all standard operations in the rental procedure must be homogenous. Further, all operators in the car sharing industry must adhere to strict standards of quality and service. ICS undertakes monitoring of service, number of users, distances driven and hours of use, surveying satisfaction levels every two years. As car clubs reach a critical mass in London, planners should at least consider the possibility of creating an industry oversight body to monitor the safe expansion of services and promote interoperability and sharing of best practices among operators. It is important that as the car club fleets age, service does not become an issue for users.

EV Comparison Cities (U.S.)

Chicago, Illinois

On February 18, 2011, the city of Chicago announced its $8.9 million EV Infrastructure Project, an ambitious effort to install 280 new charging stations in the city by the end of 2011. The most notable aspect of this project is its focus on DC quick-chargers, which can recharge an EV to 80% in 30 minutes. Of the 280 stations introduced by the project, 73 are DC quick-chargers, making Chicago home to the most quick-charging stations in the world.

Chicago's focus on quick-charging stations is an attempt to make the city more accessible to EV drivers. Consumer survey data from Nissan show that 80% of drivers prefer to charge their vehicles quickly. In addition, 75% would agree to pay more in order to charge at public stations with quick-charging capabilities. Without question, charging time is one of the most significant considerations for potential EV drivers. By providing the option to charge quickly on the go, DC quick-chargers will alleviate some of these concerns.

In May of 2011, London introduced Source London, the city's first network of publicly available EV charge points. Although there are currently 286 charge points now available through Source London, as of November 2011, only 13 of these points can fully charge a vehicle in under four hours. The additional 263 points charge in eight hours. Source London projects that it will install a total of 1,300 charge points by 2013. In order to better appeal to consumer preferences, London's charging network should seriously consider implementing a quick-charge focus similar to that of Chicago.

New York, New York

In 2007, Mayor Michael Bloomberg initiated PlaNYC, a comprehensive sustainability plan to prepare New York City for economic and climate change challenges in the future. One of the key tenants of the plan is for the city as a whole to reduce its greenhouse gas emissions in 2030 by 30%. Transportation emissions currently account for 22% of New York City's greenhouse emissions, so EVs, with zero tail-pipe emissions, have become a major part of the city's initiatives moving forward.

Since the inauguration of PlaNYC, Mayor Bloomberg has pushed to increase the amount of fuel-efficient vehicles in the city's transportation fleet. In fact, with over 430 EVs, New York City currently has the largest low-emissions fleet in the country. The mayor's focus on greening city transportation has led to a new venture: fully electric taxicabs.

In the spring of 2012, Nissan is partnering with the New York City Taxi and Limousine Commission to introduce six electric taxicabs as part of a pilot program. The goal of the program is to gain information on how EVs function as taxicabs. For example, taxis typically service short trips throughout the city, which may be accommodating to the limited range of EVs.

Depending on the feedback from New York City's pilot program, London might be an ideal place to introduce electric taxicabs. In December of 2010, Mayor Johnson and TfL actually announced a £1 million fund to encourage taxi owners to upgrade to low emission vehicles; however, there has been no follow-up information on how the program is progressing. One of the main problems that electric taxis are likely to face in New York City is a relatively small charging network. London, on the other hand, through the recent developments of Source London, will have an extensive network by 2013. London currently has 21,000 licensed taxis; even turning a small proportion of this fleet into EVs could significantly help the city to reduce its overall emissions.

San Francisco, California

In a 2011 survey commissioned by Siemens Corporation, San Francisco was named the greenest city in North America. True to their ranking, the Bay Area has become an early adopter of EV technologies. Two of the city's most recent EV initiatives are free charging stations in public lots and an EV car-sharing scheme at the San Francisco Airport Marriot Waterfront. Each of these new innovations has transferable potential to the current EV developments in London.

In an effort to reduce range anxiety and increase public awareness about EVs, San Francisco's Mayor Ed Lee announced in May of 2011 that EV charging would be free in city-owned parking garages until the end of 2013. The intention of the free charging stations is to provide a "top off" supplement to overnight home chargers. In addition, the stations will also help the city gather data on how often people use public charging and where charging stations should be located. Several London Boroughs, such as Westminster and Richmond, have started offering parking subsidies for EV owners—free charging at these car parks could be a further policy innovation to spur EV demand.

In addition to free charging stations, San Francisco citizens and visitors will benefit from the recent partnership between Hertz and Marriot hotels to introduce an EV car-sharing program at San Francisco's international airport. Through Hertz's On Demand car sharing, the new initiative will allow hotel guests and San Francisco residents to drive a variety of EVs on an hourly or daily basis. In 2011, Hertz also became the first car rental company to deploy EVs in London. As a major international city with five airports, London may be an interesting candidate for Hertz's future airport-hotel EV programs.

EV Comparison Cities (Europe)

Paris

Paris became the first city in the world which delivered a wholly self-service EV rental project-, autolib, on December 5, 2011 with other 45 partner towns. 250 EVs and 250 stations were there on the day, which would eventually extend to 3,000 EVs and 1,100 stations.

A French conglomerate Bolloré Group runs this €235 million project. The city of Paris has spent €35 million for the stations, while the group has invested €200 million. The local authority also spends €50,000 per station, but will be covered by €4 million grant of the authority. One of the reasons why the Bolloré Group investment is so huge is that it developed the 100% electric 'Blue car' by itself with a famous Italian designer. Although the group will also have to pay €750 fee annually for each car space, a profit will be expected from the sixth or seventh year.

Citizens are offered three different rental packages: annual ‘Premium Subscription Solo or Family)’, ‘Weekly 7 days Subscription’ and ‘24 hours Discovery Subscription’. All require a subscription fee, but those who registered can drive by €4-8 in half an hour. Private EV owners are also allowed to use the scheme if they pay subscription.

The autolib project was launched by the initiative of Paris mayor Delanoë who aimed to duplicate the successful non-human bike rental service (Velib’) in 2008 . He explains its merit as ‘0 noise x 0 emissions x 0 fumes’. Also, introduction of 3,000 Bluecars are estimated to reduce 22,500 private car owners, which leads less congestion, less stress and more time. In addition, it employs more than 1,000 staffs in order to run 24 hour opening autolib’ centers .

London has already replicated Velib’ system. In addition to the copy of Velib, an environment committee in London suggests its mayor that Autolib’ can be a good alternative if EV ownership does not take-off soon .

Berlin, Germany

Berlin launched e-mobility Berlin in collaboration with Daimler and RWE in 2008 by support of federal government. The original plan was to provide 100 EVs by Daimler and 500 charging points by RWE by 2010. The concept of e-mobility is that to realize ‘environmentally compatible and customer-friendly mobility.’ The concrete policies set by the city are; first, to increase the number of EVs and E-bikes. Second, to integrate EVs and E-bikes in the public transport through a common ticket. Not only citizens, but also tourists should be connected. Third, to implement a car-sharing with EVs and E-bikes and scooters.

Berlin is one of the cities in the world which testing out V2G (Vehicle to Grid) scheme. That is, EVs are placed as one of policies to create ‘smart grid city’. V2G is said to increase both energy efficiency and security, because of its concept of linking EV battery storage to the grid. If the number of EVs increases, the number of ‘virtual electric plants’ also increases under this concept . Although Greater London Authority has not used the explicit word of ‘V2G’, its concept may be useful to reduce more carbon dioxide.

Amsterdam, Netherlands

Amsterdam has an ambitious target that it makes all motorized traffic in the city emission free by 2040. Plan of the city is quite concrete compared to other cities; 10,000 EVs by 2015, by 2020, 40,000, and by 2040, 200,000.

Tokyo, Japan

Tokyo started ‘the project to promote widespread use of EVs and pHVs’ in May 2009. In the report, it says 15,000 EVs /pHVs and 80 quick charging facilities are widely used by 2014. The notable thing is that the number of stations is set by bottom-up approach. Tokyo thinks it necessary to provide one quick charging station within a 5-kilometer radius in order to give a sense of ease to EV consumer.

Also, Tokyo’s specificity is its carrots and sticks approach to business sector. It distributes special EV subsidies for small and medium sized companies. On the other hand, Tokyo demands companies with over 200 automobiles have obligations to introduce low carbon emission cars by its code.

Appendix C.
List of Interviewees and Key Topics Discussed

Kate Gifford, Strategy and Business Manager, Carplus, 2 February, 2012

We discussed Carplus' role in promoting car clubs, the future of the industry, realistic market projections, and possible government incentives to promote car club membership. We reviewed with her our car club CBA for both the public sector and consumer; which she said were reasonable and grounded on quality assumptions.

Jack Hussey, Member Services Executive, Zipcar, 25 January, 2012

We asked Mr. Hussey the same interview questions that we asked each of the representatives from the Big Three car club operators. These focused on their number of vehicles and inventory in Central London, which type of vehicle is most frequently used by their target consumer, and other fees that one could possibly incur during the rental period.

Keith Kelly, City Car Club, 20 January, 2012

We asked Mr. Kelly the same interview questions that we asked each of the representatives from the Big Three car club operators. These focused on their number of vehicles and inventory in Central London, which type of vehicle is most frequently used by their target consumer, and other fees that one could possibly incur during the rental period.

Joseph Rubin, Member Care Centre Administrator, Hertz-on-Demand, 17 January, 2012

We asked Mr. Rubin the same interview questions that we asked each of the representatives from the Big Three car club operators. These focused on their number of vehicles and inventory in Central London, which type of vehicle is most frequently used by their target consumer, and other fees that one could possibly incur during the rental period

Aaron Weeks, TfL, 22 November 2011

We discussed TfL's historical role and position with regard to car clubs, TfL's assessment of the demand levels in London, key opportunities and barriers, and key decision points regarding financing and overall industry growth in London.

Phillip Rode, Executive Director, LSE Cities and Senior Research Fellow at the London School of Economics, 8 February, 2012

We asked Philipp to look at our EV cost-benefit analysis (for both the public sector and individual consumer) and provide any suggestions for improvement. His main comments focused on the public sector cost side. At the time of our meeting, we still were looking for ways to disaggregate the UK government's Plug-In Car and Plugged-In Places grants into London's total EV costs. Philipp discouraged against this and suggested that we only incorporate direct costs to the GLA. Heeding his advice, we discarded the UK grants and only included TfL's funding for the Source London charging network. In addition to directing our focus onto GLA-specific costs, Philipp also suggested that we include the public sector cost of foregone parking revenue, because each Source London charging point takes up a public, revenue-generating London parking space.

Philipp's final recommendation was more qualitative. He suggested that we research cities, such as Paris, Berlin, and San Diego, which have successfully integrated EVs into car sharing programs. The 'electrification of car sharing,' according to Phillip, will be critical for the future development and uptake of EVs. In addition, he also recommended that we consider not only the general concept of EVs but also the types (designs and models) of EVs as well. He foresees future cars becoming lighter, smaller, and more intelligent and feels that new EVs should align with this vehicle reinterpretation.

Appendix D.
Project Timeline

Timeline: November 2011 to Present (~20 work weeks)

Weeks 0-4 | **Initial Research**

- Performed extensive literature review and sourced expert contacts with whom to conduct interviews
- Conducted initial interviews with experts – TfL, LSE, private sector operators
- Identified initial list of costs and benefits to consider

Weeks 5-10 | **Market Analysis**

- Market sizing analyses for EVs and car clubs; developed base/high/low scenarios
  - Examined comparable cities for potential best practices and to inform as to market uptake and key drivers
- Performed deep analysis of the London car club and EV private markets, operators, and users
- Examined potential CO_2 impact via review of academic and other environmental studies

Weeks 10-15 | **Cost Benefit Analyses**

- Finalized list of costs and benefits to consider
- Began construction of comprehensive Excel-based cost benefit models; developed assumptions for each cost and each benefit
  - Four analyses: EV public sector, EV consumer, car club public sector, car club consumer)
- Revisited with interviewees and other experts in order to test each assumption

Weeks 16-20 | **Final Analysis and Recommendations**

- Continued to refine and further develop model and consult with experts
  - Analyzed other qualitative factors and incentivization potential
  - Considered practices of other cities, potential risks and opportunities, other qualitative factors
  - Developed sensitivity analyses to test the relative importance of each assumption
- Developed final recommendation for car club and EV policy in London

Appendix E.
Additional Model Snapshots
Assumptions Dashboard – Car Clubs CBA at the Public Sector Level

ASSUMPTIONS - PUBLIC SECTOR COST BENEFIT							
CLICK + TO EXPAND		1	2	3			
	Choose	**Low**	**Base**	**High**	**Selected**		**Notes**
Market Sizing (Users) - Car Clubs							
Net Car Differential per Club Car	2	15	20	25	Base	20	Estimated ranges based on TfL survey and CarPlus surveys.
Users per Club Car	2	45	50	55	Base	50	Cases based on TfL survey estimate (2007) and market analysis.
Adult Population with Driving License - Growth	2	0.5%	1.0%	1.5%	Base	1.0%	Growth assumed constant. Based on historical London population growth.
Growth Scenario	2		*See projection curves below (in Yellow)*		Base		Cases based on an early stage product life cycle fit to various estimated curves of car club user growth.
BENEFITS							
Emissions and Clean Air							
CO2 Emissions per Regular Car (Tons CO2 / year)	2	4.680	5.200	5.720	Base	5.200	Average passenger vehicle produces 5.2 metric tons CO2 per year. Low and high are -/+ 10% from base.
CO2 Emissions per Club Car (% savings over Regular)	2	23.4%	26.0%	28.6%	Base	26.0%	Midpoint based on CarPlus report p. 22. Low and high are + / - 10% from base.
Value of Clean Air per Tons CO2 Removed	2	27.911	31.013	34.114	Base	31.013	Based on University of Wisconsin compilation of studies examining the value of health benefits per ton CO2. Low and high are -/+ 10% from base.
Carbon							
Cost of Carbon (£/tonne CO2)	2		*See projection curves below (in Yellow)*		Base		Per Department of Energy and Climate Change guideline carbon values.
Noise Reduction							
Median London Home Price	2	£306,000	£340,000	£374,000	Base	£340,000	Per home.co.uk guidance prices.
London Households	2	2,970,000	3,300,000	3,630,000	Base	3,300,000	Per Greater London Authority.
% in Central London	2	22.8%	25.3%	27.8%	Base	25.3%	We apply noise reduction only to those in Central London
Property Price Decrease per Decibel (%)	2	0.160%	0.200%	0.240%	Base	0.200%	One-half standard deviation around Lake et al's key finding that each decibel increase results in a 0.200% decrease in home price.
Total Value of Noise Reduction per Decibel						£567,732,000	Noise reduction value per decibel per home times number of homes.
Congestion							
Annual Estimated Cost of Congestion - UK	2	£18,000,000,000	£20,000,000,000	£22,000,000,000	Base	£20,000,000,000	Estimated annual cost of congestion per Smith (1999).
London Share	2	22.5%	25.0%	27.5%	Base	25.0%	Based on approximate historical London share of UK GDP.
London Cost of Congestion (£ Annual)						£5,000,000,000	Product of cost of congestion and London share.
Public Perception							
Annual Value	2	£4,500,000	£5,000,000	£5,500,000	Base	£5,000,000	Based on interviews.
COSTS							
Government Support / Costs							
TfL Support per Additional Bay	2	£275	£300	£325	Base	£300	Based on approximate historical support per bay. Assumed to continue in step with additional bays.
Congestion Charge per Annum per Car	2	£2,050	£2,278	£2,506	Base	£2,278	Base case is cost to purchase a one year congestion charge pass.
% Joiners using One Year Congestion Pass	2	5.0%	10.0%	15.0%	Base	10.0%	Base case assumes 10% of car club users previously paid this, based on usage surveys.
						£227.80	
Vehicle Registration Cost per Car	2	£50	£55	£61	Base	£55	One time charge per car removed per year. £55 as of Feb 2012.
VED Road Tax / Registration	2	£93	£103	£113	Base	£103	Annual tax, thus each year more cars are removed, taxes lost increases. Low and high are -/+ 10% from base.
Research Studies - Annual Support (£)	2	£108,000	£120,000	£132,000	Base	£120,000	Base case is 25% of current annual support of £480,000 for car clubs. Low and high are -/+ 10% from base.
Marketing/Advertising Spend per Year	2	£64,800	£72,000	£79,200	Base	£72,000	Base case is 15% of current annual support of £480,000 for car clubs. Low and high are -/+ 10% from base.
OTHER ASSUMPTIONS							
Social Discount Rate	2	1.2%	1.3%	3.0%	Base	1.3%	See main document for discussion of social and consumer discount rates.
Estimated UK Car Fleet - 2011	2	27,000,000	30,000,000	33,000,000	Base	30,000,000	Per BERR report
% vehicles in London	2	8.1%	9.0%	9.9%	Base	9.0%	
Cars in London						2,700,000	

Appendix E.
Additional Model Snapshots
Assumptions Dashboard – Car Clubs CBA at the Consumer Level

ASSUMPTIONS - CONSUMER COST BENEFIT							
Driving Habits							
Average Miles/Year Before Joining	2	2,070.9	2,301.0	2,531.1	Base	2,301.0	Car club joiners drive substantially fewer miles than typical UK car drivers.
Length of Average Trip After Joining (Miles)	2	30.3	37.3	44.4	Base	37.3	Based on survey data.
Average # Trips / Year After Joining	2	8.4	9.7	14.4	Base	9.7	Based on survey data.
Time Length of Average Trip After Joining (Hours)	2	5.4	6.8	9.0	Base	6.8	Based on survey data.
Average Miles/Year After Joining						361.8	
Average Annual Hours/Year After Joining						66.0	
BENEFITS							
Cost Savings							
Car Reduction per Member	2	0.38	0.42	0.46	Base	0.42	Based on survey data.
Percentage Members Foregoing New Vehicle Purchase	2	25%	28%	31%	Base	28%	Based on survey data.
Value of Foregone Vehicle Purchase	2	£15,475.5	£17,195.0	£18,914.5	Base	£17,195.0	Only year 0 - based on cars removed / member. Based on price of most common car in London, Honda Civic.
Savings from Foregone Vehicle Purchase						£4,814.60	Product of percent members forgoing new vehicle purchase and purchase price.
Annual Standing Costs (£ / annum)							
Insurance	2	£367.0	£407.8	£448.6	Base	£407.8	Based on survey data.
Depreciation	2	£932.5	£1,036.1	£1,139.8	Base	£1,036.1	Based on survey data.
Breakdown Cover	2	£45.0	£50.0	£55.0	Base	£50.0	Based on survey data.
VED Road Tax	2	£92.6	£102.9	£113.2	Base	£102.9	Based on survey data.
Cost of Capital / Leasing Cost	2	£143.6	£159.6	£175.6	Base	£159.6	Based on survey data.
Annual Running Costs (Variable by Miles)							
Fuel							
Miles per Liter - Average Car	2	11.709	13.010	14.311	Base	13.010	Based on survey data.
£ / Liter Cost	2	£1.206	£1.340	£1.474	Base	£1.340	Based on survey data.
Fuel Cost / Mile						£0.103	
Savings on Fuel Costs						£99.5	
Service / Labour/ Parts / Tyres Costs	2	£0.072	£0.080	£0.088	Base	£0.080	Based on survey data.
Total Service / Labour Costs Savings						£77.3	
Parking	2	-£100	£0	£100	Base	£0	Assumed neutral (see main doc).
Congestion Charging	2	-£100	£0	£100	Base	£0	Assumed neutral (see main doc).
COSTS							
Cost of Membership							
Average Annual Membership Fee	2	£50.0	£54.8	£59.5	Base	£54.8	Based on industry data.
Weighted Average Hourly Cost	2	£5.56	£6.18	£6.79	Base	£6.18	Average annual membership costs
Variable Mileage Fee	2	£0.22	£0.24	£0.26	Base	£0.24	Based on industry data.
Free Mileage (first x miles are free) (miles)	2	0.0	20.0	40.0	Base	20.0	Based on industry data.
Total Average Annual Membership Cost						£466.2	
Total Convenience Cost per Round Trip	2	£1.37	£1.52	£1.67	Base	£1.52	Based on industry data.
Total Convenience Cost / Year						£14.74	
OTHER ASSUMPTIONS							
Consumer Discount Rate	2	2.0%	3.9%	5.0%	Base	3.9%	See main document for discussion of social and consumer discount rates.
Inflation Rate	2	2.0%	3.0%	4.0%	Base	3.0%	Based assumed at 3%.

Appendix E.
Additional Model Snapshots
Market Sizing Output – Car Clubs

MARKET SIZING - CAR CLUB USERS

CLICK + TO EXPAND

	HISTORICAL					PROJECTED									
	Year ending 31 December					Year ending 31 December									
	2007	**2008**	**2009**	**2010**	**2011E**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total Users - UK	32,000	64,000	112,298	161,172	231,317	312,278	405,961	507,451	608,941	700,283	770,311	847,342	932,076	978,680	1,027,614
% Change		*100.0%*	*75.5%*	*43.5%*	*43.5%*	*35.0%*	*30.0%*	*25.0%*	*20.0%*	*15.0%*	*10.0%*	*10.0%*	*10.0%*	*5.0%*	*5.0%*
Vehicles			2,259	3,055	4,626	6,246	8,119	10,149	12,179	14,006	15,406	16,947	18,642	19,574	20,552
% Change				*35.2%*	*51.4%*	*35.0%*	*30.0%*	*25.0%*	*20.0%*	*15.0%*	*10.0%*	*10.0%*	*10.0%*	*5.0%*	*5.0%*
Users/Vehicle			49.7	52.8	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
% Change				*6.1%*	*-5.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total Users - London	**30,000**	**60,000**	**90,000**	**133,135**	**196,944**	**265,874**	**345,636**	**432,045**	**518,454**	**596,222**	**655,845**	**721,429**	**793,572**	**833,250**	**874,913**
% Change	*NA*	*100.0%*	*50.0%*	*47.9%*	*47.9%*	*35.0%*	*30.0%*	*25.0%*	*20.0%*	*15.0%*	*10.0%*	*10.0%*	*10.0%*	*5.0%*	*5.0%*
% of UK Users	*93.8%*	*93.8%*	*80.1%*	*82.6%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*	*85.1%*
Growth Scenarios															
% Change						***Growth Assumptions (edit below)***									
Low		*100.0%*	*50.0%*	*47.9%*	*47.9%*	*25.0%*	*20.0%*	*15.0%*	*10.0%*	*5.0%*	*5.0%*	*5.0%*	*3.0%*	*3.0%*	*3.0%*
Base		*100.0%*	*50.0%*	*47.9%*	*47.9%*	*35.0%*	*30.0%*	*25.0%*	*20.0%*	*15.0%*	*10.0%*	*10.0%*	*10.0%*	*5.0%*	*5.0%*
High		*100.0%*	*50.0%*	*47.9%*	*47.9%*	*40.0%*	*35.0%*	*30.0%*	*25.0%*	*25.0%*	*15.0%*	*15.0%*	*15.0%*	*10.0%*	*10.0%*
Users															
Low	30,000	60,000	90,000	133,135	196,944	246,180	295,415	339,728	373,701	392,386	412,005	432,605	445,583	458,951	472,719
Base	30,000	60,000	90,000	133,135	196,944	265,874	345,636	432,045	518,454	596,222	655,845	721,429	793,572	833,250	874,913
High	30,000	60,000	90,000	133,135	196,944	275,721	372,223	483,891	604,863	756,079	869,491	999,914	1,149,902	1,264,892	1,391,381
Implied Vehicles (Bays) - London			1,810	2,524	3,939	5,317	6,913	8,641	10,369	11,924	13,117	14,429	15,871	16,665	17,498
Population of London	7,602,200	7,668,300	7,753,600	7,825,200	7,900,500	7,983,380	8,066,260	8,149,140	8,232,020	8,314,900	8,368,300	8,421,700	8,475,100	8,528,500	8,581,900
% Change		*0.9%*	*1.1%*	*0.9%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*
Adult population with Driving License				3,871,128	3,909,839	3,948,938	3,988,427	4,028,311	4,068,594	4,109,280	4,150,373	4,191,877	4,233,796	4,276,134	4,318,895
% Change					*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*
Members as a % of Eligible Population (Penetration)				***3.4%***	***5.0%***	***6.7%***	***8.7%***	***10.7%***	***12.7%***	***14.5%***	***15.8%***	***17.2%***	***18.7%***	***19.5%***	***20.3%***
Cars removed (Cumulative)			36,209	50,471.23	78,777	106,350	138,254	172,818	207,382	238,489	262,338	288,572	317,429	333,300	349,965
Cars removed (by Year)				14,262	28,306	27,572	31,905	34,564	34,564	31,107	23,849	26,234	28,857	15,871	16,665
Frost and Sullivan Assumption - CAGR	41.7%														
Users - London	30,000	60,000	90,000	133,135	188,652	267,320	378,793	536,749	760,574	1,077,733	NA	NA	NA	NA	NA
% Change		*100.0%*	*50.0%*	*47.9%*	*41.7%*	*41.7%*	*41.7%*	*41.7%*	*41.7%*	*41.7%*	*NA*	*NA*	*NA*	*NA*	*NA*
CarPlus Assumption - CAGR	22.4%														
Users - London	30,000	60,000	90,000	133,135	162,891	199,297	243,840	298,338	365,016	446,597	546,412	668,535	817,952	1,000,765	1,224,436
% Change		*100.0%*	*50.0%*	*47.9%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*	*22.4%*
Midpoint															
Users - London	30,000	60,000	90,000	133,135	175,771	232,062	306,380	404,499	534,039	705,065	NA	NA	NA	NA	NA
% Change		*100.0%*	*50.0%*	*47.9%*	*32.0%*	*32.0%*	*32.0%*	*32.0%*	*32.0%*	*32.0%*	*NA*	*NA*	*NA*	*NA*	*NA*

Appendix E.
Additional Model Snapshots
Emissions and Noise Assumptions – Car Clubs

EMISSIONS AND NOISE ASSUMPTIONS - PROJECTION
CLICK + TO EXPAND

	HISTORICAL Year ending 31 December					PROJECTED Year ending 31 December									
	2007	**2008**	**2009**	**2010**	**2011E**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Car Club Users	30,000	60,000	90,000	133,135	196,944	265,874	345,636	432,045	518,454	596,222	655,845	721,429	793,572	833,250	874,913
Car Club Users (Growth in Members)		30,000	30,000	43,135	63,809	68,930	79,762	86,409	86,409	77,768	59,622	65,584	72,143	39,679	41,663
Car Club Cars			1,810	2,524	3,939	5,317	6,913	8,641	10,369	11,924	13,117	14,429	15,871	16,665	17,498
Car Club Cars (Growth in Number)				713	1,415	1,379	1,595	1,728	1,728	1,555	1,192	1,312	1,443	794	833
Removal of Cars															
Beginning Number of Cars					2,700,000	2,671,694	2,644,122	2,612,217	2,577,653	2,543,090	2,511,982	2,488,133	2,461,900	2,433,042	2,417,171
Net Vehicles Removed/Club Car				20	20	20	20	20	20	20	20	20	20	20	20
Total Cars Removed/Year				**14,262**	**28,306**	**27,572**	**31,905**	**34,564**	**34,564**	**31,107**	**23,849**	**26,234**	**28,857**	**15,871**	**16,665**
Ending Number of Cars					2,671,694	2,644,122	2,612,217	2,577,653	2,543,090	2,511,982	2,488,133	2,461,900	2,433,042	2,417,171	2,400,506
Regular Vehicle Emissions/Car/User/Year (tons CO2)					5.200	5.200	5.200	5.200	5.200	5.200	5.200	5.200	5.200	5.200	5.200
Tons CO2 Reduction/Year - Cars Removed					**147,192**	**143,375**	**165,905**	**179,731**	**179,731**	**161,758**	**124,014**	**136,416**	**150,057**	**82,531**	**86,658**
Usage and Efficiency Differences															
Tons CO2 Emissions if All Club Cars Standard					20,482	27,651	35,946	44,933	53,919	62,007	68,208	75,029	82,531	86,658	90,991
Percent Efficiency Gained					26.0%	26.0%	26.0%	26.0%	26.0%	26.0%	26.0%	26.0%	26.0%	26.0%	26.0%
Tons CO2 Reduction/Year - Usage and Efficiency Savings					**5,325**	**7,189**	**9,346**	**11,683**	**14,019**	**16,122**	**17,734**	**19,507**	**21,458**	**22,531**	**23,658**
Total tons CO2 reduction (by Year)					**152,518**	**150,564**	**175,251**	**191,413**	**193,750**	**177,880**	**141,748**	**155,923**	**171,515**	**105,063**	**110,316**
Assumed Cost of Carbon (in £2011 / ton CO2)						***EU Emissions Trading Cost per Ton CO2 (per DECC)***									
Low					106.0	107.6	109.2	110.9	112.5	114.2	115.9	117.7	119.4	121.2	123.3
Base					212.1	215.2	218.5	221.8	225.1	228.5	231.9	235.4	238.9	242.5	246.5
High					318.1	322.9	327.7	332.6	337.6	342.7	347.8	353.0	358.3	363.7	369.8
Total Cars Removed thru 2021						271,188									
% of Beginning % of Cars						10.04%									
Associated Noise Reduction (dB)						(0.35)									
Total Value - Noise Reduction (£)						**198,706,200**									
Total Value - Congestion Reduction (£)						**502,199,491**									

Appendix E.
Additional Model Snapshots
Assumptions Dashboard – EV CBA at the Public Sector Level

ASSUMPTIONS DASHBOARD - PUBLIC SECTOR COST BENEFIT							
CLICK + TO EXPAND		1	2	3			
	Choose	Low	Base	High	Selected		Notes
Market Sizing (Users) - Electric Vehicles							
Net Car Differential per Electric Vehicle	2	-0.25	0.00	0.25	Base	0	Each EV is assumed to displace one internal combustion engine car. Based on survey data.
Adult Population with Driving License - Growth	2	0.5%	1.0%	1.5%	Base	1.0%	Growth assumed constant. Based on historical London population growth.
Growth Scenario	2		*See projection curves below (in Yellow)*		Base		Cases based on an early stage product life cycle fit to various estimated curves of car club user growth.
BENEFITS							
Emissions and Clean Air							
CO2 Emissions per Regular Car (Tons CO2 / year)	2	4.68	5.20	5.72	Base	5.20	Average passenger vehicle produces 5.2 metric tons CO2 per year.
ICE Wheel to Well efficiency (grams CO2 / km)	2	147.00	154.15	161.30	Base	154.15	Per SMMT report.
EV Wheel to Well efficiency (grams CO2 / km)	2	69.30	77.00	84.70	Base	77.00	Per SMMT report.
Percent reduction in CO2 (EV versus ICE)						50.0%	% change in figures above.
Implied Carbon Reduction per EV (Tons CO2 / year)						2.60	Product of CO2 emissions per regular car and percent reduction per EV.
Value of Clean Air per Tonne CO2 Removed	2	27.911	31.013	34.114	Base	31.013	Based on University of Wisconsin compilation of studies examining the value of health benefits per ton CO2. Low and high are -/+ 10% from base.
Carbon							
Cost of Carbon (£/mgCO2)	2		*See projection curves below (in Yellow)*		Base		Per Department of Energy and Climate Change guideline carbon values.
Noise Reduction							
Avg Noise Level of Regular ICE Cars (dB)	2	50	55	61	Base	55	Per Nissan.
Avg Noise Level of EV Cars (dB)	2	43	48	53	Base	48	Per Nissan.
% EV Noise Difference versus ICE						-12.727%	Calculated from above.
Median London Home Price	2	£306,000	£340,000	£374,000	Base	£340,000	Per home.co.uk guidance prices.
London Households	2	2,970,000	3,300,000	3,630,000	Base	3,300,000	Per Greater London Authority.
% in Central London	2	22.8%	25.3%	27.8%	Base	25.3%	
Property Price Decrease per Decibel (%)	2	0.160%	0.200%	0.240%	Base	0.200%	One-half standard deviation around Lake et al's key finding that each decibel increase results in a 0.200% decrease in home price.
Total Value of Noise Reduction per Decibel						£567,732,000	Noise reduction value per decibel per home times number of homes.
Congestion							
Annual Estimated Cost of Congestion - UK	2	£18,000,000,000	£20,000,000,000	£22,000,000,000	Base	£20,000,000,000	Estimated annual cost of congestion per Smith (1999).
London Share	2	22.5%	25.0%	27.5%	Base	25.0%	Based on approximate historical London share of UK GDP.
London Cost of Congestion (£ Annual)						£5,000,000,000	Product of cost of congestion and London share.
Government Revenues							
Sharing Network Memberships	2	£90	£100	£110	Base	£100	Per London government.
Percent EV Users Using Car for Work (i.e. owning memberships)	2	9.0%	10.0%	11.0%	Base	10.0%	Based on survey data.
Public Perception/Direct Investment							
Annual Value	2	£4,500,000	£5,000,000	£5,500,000	Base	£5,000,000	Per interviews.
Gross Value Added from EV Job Sector per Annum (London)	2	£30,600,000	£34,000,000	£37,400,000	Base	£34,000,000	Per Ernst & Young report p. 26. Net of spillover effects.
Original Planned EV Infrastructure (Charging Points) - 2013	2	7,500	7,500	7,500	Base	7,500	Per original London government guidelines.
Updated Planned EV Intrastructure (Charging Points) - 2013	2	1,300	1,300	1,300	Base	1,300	Per updated London government guidelines.
Net Gross Value Added from EV Job Sector per Annum (London)	2	£30,600,000	£34,000,000	£37,400,000	Base	£5,893,333	GVA reduced to reflect reduced plans for infrastructure.
COSTS							
Government Support / Costs							
Lost Revenue per Year per Parking Space Used as Charging Point	2	£139	£155	£170	Base	£155	Based on Southwark Council annual report of parking fees throughout London.
TfL Support for Source London	2	£5,940,000	£6,600,000	£7,260,000	Base	6,600,000.0	Assumed same as private charger install cost.
Average Car Mileage per Year - % lower	2	8.0%	10.0%	15.0%	Base	10.0%	
Plug-In Car Grant (Cost / Vehicle)	2	4,500	5,000	5,500	Base	5,000	
Year of Plug In Grant Termination	2	2012	2013	2020	Base	2013	Grant is currently scheduled to run until March 31, 2014. Currently only the first £43 million (or 8,600 cars) are guaranteed.
Plugged In Places Programme	2	8,370,000	9,300,000	10,230,000	Base	9,300,000	Cost to be spread over 3 years
Vehicle Excise Tax Exemption (per Vehicle)	2	140	155	171	Base	155	
Year of Excise Tax Exemption Termination	2	2012	2013	2020	Base	2013	Assumed to expire at same time as Plug-In Car Grant.
Showroom Tax (first year only)	2	140	155	171	Base	155	
Year of Excise Exemption Termination	2	2012	2013	2020	Base	2013	Assumed to expire at same time as Plug-In Car Grant.
Congestion Charge (per car per year)	2	205	228	251	Base	228	Base case is cost to purchase a one year congestion charge pass. Assumes 10% of EV owners previously paid this.
Year of Congestion Charge Exemption Termination	2	2012	2013	2020	Base	2013	Assumed to expire at same time as Plug-In Car Grant.
Fuel Duties Avoided	2	557	619	681	Base	619	Based on SMMT report. This is at the UK level, not TfL - thus cost is 0. Factors into consumer benefits but not into public sector costs.
OTHER ASSUMPTIONS							
Social Discount Rate	2	1.2%	1.3%	3.0%	Base	1.3%	
Estimated UK Car Fleet - 2011	2	27,000,000	30,000,000	33,000,000	Base	30,000,000	Per BERR report
% vehicles in London	2	8.1%	9.0%	9.9%	Base	9.0%	
Cars in London						2,700,000	

Appendix E.
Additional Model Snapshots
Assumptions Dashboard – EV CBA at the Individual Consumer Level

ASSUMPTIONS DASHBOARD - CONSUMER COST BENEFIT							
Driving Habits							
Average Miles/Year Before EV	2	4,921.2	5,468.0	6,014.8	Base	5,468.0	Average midpoint figure per Institute of Mech Engineers report
% Reduction in Miles/Year After EV	2	10%	15%	20%	Base	15.0%	
BENEFITS							
Reduced Maintenance (savings per year over ICE)	2	£44	£49	£54	Base	49.3	Per SMMT report
(Other Benefits driven by Public Sector COSTS, see above)							
COSTS							
EV Cost over Traditional Car	2	£8,650	£9,650	£10,650	Base	9,650.0	Average price of a pure EV is £29,300, while the one of ICE is £19,650.
Garage Charger Installation	2	562.5	£625	687.5	Base	625.0	Midpoint of range cited by Greencar. First year only.
Charging Network Membership	2	£90	£100	£110	Base	100.0	
Proportion of EV Users Using Charging Network Membership	2	11.8%	13.1%	14.4%	Base	0.1	
Charging Time Value per Year	2	1,226.7	1,363.0	1,499.3	Base	1,363.0	
OTHER ASSUMPTIONS							
Consumer Discount Rate	2	2.0%	3.9%	5.0%	Base	3.9%	
Inflation Rate	2	2.0%	3.0%	4.0%	Base	3.0%	

Appendix E.
Additional Model Snapshots
EV Market Sizing

MARKET SIZING - EV USERS

CLICK + TO EXPAND

	HISTORICAL					PROJECTED									
	Year ending 31 December					Year ending 31 December									
	2007	**2008**	**2009**	**2010**	**2011E**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total EV Users - London			**1,700**	**9,350**	**17,000**	**25,500**	**36,975**	**51,765**	**69,883**	**90,848**	**113,559**	**130,593**	**150,182**	**165,201**	**173,461**
% Change				*450.0%*	*81.8%*	*50.0%*	*45.0%*	*40.0%*	*35.0%*	*30.0%*	*25.0%*	*15.0%*	*15.0%*	*10.0%*	*5.0%*
Total Charging Points - London (Implied after 2011)					250	1,020	1,479	2,071	2,795	3,634	4,542	5,224	6,007	6,608	6,938
Users / Charging Point					68	25	25	25	25	25	25	25	25	25	25
Charging Points Added by Year						770	459	592	725	839	908	681	784	601	330
Growth Scenarios															
% Change						***Growth Assumptions (edit below)***									
Low				*450.0%*	*81.8%*	*45.0%*	*40.0%*	*35.0%*	*30.0%*	*25.0%*	*20.0%*	*10.0%*	*10.0%*	*5.0%*	*5.0%*
Base				*450.0%*	*81.8%*	*50.0%*	*45.0%*	*40.0%*	*35.0%*	*30.0%*	*25.0%*	*15.0%*	*15.0%*	*10.0%*	*5.0%*
High				*450.0%*	*81.8%*	*55.0%*	*50.0%*	*45.0%*	*40.0%*	*35.0%*	*30.0%*	*20.0%*	*20.0%*	*10.0%*	*10.0%*
Users															
Low			1,700	9,350	17,000	24,650	34,510	46,589	60,565	75,706	90,848	99,932	109,926	115,422	121,193
Base			1,700	9,350	17,000	25,500	36,975	51,765	69,883	90,848	113,559	130,593	150,182	165,201	173,461
High			1,700	9,350	17,000	26,350	39,525	57,311	80,236	108,318	140,814	168,976	202,772	223,049	245,354
Population of London	7,602,200	7,668,300	7,753,600	7,825,200	7,900,500	7,983,380	8,066,260	8,149,140	8,232,020	8,314,900	8,368,300	8,421,700	8,475,100	8,528,500	8,581,900
% Change		*0.9%*	*1.1%*	*0.9%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*
Adult population with Driving License				3,871,128	3,909,839	3,948,938	3,988,427	4,028,311	4,068,594	4,109,280	4,150,373	4,191,877	4,233,796	4,276,134	4,318,895
% Change					*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*
Members as a % of Eligible Population (Penetration)				*0.2%*	*0.4%*	*0.6%*	*0.9%*	*1.3%*	*1.7%*	*2.2%*	*2.7%*	*3.1%*	*3.5%*	*3.9%*	*4.0%*

Electric Vehicles Estimates		
Mayor Target = 100,000 EV's (5% of total fleet)	100,000	to be reached 'as soon as possible'
UK Committee on Climate Change	153,000	to be reached by 2020
Charging Point Estimates		
Target = 1,300 charge points by 2013	1,300	per news article
TfL Estimates	7,500	by 2013
	25,000	by 2015

Appendix E.
Additional Model Snapshots
Emissions and Noise Assumptions – EVs

EMISSIONS AND NOISE ASSUMPTIONS - PROJECTION

CLICK + TO EXPAND

	HISTORICAL					PROJECTED									
	Year ending 31 December					Year ending 31 December									
	2007	**2008**	**2009**	**2010**	**2011E**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
EV Users			1,700	9,350	17,000	25,500	36,975	51,765	69,883	90,848	113,559	130,593	150,182	165,201	173,461
EV Users (Growth in Members)			1,700	7,650	7,650	8,500	11,475	14,790	18,118	20,965	22,712	17,034	19,589	15,018	8,260
CO2 Efficiency Savings per EV (assuming same usage)			2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Usage Difference Factor - % Fewer Miles Driven per Year			0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Tons CO2 reduction from Vehicle Efficiencies (by Year)			**5,088**	**22,896**	**22,896**	**25,440**	**34,344**	**44,265**	**54,225**	**62,746**	**67,975**	**50,981**	**58,628**	**44,948**	**24,722**
Beginning Number of Total Car Fleet					2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000
Net Cars Removed from EVs					-	-	-	-	-	-	-	-	-	-	-
Ending Number of Cars					2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000	2,700,000
% EV's of Total Cars					0.63%	0.94%	1.37%	1.92%	2.59%	3.36%	4.21%	4.84%	5.56%	6.12%	6.42%
Population of London	7,602,200	7,668,300	7,753,600	7,825,200	7,900,500	7,983,380	8,066,260	8,149,140	8,232,020	8,314,900	8,368,300	8,421,700	8,475,100	8,528,500	8,581,900
% Change		*0.9%*	*1.1%*	*0.9%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*	*0.6%*
Adult population with Driving License				3,871,128	3,909,839	3,948,938	3,988,427	4,028,311	4,068,594	4,109,280	4,150,373	4,191,877	4,233,796	4,276,134	4,318,895
% Change					*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*	*1.0%*
Members as a % of Eligible Population (Penetration)				***0.2%***	***0.4%***	***0.6%***	***0.9%***	***1.3%***	***1.7%***	***2.2%***	***2.7%***	***3.1%***	***3.5%***	***3.9%***	***4.0%***
Total Other ICE Cars Removed per EV (beyond first car)			0	0	0	0	0	0	0	0	0	0	0	0	0
Average CO2 Annual Output per ICE Car			5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Tons CO2 reduction from Other ICE Cars removed			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Tons CO2 Reduction by Year			**5,088**	**22,896**	**22,896**	**25,440**	**34,344**	**44,265**	**54,225**	**62,746**	**67,975**	**50,981**	**58,628**	**44,948**	**24,722**
Total Cars Removed						0									
Ending Percent of Cars EV						6.42%									
Percent Lower Noise (EV versus ICE)						12.73%									
Effective Percent Fewer Cars						5.61%									
Associated Noise Reduction (dB)						(0.10)									
Total Value - Noise Reduction (£)						**£56,773,200**									
Total Value - Congestion Reduction (£)						**£0**									
Assumed Cost of Carbon (in £2011 / ton CO2)						***EU Emissions Trading Cost per Ton CO2 (per DECC)***									
Low					106.0	107.6	109.2	110.9	112.5	114.2	115.9	117.7	119.4	121.2	123.3
Base					212.1	215.2	218.5	221.8	225.1	228.5	231.9	235.4	238.9	242.5	246.5
High					318.1	18.5	20.0	21.3	23.5	26.5	27.8	30.8	32.7	35.5	36.0