WORKING
PAPER

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Bringing the electric vehicle to the mass market

a review of barriers, facilitators and policy interventions

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Preface

This project is internally funded by RAND Europe's Direct Investment Programme and aims to develop an understanding of the factors affecting the wider adoption of electric vehicles. The project consists of two main phases: (i) a review of barriers and relevant government interventions; and (ii) a survey to determine the potential uptake of electric vehicles, using Cambridge, UK, as a case study.

This Working Paper is the output from the first phase of the project. It provides an overview of the barriers and facilitators to the wider adoption of electric vehicles (EVs), and describes a variety of EV initiatives currently underway in a pragmatic selection of countries, namely the UK, France, Denmark, and Canada. Our research suggests that subsidising EV purchase costs means spending hundreds of millions of pounds of government funds, but that this would overcome a number of consumer barriers to wider EV uptake. We conclude that the development of recharging infrastructure, which is essential for EVs' transition beyond the niche market, would rely on the success of public-private collaboration. Additionally, better information and more outreach programmes are needed to help consumers understand and take full advantage of existing EV technology. Finally, dependence on government support involves some uncertainties, especially in the current economic climate.

While this review has been undertaken with the primary purpose of informing the design of a survey about the potential uptake of electric vehicles, it could also be used as a stand-alone resource for readers, researchers or policy makers with an interest in EV uptake and related policies. RAND Europe is an independent, not-for-profit policy research organisation that aims to improve policy and decision making in the public interest, through research and analysis. RAND Europe's clients include European governments, institutions, NGOs and firms with a need for rigorous, independent, multidisciplinary analysis. This report has been peer-reviewed in accordance with RAND's quality assurance standards. For more information about RAND Europe or this document, please contact:

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List of abbreviations

ADEME: French Agency for the Environment and Energy Management

BEV: Battery electric vehicle

CAD: Canadian dollars

CFCR: Combined Fuel Consumption Rating

CO_2: Carbon dioxide

COP15: Council of the Parties number 15

DEA: Danish Energy Agency

DfT: UK Department for Transport

DKK: Danish Krone

DOE: US Department of Energy

DONG: Danish Oil and Natural Gas

EDISON: Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks

EEDA: East of England Development Agency

EME: Espace Mobilités Electriques

EPA: US Environmental Protection Agency

EPAMSA: Contracting authority for Seine Aval (Établissement public d'aménagement du Mantois en Seine Aval)

eTV: eco-TECHNOLOGY for Vehicles programme

EU: European Union

EV: Electric vehicle

GHG: Greenhouse gas

GLA: Greater London Authority

HEV: Hybrid electric vehicle

HFCV: Hydrogen Fuel Cell Vehicle

HM: Her Majesty's

HV: Hybrid Vehicles

ICE: Internal combustion engine

kWh: kilo Watt-hour

LPGV: Liquefied petroleum gas vehicle

LSV: Low speed vehicle

MBA: Master of Business Administration

MOST: Moving On Sustainable Transportation

NGPV: Natural Gas Powered Vehicle

NINJ: New Industry: New Jobs government framework

OVE: Observatoire du Véhicule d'Entreprise

PHEV: Plug-in hybrid electric vehicle

RAC: Royal Automobile Club

RAE: Royal Academy of Engineering

RD&D: Research, Development and Demonstration

TC: Transport Canada

TfL: Transport for London

TSB: UK's Technology Strategy Board

UK: United Kingdom

ULCVs: Ultra-low carbon vehicles

US: United States

WtC: Willingness to consider (a vehicle platform)

ZENN: Zero Emissions, No Noise electric vehicle

Executive summary

The objectives of this review are to provide:

- an overview of what is known about consumers' preferences and behaviour, which may serve as barriers or facilitators for wider adoption of electric vehicles; and,
- examples of electric vehicle-related government policies implemented or proposed in different parts of the world.

The choice of countries for inclusion in our review was based on our aim to include countries with approaches to the development of the electric vehicle (EV) that could be compared and contrasted with those of the UK. The examples discussed have been chosen to cover a range of EV initiatives in countries of differing size, different histories of investment in the automotive industry and new technologies, as well as different structures of electricity provision and renewable energy policies. It was also driven by an element of pragmatism in relation to the availability and accessibility of literature on various countries and the resources (e.g. language proficiency) available to carry out this review. For these reasons we chose to focus on the UK, France, Denmark and Canada.

There are many barriers to purchasing EVs, but also some facilitators

We identify a number of barriers to EV market expansion: some are technological, some social or perceptual, and some institutional. We first provide a summary of these barriers and then discuss how policy interventions may overcome some of them. The limitations around battery technology include:

- limited all-electric drive range (typically around 100 miles);
- long recharge time (typically 6-8 hours for a full charge).

Limitations in battery technology drive the high cost of batteries; hence vehicle prices are at least £15,000 more expensive than conventional (non-electric) UK passenger cars.

Central to the recharging problem is the lack of sufficient charging infrastructure and other infrastructure elements such as overnight parking dedicated to EVs. Additionally, there are concerns related to collision safety, electrical safety and the lack of engine noise.

EVs are more fuel efficient than conventional vehicles, but fuel efficiency is not a feature that is highly valued by consumers, who generally put a low value on future savings. Some consumers misunderstand the benefits of fuel economy and some associate EVs with "cheap" design. Even those who see themselves as environmental-friendly do not necessarily back up this self-proclaimed attitude with the action of purchasing EVs.

Additional barriers to EV market expansion are institutional, in the form of resistance from industry giants. We have reviewed the notable example of resistance from the automotive industry in the fierce campaign in California against the zero emissions mandate in 2001, which resulted in an end to the mandate and a temporary halt in EV development by US carmakers. However, the landscape has changed dramatically here, as many major motor manufacturers are now developing EVs such as the Nissan Leaf and the Chevy Volt.

Despite the significant number of barriers, some factors could facilitate the transition of EVs to the mass market. These factors include the effect of incentives and low running costs as well as innovations in the supporting infrastructure. At a social level, the symbolic value of the EV could encourage consumer purchase, especially among early adopters. Further market penetration could be facilitated by social processes, such as direct communication about personal experiences with EVs. In addition, the entrance of luxury car makers, such as Lotus, Porsche and Ferrari, to the EV market may reverse the perception of electric vehicles as "feeling cheaply designed" and "slow".

A plethora of government interventions

Governments around the world have launched a plethora of policies and programmes to overcome these barriers. We have chosen to focus on UK, Denmark, France and Canada, drawing examples from the initiatives currently underway in these countries. These government policies and programmes can be broadly classified into seven categories:

- **Subsidy to purchase cost**: an approach taken by all the countries reviewed. The amount is typically around £4200-£5200 per vehicle. Eligibility for government support differs by country and by scheme, but the recent interventions tend to focus on 'grid-connected' vehicles, i.e. plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).
- **Subsidy to car manufacturers**: in the UK, for example, the Nissan Sunderland plant has received £20.7m in government grants and up to £220m from the European Investment Bank, with the expectation that this policy would lead to the creation of 350-600 new jobs.
- **Subsidy to research and development**: an example is the UK's Technology Strategy Board (TSB)'s £1.3m investment in the development of a new, lightweight battery for use in electric, small, city cars to improve their performance, functionality and range.
- **Infrastructure development**: installing fast charging points and reliable, readily accessible power outlets is seen as essential by governments. However, the funding committed is an order of magnitude lower than the funding committed to subsidising purchase. Instead, there is substantial private sector investment in the provision of such infrastructure. In particular, there is quite a lot of optimism around the Better Place model.[1] [2]
- **Introducing EVs to commercial/government fleets**: La Poste, the French postal service currently owns the largest EV fleet in France; the Greater London Authority aims to introduce 1,000 EVs to its fleet by 2015.

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[1] Under the "Better Place" model, batteries will be leased, not owned, drivers will be charged by mileage driven, and a dense network of charging points and battery switching stations will be available to support quick "recharging".

[2] In January 2010, two years after the company Better Place started, it raised $350m of investment from a consortium led by HSBC. It is "the largest round of venture capital financing yet for a "clean-tech" company in the US or Europe" (see: Reed J. and Arnold M., "Better Place Draws Investors to 'Clean-Tech'," *Financial Times* 2010.)

- **Providing other preferential access**: in London, EVs are exempt from congestion charge; in central Copenhagen, EVs can park for free; and in Ontario, Canada, single occupancy EVs are allowed in high occupancy lanes.
- **Increasing public familiarity**: while most of the demonstration tests only engage a small segment of the society, the Autolib scheme in Paris would aim to give the general public the opportunity to test drive EVs.

Overcoming the upfront cost barrier

The subsidy to EV purchase is perhaps one of the most notable interventions. In the countries reviewed, the level of subsidy is typically around £4200-£5200 per vehicle, amounting to hundreds of millions of pounds of government funds. Given the large difference between the price of a conventional car and an EV (currently at least £15,000), significant purchase subsidies are required in the short term if a government wants to make EVs more competitive in the car market. This policy can help overcome the demand-side barriers in a consumer environment where potential car buyers do not put a high value on future saving but are sensitive to the upfront cost. However, heavy reliance on government funding to sustain competitiveness brings many uncertainties, particularly given the current budget deficits experienced by most governments in the developed world, which may subsequently result in political pressure to reduce subsidies.

More importantly, the EV's ability to expand its niche market to a mass market would depend on dramatic advances in technology aimed at lowering the cost of battery production while maintaining high vehicle performance. While government subsidies in research and development help in reaching this goal, technological breakthroughs are not guaranteed.

Overcoming consumers' perceptual barriers is equally important for encouraging take-up of EVs

Consumers have not been taking full advantage of the capabilities of current EV technology. Emerging findings from car trial programmes highlight the "range anxiety" issue, i.e. drivers of EVs tend to be overcautious when planning their journeys. In a recent car trial in the North East of England, the longest journey made with an EV was only 25% of the average vehicle range. In-depth interviews with EV owners in Denmark also revealed how initial unfamiliarity with the vehicle led to feelings that the vehicle was underperforming, relative to a conventional vehicle. Programmes to increase familiarity with EVs would be a supplementary intervention to maximise the capabilities of the current technology. In the short term, it would help the early adopters to appreciate their capabilities more fully; and in the long term, early adopters' opinions about EVs would affect the general car buyers' willingness to consider EVs.

Similarly, providing reliable and accessible information for potential EV customers, enabling them to understand and appreciate the benefits of fuel economy is relatively inexpensive for the government to support.

Conclusions

Our research suggests that purchase subsidies mean hundreds of millions of pounds of international government funding is to be spent, but that this would overcome a number of consumer barriers to wider EV uptake. Recharging infrastructure development, which is essential for EVs' transition beyond the niche market, would rely on the success of public-private collaboration. Additionally, better information and more outreach programmes are needed to help customers fully understand and take advantage of the current capability of existing EV technology. However, the dependence on government support results in uncertainty about the long term future of these programmes, especially in the current economic climate.

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CHAPTER 1 Introduction

1.1 Background

Climate change has recently grown in importance on the global political agenda. Governments have begun seriously to address it by implementing legislation to combat environmental issues. The UK Government claims a leadership position in the area of carbon reduction initiatives; under its 2008 Climate Change Act, the UK became the first country in the world to set legally binding carbon budgets (Department of Energy and Climate Change, 2009). The UK is committed to reducing greenhouse gas emissions by 80% by 2050, relative to 1990 levels, and in the shorter term, to cutting emissions by a third by 2020. The UK Committee on Climate Change[3] (CCC) carried out an enquiry to determine whether the current investment in research and innovation in the UK is sufficient to achieve the national climate change goals (Committee on Climate Change, 2010b). The report, published on 18th of July 2010, recommends that, as one of a variety of actions aimed at meeting climate change targets, the government should continue to develop and deploy electric vehicle technologies. The CCC warns against cutting national budgets for energy Research, Development and Demonstration (RD&D), pointing out that the current level of funding for EV-related initiatives (about £250 million) should be maintained and possibly increased towards 2020 in order to meet greenhouse gas (GHG) emission goals. Interestingly, the transport secretary confirmed on the 28th of July 2010 that the government remained committed to achieving its GHG targets, meaning that the "ultra-low carbon vehicle" consumer incentive, worth £43m, would go ahead, despite ongoing government spending discussions and the likelihood of severe budget cuts in other sectors of the UK society.

While these policies may be a step towards cleaner vehicles on UK roads, a big unknown for the wider adoption of electric vehicles is consumer acceptance. Therefore, RAND Europe has self-funded the present research project to identify barriers and facilitators for a large-scale adoption of electric vehicles, with a focus on purchase intentions, trip making patterns, the likely use of the vehicles, attitudes and life-style. In particular, we aim to identify profiles of individuals and consumer types who are most likely to adopt electric vehicles. Cambridge, UK, is used as a case study in order to provide some input for local discussion of facilitating increased EV uptake in Cambridgeshire. For example, building on

[3] The CCC is "an independent body established under the 2008 Climate Change Act to advise the UK Government on setting carbon budgets, and to report to Parliament on the progress made in reducing greenhouse gas emissions" (http://www.theccc.org.uk)

earlier plans, the Cambridgeshire County Council Local Transportation Plan 3 (Onslow, 2011), adopted on March 29 2011, explicitly lays out plans to include the use of electric vehicles to address "Challenge 7: Protecting and enhancing the natural environment by minimising the environmental impact of transport".

As part of the research project is to build an understanding of the factors affecting electric vehicle uptake, the present paper is a review of the literature on the barriers, facilitators and policies for a large-scale adoption of electric vehicles.

1.2 Objectives

The objectives of this review are to:

- provide an overview of what is known about consumers' preferences and behaviour which may serve as barriers or facilitators for wider adoption of electric vehicles; and to
- provide examples of electric vehicle-related government policies implemented or proposed in different parts of the world.

This review was developed with the primary purpose of informing the design of a survey about the potential uptake of electric vehicles, but we hope it will also be of use to readers, researchers or policymakers with an interest in the topic and related policies.

1.3 Why electric vehicles?

In the UK, a quarter of all CO_2 emissions come from transport, and road vehicles represent 90% of this environmental impact (Lytton, 2010). Thus, the decarbonisation of transport could result in substantial carbon emissions reduction. According to Stephen Glaister, director of the RAC Foundation for Motoring, the UK government's current effort in the greening of private and commercial vehicles focuses more on technological advances than on changing drivers' behaviour (Lytton, 2010). This comment was corroborated by the King Review of low-carbon cars, which highlighted that the reduction in road-based CO_2 emissions would come from a number of different sources, including the development of alternative fuels such as hydrogen, continuing improvements in internal combustion engine efficiency and the wider rollout of hybrid powertrains, and lighter weight vehicles (HM Treasury, 2007). Notably, the wider adoption of the most technologically advanced electric vehicles is expected to play a major role in the transition to a decarbonised passenger transport system.

Yet, it should be recognised that electrification is a necessary but not sufficient condition for decarbonisation. What electrification of transport could offer is the potential to substantially reduce direct, i.e. tailpipe emissions, from transport although CO_2 would be still emitted at the point of electricity generation. As pointed out by a recent report by the Royal Academy of Engineering (RAE, 2010), "EVs [battery electric vehicles] and PHEVs [plug-in electric vehicles] can only be as green as the electricity used to charge their batteries".

The question of electricity generation aside, the wider use of electric vehicles alone could still provide benefits in reducing carbon emissions. Even with the current UK energy fuel mix, the wider adoption of EVs could offer significant reductions of the order of approximately 40%[4] (Arup-Cenex, 2008). According to David Mackay, the chief scientific advisor to the UK Department of Energy and Climate Change, the energy consumption of the EV is roughly 15 kilowatt hour (kWh) per 100km, which is approximately five times more efficient than the average fossil fuel-powered car (Mackay 2009).

Additionally, because EVs have zero tailpipe emissions, their wider adoption would reduce urban air pollution. According to a recent inquiry by the Environmental Audit Committee at the House of Commons (2010), the number of premature deaths related to air pollution is 35,000 per year. Therefore, the health benefits of wider EV adoption could be substantial.

1.3.1 Types of electric vehicles

There are three main types of vehicles which are propelled by electric motors and which get their energy from a battery: hybrid electric, plug-in hybrid and battery electric vehicles.

Battery electric vehicles

The Battery electric vehicles (BEVs), also known as the all-electric, the full-electric or the pure-electric vehicle, is powered solely by an electric motor and has no internal combustion engine (ICE). The battery is charged entirely by electricity from the grid. As the battery is the sole power source, BEVs tend to be equipped with powerful lithium-ion batteries with a capacity of typically 20 kWh or more than 50kWh for high performance models (Lytton, (2010); Perugo and Ciuffo, (2010)). Some common examples of the BEV are: the G-Wiz, the Tesla Roadster, the Nissan Leaf and Mitsubishi i-MiEV.

Plug-in hybrid electric vehicles

Plug-in hybrid electric vehicles (PHEVs) have an ICE and a battery with up to 40 kWh capacity, typically lithium-based, that could either be charged by the ICE or directly from the grid. They are able to run on electric power alone, at urban speeds, for short distances and have an all-electric range of 5 to 50 miles, according to Lytton (2010). When the all-electric range reaches its range limit, the ICE would kick in and provide power. The PHEV addresses the range issues of the BEV by combining the electric motor and battery with the combustion engine. Examples include: the Toyota Prius Plug-in Hybrid[5] and the Chevrolet Volt.

Hybrid electric vehicles

The hybrid electric vehicle (HEV) used to be known simply as the “hybrid” or the “full hybrid” but nowadays is often referred to as the “conventional hybrid”. It has a battery which is charged by the ICE and by regenerative braking[6] but not from an external source of electricity. Typically, it is capable of pure electric drive at low speeds and for a limited range, equipped with batteries that have up to 30 kWh capacity (Lytton, 2010). We often

[4] The Arup-Cenex analysis considers the full life cycle, taking account of emissions from power generation, production and disposal.

[5] Early versions of the Toyota Prius were HEV and only the 2009 and onwards models of the Toyota Prius are PHEVs.

[6] A key feature of the EV is regenerative braking. While conventional brakes dissipate the energy lost during stopping, EVs capture some of the lost energy and store it in a battery for later use. Regenerative brakes roughly halve the energy lost in braking making them particularly suitable for congested traffic.

hear the terms “micro hybrid” or “mild hybrid”; these are categories representing the extent of electrification and the fuel efficiency provided by the electric motor (“mild hybrid” provides more efficiency gain than the “micro hybrid”). We also often hear the terms “parallel hybrid”, “series hybrid” (or “range-extended electric vehicle”), and “mixed hybrids”. Each of these is a sub-category of the HEV, involving different configurations of batteries and ICEs. We refer interested readers to Lytton (2010) for more information about these configurations. Although it is important to emphasize the distinction between the PHEV and the HEV: the PHEV draws electricity from the grid, whereas the HEV does not. Some common examples of the HEV are the early versions of the Toyota Prius, Honda Insight and Honda Civic Hybrid.

Table 1 presents a comparison of different features across BEVs, PHEVs and HEVs.

Table 1: Comparison of BEVs, PHEVs and HEVs

	Battery electric vehicles (BEVs)	Plug-in hybrid vehicles (PHEVs)	Hybrid electric vehicles (HEVs)
Grid-connected?	Yes	Yes	No
Include an ICE	No	Yes	Yes
All-electric range	50 -250 miles, typically around 100 miles	5 to 50 miles	Short
Battery capacity	Typically 20kWh; 50kWh+ for high performance models	40kWh or less	30kWh or less

Source: Lytton (2010) and Perugo and Ciuffo (2010)

1.3.2 Vehicles eligible for government incentive schemes in selected countries

As discussed in more detail in the rest of this paper, and in Section 4.1 in particular, we have chosen to compare and contrast EV initiatives in the UK with those in a selection of other countries. We draw on examples from the United States (e.g. the New York case study in Section 5.6) and briefly refer to initiatives in Israel, Australia and Japan (see Section 4.4) but have chosen to focus on France, Denmark and Canada. These countries have been chosen to cover a range of initiatives in countries of various sizes, with different histories of investment in the automotive industry and new technologies, as well as with different structures of electricity provision and renewable energy policies.

Eligibility for government support for EVs differs across countries and initiatives. The UK has a rather “demanding” set of eligibility criteria for government support (Department for Transport, 2009a). Eligible vehicles must be grid-connected, i.e. the PHEV and BEV qualify whereas the HEV does not. Notably, there is a strong emphasis on vehicles with “mass market potential”. Thus, vehicles must meet certain performance standards in order to qualify, such as a minimum electric drive range (70 miles for BEV and 10 miles for PHEV) and a minimum top speed of 60mph. These requirements are described in Table 2.

Table 2: Vehicle eligibility criteria for consumer incentive in the UK

Vehicle type	Passenger cars (i.e. class "M1" in the European Whole Vehicle Type Approval Process)
Tailpipe missions	0 g CO_2/km for BEV, and 75gCO_2/km for PHEV
Minimum electric drive range	70 miles for BEV and 10 miles for PHEV
Minimum top speed	60 mph
Safety	Rated as at least 4 stars under the EuroNCAP scheme
Warranty	• 7 years or 100,000 miles for electric power train (including the battery) • 3 years or 60,000 miles for other conventional elements of the vehicle

Source: Department for Transport (2009b) Ultra-low carbon cars: Next steps on delivering the £250 million consumer incentive programme for electric and plug-in hybrid cars.

In contrast, the eligibility criteria used in France are guided by CO_2 emissions. Any vehicle that meets the CO_2 emissions standard would qualify, meaning that initiatives do not solely target electric vehicles but also other "cleaner" vehicles such as those that are diesel powered, natural gas powered and hydrogen fuel cell vehicles.

Furthermore, looking at three of the most prominent initiatives in Canada, the focus has moved from generic criteria to do with vehicle fuel efficiency to more specific criteria focussing on PHEVs and BEVs. The "ecoAUTO" initiative, led by Transport Canada, which took place in 2007-2008, used vehicle efficiency as its eligibility criterion; a more recent programme in Ontario which ended in June 2010 focused on the fuel types used by vehicles; and the most recent program in Ontario specifically targets BEVs and PHEVs. We provide a cross-country comparison of these eligibility criteria in Table 3.

With the aim of facilitating the transition towards the electrification of transport, recent policies in both Canada and the UK tend to support only grid-connected electric vehicles, i.e. BEV and PHEV. For simplicity's sake, we use the common term "electric vehicle" to refer to both of these in the rest of the document.

Table 3: Vehicles eligible for government subsidy of purchase price, cross-country comparison

Country/ Province	Terminology	Emissions or efficiency requirements	HEV	PHEV	BEV	HFCV[1]	NGPV[1], LPGV[1], Diesel, and other
UK	"ultra-low carbon vehicles"	EV: 0gCO_2/km; PHEV: 75gCO_2/km or less (for more on performance standard, see Table 2)		✓	✓	? [2]	
France	"véhicules propres" (clean vehicles)	Any vehicle that has less than 60g CO_2/km (€5000), 61-95g (€1000), 96-115g (€500), 116-125g(€100)	✓	✓	✓	✓	✓
Denmark	"Eldrevne motorkøretøjer" (Electricity-powered vehicles)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	"ecoAUTO" (federal initiative, ended in Dec 2008)	New car: 6.5 L/100km or better; New light trucks: 8.3 L/100km or better. New flexible-fuel vehicles with combined fuel consumption ratings of 13.0 L/100km or better *(2006, 2007 and 2008 model-year only)*	✓	✓	✓	✓	✓
Ontario, Canada	Ontario 's Alternative Fuel Retail Sale Tax Rebate Program	Alternative fuel includes: •$750 for propane vehicles •$1,000 for vehicles powered by any other alternative fuel •$1,000 for HEVs delivered to purchasers after May 9, 2001 and before March 24, 2006 •$2,000 for HEVs delivered to purchasers after March 23, 2006 and before April 1, 2012.	✓	✓	✓		✓
Ontario, Canada	Ontario's Electric Vehicle Incentive Program	Selected BEV and PHEV only, no detailed specification		✓	✓[3]		

Footnote:

[1]Abbreviations: Hydrogen Fuel Cell Vehicle (HFCV), Natural Gas Powered Vehicle (NGPV), Liquefied Petroleum Gas Vehicle (LPGV)

[2] Department for Transport report (2009b) published in July indicated that hydrogen fuel-cell vehicles would not be included, while the HM Government report (2009b) published in April suggested it would be included. According to the Department for Transport, final criteria would be published at www.dft.gov.uk/olev.

[3]As of July 1, 2010, the Tesla Roadster is the only vehicle qualified for the subsidy.

CHAPTER 2 Government motivations for EV market expansion

2.1 Governments' motivations for EV market expansion

Incentivising EV use is typically just one aspect of a wider set of initiatives, including those to reduce GHG emissions or other pollutants, as well as more general environmental and economic concerns. Governments' motivations for investing in EVs vary. Nevertheless, initiatives tend to be interrelated, context-specific, and influenced by national as well as international political scenarios. In this chapter, we explore in more detail the motivations behind EV policies of Denmark, France and Canada.

2.1.1 Environmental concerns

Denmark sees itself as a leader in the arena of climate change initiatives. In late 2009, Denmark hosted the UN Summit on Climate Change, COP 15. The then Danish Energy and Climate minister, Connie Hedegaard, has since been appointed as the European Union's (EU) first Climate Action Commissioner and plans to use this position to build on the progress made in Denmark in 2009 towards achieving an ambitious international climate agreement (European Union, 2010). The Danish government continues to adapt its legislation in order to play a leading rode in complying with EU guidelines. For example, as a means of combating vehicle tailpipe particulate emissions, the Danish Parliament, on the 18th of December 2009 (Danish Parliament [Folketinget], 2009), voted to amend vehicle taxes in order to penalise owners of vehicles with tailpipe particulate emissions of more than 5 mg/km from April 2010. As discussed below, BEVs are exempt from certain vehicle taxes, providing a monetary incentive for their purchase by consumers.

The French Government, represented by the Ministry for the Environment, Energy, Sustainable Development and the Sea, has proposed the widespread use of BEVs ("véhicules électriques") and PHEVs ("hybrides rechargeables") as a means of addressing concerns about the climate, local air pollution as well as mitigating the effects of an increasing number of vehicles on the roads. Combined with the largely decarbonised electricity produced in France, EV use is seen as a boon for the environment by the government (Government of France, 2010).

Ontario is the first Canadian province to move towards sustainable transport and it also has a goal of eliminating the use of coal-fired electricity by 2014 (Ontario, 2009). Through its Climate Change Action Plan, the province aims to reduce the environmental footprint of each resident by more than half the current national average of about 10 tonnes by 2020 (Ontario, 2009). This plan was launched in 2007 and led to the drawing up of the Green

Energy Act in 2009. The Act aims to hasten the development of clean energy sources, the adoption of new technologies such as EVs, and the development of a smart energy grid to ensure an even distribution of energy use throughout the day and night. The Electric Vehicle Technology Roadmap for Canada (Electric Mobility Canada, 2008), a document produced by private sector stakeholders, highlights the fact that Canada is in a race with other countries to reap the financial benefits of EV market expansion.

2.1.2 Economic concerns

Reviving the Automotive Industry through Job Creation

The UK enjoys a global reputation for research and development in automobile design engineering and manufacturing (Arup-Cenex, 2008). A revival of the car industry could be driven by a focus on EVs, initially led by national demand, as the UK is the second largest passenger market in Europe. The Nissan Sunderland plant has received £20.7m from the UK government Grant for Business Investment and up to £220m from the European Investment Bank for the production of the Nissan LEAF (Nissan, 2010a), with the expectation, depending on the source consulted, that 350-600 jobs would be created (BBC, 2010). France also has a large automotive industry, which aims to stimulate and modernise through its national plan for the development of EVs and HEVs (Secteurpublic, 2009a).

Canada also has a stated goal of stimulating job creation by becoming a world leader in EV technology and market expansion (Electric Mobility Canada, 2008). For centres of vehicle manufacture such as Ontario, Canada, it is imperative that the industry transforms itself in order to retain jobs, create growth, and become competitive (Electric Mobility Canada, 2010). In Ontario the car industry represents a quarter of manufacturing jobs (Better Place, 2010e). Ontario's motivations for collaborating with Better Place[7], a private company specialising in the provision of EV charging infrastructure solutions, are similar to those of the US: job creation, rejuvenation of the car industry, and a reduction of the use of energy from fossil fuels. Although environmental concerns are seen as important, economic benefits seem to take priority.

Boosting the renewable energy sector

A core aspect of the UK government's Renewable Energy Strategy (HM Government, 2009a) involves the development of infrastructure for the production of energy from offshore wind. This is intended, amongst other things, to contribute to the provision of renewable energy for the transportation sector and to support the aim of having 10% of transport energy from renewable sources by 2020. Electric vehicles (as well as hydrogen and fuel cell vehicles, i.e. other low emissions vehicles) are specifically envisaged to play a significant role in achieving this 10% target.

Creating innovation clusters

Both the UK and Denmark aim to promote economic growth by becoming hubs for EV innovation. Initiatives include vehicle production, the manufacture of components such as batteries and computer systems, and the design and manufacture of supporting infrastructure. Battery producers such as Axeon, are supportive of government incentives

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[7] A private company specialising in the provision of EV charging infrastructure solutions, discussed in more detail below.

for EVs, whether these target consumers or producers themselves, as these initiatives help to create a market for EVs (Axeon, 2010a). The UK government's Technology Strategy Board (TSB), in cooperation with other government departments, works closely with manufacturers to ensure that advances in technology continue, hastening the widespread use of EVs. For example, the TSB has invested over £1.3m in the development of a new, lightweight battery for use in electric small city cars with the aim of improving their performance, functionality and range. John Laughlin, the TSB's Low Carbon Vehicles programme manager, explains: "We are investing to put the UK at the forefront of low carbon vehicle technology. A major barrier to the widespread acceptance of electric and hybrid vehicles is the difficulty in balancing the range of the vehicle against the available stored energy" (Axeon, 2010b).

Denmark is also a testing ground for the Better Place model of EV infrastructure because of its manageable geographic size, its readily available renewable wind energy, and the general political and public interest in sustainable transport. Invest in Denmark, under the Danish Ministry of Foreign Affairs, hopes that Better Place would provide the country with a "first mover" advantage (Invest in Denmark, 2009). This and similar initiatives are intended to provide the seeds of innovation hubs related to electric vehicles.

Reducing dependence on foreign oil

This motivation is particularly strongly highlighted in discussions in France (and the US), for example, and points to the worldwide dependence on petrol for transportation as contributing to economic and geopolitical problems that could be mitigated by increased EV use. The drive to increase the use of hydrogen powered vehicles in Denmark was in part motivated by the oil crisis of the 1970s (Danish Energy Agency, 2009b).

CHAPTER 3 Barriers and facilitators to wider EV adoption

3.1 Barriers to wider EV adoption

There are a number of barriers to EV market expansion, some are technological, some are social or perceptual and some are institutional.

The issues around battery technology include the limited (all-electric) range of EVs, long battery recharge time, and high cost of batteries. Another important barrier is the lack of sufficient charging infrastructure and other elements such as overnight parking dedicated to EVs. Additionally, safety issues related to EVs, namely collision safety, electrical safety and the lack of engine noise, are also cited as barriers to the vehicles' wider adoption. Furthermore, consumers are hesitant to adopt EVs because they generally put a low value on future savings and have a negative perception or misunderstand the benefits of fuel economy. For some, EVs are associated with "cheap" design. Additional barriers to EV market expansion are institutional, in the form of resistance from industry stakeholders.

Much of the evidence in this chapter comes from research in the US. While we recognise that attitudes to cars and fuel may be very different in the US, we find much of the US experience provide useful insights to researchers in UK and Europe. Where possible, we cite evidence from Europe and use the US evidence as a crosscheck.

3.1.1 Limited range, long recharge time and high cost

Many of the barriers to the wider adoption of electric vehicles are technological. Based on previous studies (e.g., Romm, 2006; RAE, 2010; Sovacool and Hirsh, 2009), we divide these technological limitations into the following categories: limited range, long recharge times, and high cost of batteries.

Limited range

In 1996, the first generation of EV1 by General Motors ran on lead–acid batteries and had a range of 90–120 km on a full charge. The second generation EV1, which used nickel–metal hydride batteries, had a slightly longer range of about 135 km (Werber et al, 2009). The development of lithium-ion battery technology now allows for greater range and reduced weight (Mackay, 2009). The Tesla Roadster, which came to the UK market in 2010, travels 211 miles (340 km) on a single charge (TESLA motors, 2010). Nevertheless, the majority of electric vehicle buyers cannot afford high performance models, and most electric vehicles still have limited range. For example, the Nissan Leaf which is expected to become available in the car market in 2010/2011 has only a 100-mile range.

PHEVs address range issues by combining the electric motor and battery with the combustion engine, but they are still priced higher than conventional vehicles.

The problem of range limitation is compounded by users' anxiety. In a recent electric vehicle trial in the North East of England (Carroll, 2010), four electric passenger cars were integrated into selected organisations' fleets in order to collect data on vehicle performance in a real setting, together with users' driving habits and attitudes. The study found that users tended to be extremely cautious when planning journeys by electric vehicles. The longest journey made was only 25% of the average vehicle range, and almost all of the journeys (93%) involved a battery at least 50% charged. Some commercial EV users in Denmark, interviewed by Ulk et al. (2009) exhibited similarly cautious behaviour and were concerned that the range of their EV was far inferior to that of a fossil fuel-powered vehicle, even though this range was more than adequate for their daily needs.

Long recharge times

Charging points in London currently enable 'standard charging', which uses a 13A single phase current. On average, the charging time is 6-8 hours for a full charge (Transport for London, 2010). Technology is being developed to provide 'fast charging' (32A) and 'rapid charging' with direct (DC) rather than alternating current (AC). Fast charging is expected to be available in the near future and would significantly reduce the charging time to 1-3 hours for 80 per cent charge (Transport for London, 2010). Rapid charging technology is likely to be a longer-term development and is expected to reduce charge time to around 15 minutes. However, the long recharge time of the EV continues to make it less attractive than the fossil fuel-powered vehicle which takes only a few minutes to refuel. Innovation in recharging infrastructure, such as the Better Place battery exchange system, which could replace the car battery within two minutes using robots (Better Place, 2010d), may help to overcome this problem The Better Place battery exchange system and its business concept are discussed in greater detail in Chapter 4.4.

High cost of the batteries

One of the major impediments to reducing the cost of EVs remains the cost of their batteries, which can make up about 50% of vehicle production costs (Lytton, 2010). A shift to the use of lithium-ion (Li-ion) batteries[8] has reduced costs, but there is still a need for greater economies of scale or technological improvements to bring costs down further.

Battery manufacturers currently trade off price with performance. Axsen et al. (2010) examine the performance goals of the batteries for PHEVs, listing five major performance categories: power, energy capacity, life, cost and safety. Of the five categories, battery cost is cited as one of the most important factors affecting the successful deployment of electric-drive vehicles (Kalhammer et al, 2007). High cost of battery production translates into

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[8] Some argue that there is a future risk that increasing numbers of EVs will create dependencies on lithium and "rare earths", metals required in the manufacture of magnets in electric motors. Those with a concern for geopolitics point out that China has a virtual monopoly on the production of rare earths and has recently implemented a cap on their trade (China, Rare Earths Industry Development Plan 2009-2015, referenced in RAC Foundation 2010). We will not investigate this in detail here, given the remaining uncertainty as to whether the EV will reach the mass market.

high EV purchase costs for consumers. In 2010, the prices of EVs available in the UK range from about £10,000 (the G-Wiz i) to more than £88,000 for high-performance models (the Tesla Roadster) (Table 4). The G-Wiz i is a quadricycle[9] and does not have comparable performance with a conventional household car. Excluding the G-Wiz i, the minimum price of an EV is at £29,000, whereas the most common new car in the UK, Ford Fiesta, is priced at around £14,000 (Department for Transport, 2010b; Ford, 2010). In other words, the EV is currently at least £15,000 more expensive than a typical conventional vehicle in the UK.

Table 4: Prices of selected EVs against a conventional Ford Fiesta

Model	Prices in 2010 (incl. 17.5% VAT)	Remark
G-Wiz i	£10,000	does not have comparable performance with a typical car
Nissan Leaf	£29,000	
Mitsubishi i-Miev	£38,700	
Tesla Roadster	£88,000	High performance model
The most common newly registered conventional car in the UK:		
Ford Fiesta	£14,000	Not an EV

Source: Goingreen (2010), Nissan (2010b), Mitsubishi (2010), Tesla Motors (2010), and Ford (2010)

3.1.2 Limited recharging availability

The limited availability of recharging stations is a major impediment to the wider adoption of electric vehicles. Melaina and Bremson (2008) described the situation as a "three-way" bind between key stakeholders: consumers are reluctant to purchase vehicles that cannot be easily refuelled, vehicle manufacturers are reluctant to produce vehicles that would not be purchased, and fuel providers are reluctant to provide a service for vehicles that do not exist.

Perhaps less obviously, parking presents an additional infrastructure issue. Because of the relatively long time required to achieve a full charge, EV owners need access to reliable power outlets for overnight recharging. However, as pointed out by the 2010 report by the Royal Academy of Engineering, a large proportion of EVs in the UK are parked on public roads, often some distance from owners' homes. In London, two thirds of potential EV consumers are hampered by the limitations of their own homes: they do not have off-street parking (RAE, 2010).

3.1.3 Safety concerns

There are three main safety issues related to the use of EVs: collision safety, electrical hazards and the absence of engine noise.

Collision safety

Being smaller, lighter and having relatively low horse power than conventional vehicles, some electric vehicles are classified as 'heavy quadricycles' by the Driver and Vehicle Licensing Agency in the UK, meaning that they are subject to less stringent safety tests than typical passenger vehicles (City of Westminster, 2010). According to the Times newspaper in 2007, the UK Department for Transport found "serious safety concerns"

[9] A light four-wheeled motorised vehicle

after crashing the original (now discontinued) G-Wiz at 35 mph into a deformable barrier (Webster, 2007). A subsequent G-Wiz model includes more safety features, e.g. a strengthened chassis that allows the vehicle to pass a crash test at 40 km/h (25 mph). Despite improvements in newer models, the adverse publicity has damaged consumers' perception of the safety of EVs (Department for Transport, 2009b).

Electrical safety

There are also electrical safety concerns, as Lithium-ion batteries could be dangerous if short-circuited or overheated (Mackay, 2009). The EU, however, is currently working on establishing common safety standards (EUROPA, 2010). Mackay (2009) has also pointed out that the battery industry is working on developing safer battery technology, such as lithium phosphate batteries.

The absence of engine noise

The electric vehicle produces little or no engine noise. Some believe that the absence of engine noise poses a safety hazard to pedestrians, particularly to the visually impaired (Thomas, 2010), although most people see the absence of engine noise as a desirable feature. Nevertheless, car makers and industrial designers are looking into adding artificial sounding devices in EVs to address this apparent shortcoming (Hagiwara and Kitamura, 2009).

3.1.4 Consumers' negative perception and understanding of future savings

Although EVs offer the benefit of fuel economy and thus long term saving for consumers, research suggests that consumers tend to put a low value of future savings and do not, or are unable to, appreciate fully fuel-efficiency benefits. Furthermore, EVs carry the social stigma of being of cheap design and slow. We discuss the evidence base for each of these consumer perceptual barriers in turn.

Consumers put a low value on future savings

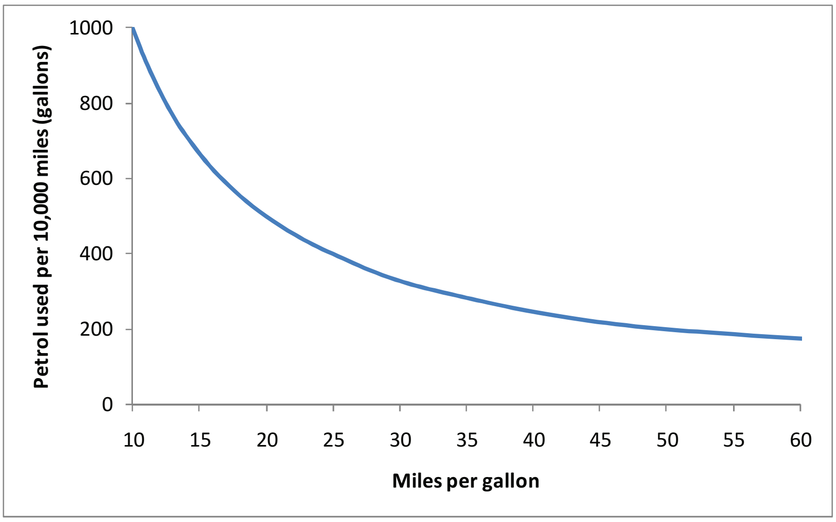
Research has shown that consumers are often either unable or unwilling to conduct careful economic calculations of their car purchases. Turrentine and Kurani (2007) conducted in-depth interviews with 57 Californian households and found that none of the respondents made a quantitative assessment of the present value of future fuel savings as part of a decision to purchase a new vehicle. The relatively high purchase cost of EVs remains a significant barrier. In a study by the International Energy Agency (2005), the authors cited research undertaken in the US in the 1970s and 1980s which found that the implicit discount rates (the rate at which consumers want to recover their investment) were around 20-35% for home air-conditioners and home insulation, more than 81% for water heaters and furnaces, and 500-800% for gas water heaters. A high implicit discount rate means that consumers expect a very short payback period, and it is expected that this would be the case with respect to EVs.

Consumers' misunderstanding of fuel economy benefits

Previous research has shown that consumers have difficulties in understanding fuel economy benefits. Larrick and Soll (2008) showed that consumers systematically misjudge fuel efficiency improvement when fuel efficiency is expressed as miles per gallon (mpg), the most common measure used in the US. Larrick and Soll (2008) argue that the measure mpg is non-intuitive. Although it is clear that higher mpg means better fuel efficiency, the curvilinear nature of the mpg curve obscures the value of small mpg improvements on inefficient cars (Figure 1).

For example, if one is considering changes to existing vehicles, a change from 16 to 20 mpg could help save as much petrol as a change from 33 to 50 mpg. Through the use of simple experiments to test whether people could evaluate mpg information correctly, the authors proved that people typically use linear reasoning, which leads them to underestimate the value of apparently small mpg improvements on inefficient cars while overestimate the value of apparently large jumps between efficient cars. The authors therefore emphasised the importance of clear, accessible and more intuitive information for consumers, and suggested fuel efficiency should be expressed in terms of amount of gas consumed for a given distance such as gallons per 100 miles, or litres per 100 km.

Because of the negative perceptions and misunderstandings of fuel economy, many car buyers may not appreciate the benefits of EVs.



Source: Larrick and Soll (2008)

Figure 1 Gallons of petrol used per 10,000 miles driven as a function of car fuel efficiency

Consumers value top speeds and acceleration more

If fuel economy is not highly valued by consumers, then what performance attribute is desired? Evidence regarding consumers' valuation of specific vehicle performance attributes has been examined in stated preference surveys[10]. Burge et al. (2007) conducted a stated preference survey with 1,100 car travellers to central London, investigating likely vehicle purchasing choice and other traveller responses under various emissions-based charging schemes. With regard to purchasing new vehicles, respondents were asked to trade-off car purchasing cost with car size, acceleration, top speed, fuel economy and level of charge for driving in to central London. The authors found that, all else being equal, low income households would be prepared to pay £39 for each extra mph of top speed while higher

[10] Stated preference is a well-established quantitative technique in environmental economics that is commonly used for the valuation of specific characteristics of non-market goods or new products (see, for example HM Treasury, "The Green Book: Appraisal and Evaluation in Central Government," 6 December 2009 (2003), http://www.hm-treasury.gov.uk/d/green_book_complete.pdf (as of Access Date).

income households would be prepared to pay £88. Additionally, all else being equal, low income households would be prepared to pay £134 for each second reduced from the 0 – 60 mph acceleration time while higher income households would be prepared to pay £297. Fuel efficiency, speed and acceleration were found to be less important when compared alongside attributes such as congestion charges. Nevertheless, consumers' valuation on fuel economy and other vehicle performance characteristics might change given the recent economic recession and rise in oil prices.

The finding that consumers value acceleration characteristic should work in favour of the EVs. Electric vehicles could achieve performance levels comparable to conventional cars, if not better, in terms of acceleration from a standing start. The all-electric sports vehicle, the Tesla Roadster, can accelerate from 0 to 60 mph in 3.7 seconds (TESLA motors, 2010). Other manufacturers of sports cars, such as Lotus, Porsche and Ferrari have also unveiled vehicles driven partly by electric motors in the 2010 Geneva car show (The Economist, 2010). High performance vehicles may bring about a change in the public's perception of EVs, but evidence on this attitudinal change is not yet available.

Social stigma

Research has also shown that consumers have a negative perception towards vehicles being economical. Turrentine and Kurani (2007) found a social stigma against fuel-efficient vehicles. Respondents in the US indicated that vehicles with good fuel economy were often considered "cheap" and less appealing to middle and upper class buyers. Interviewees in an ongoing Danish study which is based on 50 in-depth interviews with consumers (some of whom were electric vehicle users), were asked to comment on the prejudices that people generally had towards electric vehicles (Ulk et al, 2009). One of the early adopters of EVs mentioned that a commonly held belief among non-EV owners was that EVs were slower than conventional vehicles and ugly, looking much like plastic toy cars.

3.1.5 Consumers' attitude-action gap

Lehman et al. (2003) found evidence of an attitude-action gap in car purchasing behaviour. Interviews with 435 recent and prospective new car buyers in the UK showed that buyers expressed concern for their future car's impact on the environment, but this concern did not necessarily translate into behavioural change. The "environmentally concerned" respondents perceived that it is mainly the responsibility of the government and car manufacturers to ensure that steps are taken to protect the environment, not car drivers. Price, fuel consumption (in terms of cost, not emissions), size, reliability and comfort were the most important factors in their car purchasing decisions, while environmental considerations were not significant.

3.1.6 Customers' unfamiliarity with EVs

Customers' initial unfamiliarity with EVs could be a barrier to wider use. For example, in a Danish consumer study one of the interviewees who used an electric vehicle at work explained how he felt that the vehicle was underperforming compared to a conventional vehicle, but admitted that this could be a result of his unfamiliarity with the best practices to prolong battery life (Ulk et al, 2009). He had received an instruction sheet explaining that it was best for battery life to allow the EV battery to be completely discharged before recharging it, but he did not feel comfortable allowing the battery to become this depleted before recharging it, in case the vehicle stopped before he could reach the recharging post.

Studies in the US also support this finding. Sovacool and Hirsh (2009) cited studies that shown some motorists are unaware of how their driving patterns and habits may have negatively impacted the car's performance.

In general, the wider adoption of new technologies could be facilitated by social communication, such as direct word of mouth. Struben and Sterman (2008) introduced the concept of "willingness to consider a vehicle platform" (WtC) in which drivers use cognitive and emotional processes to gain information and form emotional attachments when considering a vehicle purchase. According to Struben and Sterman (2008), WtC could be generated by marketing and media, as well as social exposure and word of mouth. Using a behaviour dynamic model, the authors illustrated that the impact of word of mouth is poorer when most drivers own ICE vehicles. They also found the long lifetime of existing vehicles impedes the transition of alternative fuel vehicles to the mass market. Therefore, the authors concluded that policies aimed at removing old combustion engine vehicles from roads may provide higher leverage. Such policies might include incentives to vehicle owners who not only buy alternative vehicles but have their old vehicles scrapped rather than sold into the used car market.

3.1.7 Institutional barriers

In the past, EVs have faced strong resistance from car manufacturers, oil companies, and repair businesses that have invested billions of dollars in the supply and production of infrastructure for conventional vehicles (Sovacool and Hirsh, 2009). To protect their businesses, these industries seek to influence policy makers and the public to maintain the status quo. A notable example of resistance from the automotive industry came in California after the zero emissions mandate of 2001. The automotive industry successfully lobbied the California Air Resources Board to relax the requirement that 10% of new cars be emission-free by 2003. Once the mandate was relaxed, GM and Honda promptly called in all their leased electric vehicles and scrapped them (Sovacool and Hirsh, 2009).

3.2 Facilitators to wider EV adoption

Despite the significant number of barriers to the expansion of the EV market, we also identify a number of facilitators to its expansion. These include the effects of incentives and consumers' price sensitivity, innovations in the supporting infrastructure for EVs, as well as social factors that can play an important role in increasing EV adoption.

3.2.1 Incentives and consumers' price sensitivity

Potoglou and Kanaroglou (2007) examined the factors and incentives most likely to affect Canadians' uptake of cleaner vehicles. Using stated preference survey data and discrete choice models, Potoglou and Kanaroglou (2007) found that reductions in monetary costs, purchase tax relief and low emission rates might encourage households to adopt cleaner vehicles. However, incentives such as free parking and permission to drive in high occupancy vehicle lanes were not found to have significant effects.

In the US, monetary incentives have recently been highly effective in affecting consumers' vehicle purchase decision and ownership (Lipman, 2009). Under the "cash for clunkers" program in 2009, drivers were reimbursed a credit of up to $4,500 when a vehicle with fuel economy of less than 18 mpg was scrapped. The programme was so popular that demand vastly exceeded available funds, despite an additional appropriation from Congress, which prompted the programme to be concluded sooner than expected. This programme covered both EVs and other fuel-efficient cars, and illustrates that consumers are sensitive to financial incentives.

On the other hand, Diamond (2009) examined the impact of government incentives designed to promote HEVs in the US. He found a strong relationship between petrol prices and hybrid adoption, but a much weaker relationship between incentive policies and hybrid adoption. However, it should be noted that fuel prices are volatile. High sensitivity to fuel prices worked in favour of fuel efficient cars in the 1970s, but fuel efficient vehicles fell out of favour again when petrol prices declined in the 1980s.

3.2.2 Innovations in supporting infrastructure

Innovative charging systems, such as the Better Place battery exchange, carry significant potential in overcoming technological problems of limited travel range and long recharge time (Andersen et al, 2009). Under the Better Place model, batteries would be leased, not owned. Drivers would be charged by the mileage driven within a dense network of charging points and battery switching stations to support quick "refuelling". More information about the Better Place battery exchange system is discussed in Chapter 4.4.

Additionally, vehicle-to-grid technology, also known as "mobile energy" or "smart charging", combines EVs with the electric power system (Sovacool and Hirsh, 2009). Using "smart chargers", EV owners would be able to charge the vehicle during the night, when electricity prices are low. Utilities may allow vehicle-to-grid discharging, whereby EV owners could profit from selling excess electricity back to the grid in peak hours when electricity prices are high. Sovacool and Hirsh (2009) cited studies that predicted the value of vehicle-to-grid services at $12 billion per year, some of which would flow to vehicle owners. However, it should be noted that charging and discharging involves using up the limited cycle life of the electric vehicle's battery. Moreover, the future of "smart charging" seems like an important element in relation to EVs, the future of which is dependent on the stance of the utility providers and regulators. There are many initiatives regarding smart grids worldwide, e.g. the UK and the EU's smart grid initiatives (Smart Grids, 2010), which includes a large array of technologies, notably smart meters. It nevertheless remains unclear at present to what extent grid discharging would be rolled out.

3.2.3 Symbolic values and early adopters

While electric vehicles are perceived as cheap and unattractive by some (as discussed in Section 3.1.4), the values that the electric vehicle symbolises may persuade other to purchase EVs, especially among early adopters (e.g. Gjoen and Hard (2002), cited in Sovacool and Hirsh (2009). In the US, early adopters of EVs in the late 1990s attempted to establish an alternative "traffic culture based on slower speeds, more careful driving, and fewer accidents". Additionally, Heffner et al. (2007) found that early adopters' reasons for their EV purchases included "a strong ethical belief to protect the environment or oppose war", "a desire to reduce dependence on foreign oil", "an assertion of individualism and embrace new technology" and "gaining social standing.

The report by the UK Low Carbon Partnership (cited in Lane and Potter (2007)) suggested that targeting early adopters could be a cost-effective strategy during the initial stage of market development[11].

The electric vehicle is considered a "disruptive innovation", i.e. a new technology with performance attributes initially undervalued or unfamiliar to mainstream consumers, yet once it takes hold in the initial niche market, the performance attributes could improve very quickly so that it has the potential to take over the wider market (Bower and Christensen, 1995). One example of a disruptive innovation is the digital camera. The early digital camera had poor picture quality, low resolution, and long shutter lag, but it soon created a new market for cameras that provide instant viewing, store hundreds of pictures, and minimise the need for photo development. This is not to say that the electric vehicle would succeed, because the digital camera's success was also strongly linked to Moore's law, i.e. the memory capacity of cameras and the number and size of pixels doubled roughly every 18 months (Myhrvold, 2006); it is unclear whether the electric car would have a similarly rapid development.

[11] It should be noted that the source of this finding cited in Lane and Potter (2007) is by an unnamed MBA student from Cambridge. It is unclear how strong the evidence base is.

CHAPTER 4

Policies and programmes for wider EV adoption

4.1 Our approach in selecting countries for comparison with the UK

Using UK initiatives as a starting point, we compare and contrast those of other selected countries. The examples discussed have been chosen to cover a range of EV initiatives in countries of differing size, different histories of investment in the automotive industry and in new technologies, as well as different structures of electricity provision and renewable energy policies. The countries chosen for closer examination are: France, Denmark and Canada.

France represents a large European economy with a long history of automobile manufacture, including early EV experimentation. An interesting difference between France and the UK is that France has retained its home-owned industry whereas the UK assembles cars for foreign-owned manufacturers. The similarities between the UK and France in terms of vehicle fleet characteristics, vehicle and fuel costs, as well as other aspects, facilitate an in-depth examination of their respective approaches to electric vehicles. However, the somewhat limited availability of information in English regarding the French context, as well as on the resources available to pursue this area of research, mean that we have chosen to only highlight a few key aspects of French EV-related policies.

Denmark is included as our small-country European example, where the focus is particularly on renewable energy for EV charging. Denmark has similar aims to the UK in terms of GHG emissions reductions and a stated desire to become an innovation hub for EV technology. So, despite having comparable motivations and aims regarding EV market expansion Denmark is significantly different from the UK in terms of size, infrastructure and industrial make-up.

We choose Canada because of its high percentage of private car ownership and its historic role in the automotive industry, both of which can be compared to the UK context. The federal body responsible for nationwide transportation policies and programmes, Transport Canada, provides an easily accessed, coherent overview of federal EV initiatives. In addition, the Canadian regional governments present their EV initiatives in an easily accessible manner. Other countries present their information in a less systematic, more diffuse way, perhaps suggesting that there is less national control of EV-related projects, with several different agencies involved in the administration of national funds. Canada also has close economic ties with the US and also tends to harmonise its vehicle legislation with the US. Although we discuss aspects of US EV market expansion, such as the New York City case, and although there are EV initiatives underway across the US (e.g. California and Hawaii), Canada is our North American case for detailed discussion. Our approach in choosing these countries highlights the effects of US environmental and EV policies on its neighbours, showing why national and regional EV initiatives should not be discussed in isolation.

Table 5: Similarities and differences between the UK and selected case study countries

Country	Main similarities with the UK	Main differences to the UK
Canada	Economic importance of the automotive industry	North American policy and cultural context Proximity to and influence from the US
Denmark	Taking the lead in emissions reduction and renewable energy	Country size Infrastructure Economic make-up
France	Long history of vehicle manufacture Comparative economic size	Home-owned automotive industry based in the country Earlier EV experimentation

EV initiatives are underway in a number of other countries across the world. China and India have growing automotive industries with, potentially, sizeable internal markets for the sale of EVs. Germany, as a large economic and political player on the world stage, is also investing in EVs. Recent German plans include: producing better electric vehicles, becoming a global market leader (Die Bundesregierung, 2009), achieving energy independence, and developing renewable energy sources so that EV recharging is sustainable (Chambers, 2008). German initiatives are wide-ranging, with examples such as "e-mobility Berlin", and a substantial project for environmentally friendly electric vehicles (Daimler AG, 2008). The vehicle manufacturer Daimler is contributing a fleet of over 100 electric vehicles to this project, including vehicles from Mercedes-Benz, while the power company RWE AG would provide 500 charging points. Although it would be interesting to include these and other countries in our current examination of EV policies, we have taken a pragmatic approach and have chosen to focus on countries that are directly comparable to the UK in terms of some of their justifications for EV development or in their economic make-up.

4.2 Incentivising EV market expansion

4.2.1 UK

Since the publication of the King review (HM Treasury, 2007), the UK government's interest in grid-connected EVs has increased significantly (Lytton, 2010). According to a joint publication by the Department for Transport (DfT), the Department for Business, Enterprise and Regulatory Reform (BERR) and the Department for Innovation, Universities and Skills (DIUS) (HM Government, 2009b), it is envisioned that the number of ultra-low carbon vehicles, i.e. PHEV, BEV and Fuel Cell Vehicles, on UK roads would increase to hundreds in 2010 as a result of the government's demonstration projects. The number is expected to increase to thousands in the early 2020s. Eventually, ultra-low carbon vehicles would become "a common sight" by the end of the 2020s. To achieve its vision, the UK government sees that it would have a role in:

- Supporting the automotive industry
- Supporting research, development and demonstration projects
- Providing the necessary charging infrastructure, focusing on a "core" of electric car cities and regions
- Fostering the skill base that meets the automotive industry's needs
- Making ultra-low carbon vehicles competitive
- Coordinating the activities across cities, utilities, the automotive industry, consumers, infrastructure providers, and government departments

The UK government's strong emphasis on supporting the automotive industry as well as research, development and demonstration is reflected in the amount of funds invested, notably the Automotive Assistance Programme, worth £2.3bn, and the Low Carbon Vehicles Innovation Platform, worth over £120m (HM Government, 2009b). Under the Innovation platform, R&D competitions have been launched to facilitate the development of enabling system and sub-system technologies of ultra-low carbon vehicles. For example, over £1.3m was given to a consortium led by the battery supplier Axeon to support the development of a new, lightweight battery for use in electric small city cars with the aim of improving their performance, functionality and range (Technology Strategy Board, 2009).

In 2009, the Labour government announced major incentive package for PHEVs and BEVs in the UK, which involve the distribution of approximately £230 million to consumers from 2011 to 2014 in the form of grants for the purchase of EVs (Department for Transport, 2009b). There was speculation that this scheme would be cancelled under the new Conservative and Liberal Democrat coalition government. However, the Transport Secretary confirmed on 28th July 2010 that the government remained committed to achieving its GHG targets, meaning that the "ultra-low carbon vehicle" consumer incentive, worth £43m, would go ahead[12]. This scheme targets grid-connected vehicles (BEVs and PHEVs) that have "mass market potential". Thus, the eligibility criteria are rather "demanding" (Department for Transport, 2009b), including a minimum requirement of an electric drive range of 70 miles for a BEV and 10 miles for a PHEV, as well as a minimum top speed of 60 mph. In addition, the government uses secondary incentives, such as exemption from congestion charges, as discussed in London's case (Section 5.1).

Despite the UK government's demonstrable commitment (Department for Transport, 2010a) in providing incentives to widen the market for EVs, we have found that the

[12] This is good news to those who are concerned with the future of EV market expansion and UK's ability to meet its GHG emissions targets. However, according to the Committee on Climate Change, even stronger incentives might be needed during the early phases of EV introduction. It has suggested an increased cash incentive such as £10,000 per vehicle for the first 25,000 BEVs/PHEVs sold. It also recommends a spending increase to £800 million, meaning that total price support for a projected number of 1.7 million BEVs/PHEVs in 2020 would reach £9 billion Committee on Climate Change, "Meeting Carbon Budgets - the Need for a Step Change, Progress Report to Parliament Committee on Climate Change," (2009).

available information regarding EV initiatives is not consolidated in one place, and is not always consistent across sources in the amount of detail provided. The Committee on Climate Change (2010a) similarly points out that this detracts from the efficiency of incentives schemes. It seems that there is room for improvement in terms of the government's role in coordinating the activity among its departments.

Table 6: Examples of incentives for increasing EV adoption in the UK

Initiative (name)		Funding	Time frame
Automotive Assistance Programme (AAP) Includes incentives to promote EVs Support for the automotive sector in the economic downturn, with a focus on becoming a low carbon industry world leader.		£2.3 billion total	2009-2011
Low Carbon Vehicles Innovation Platform administered by the Technology Strategy Board Includes R&D competitions		over £120m	From 2007
Promotion of PHEVs and BEVs under low carbon investment scheme Incentives for public and private EV adoption including the below		£250m total	2009-2011
	Plugged-in Places Electric Vehicle Infrastructure Framework Development of EV charging infrastructure	£20m from low carbon investment scheme (HM Government, 2009b) £10m from Strategic Investment Fund, low carbon element (Department for Transport 2009b)	Up to 2011
	Fund administered by Department for Transport Incentive package for BEV and PHEV promotion	£230m Grants of £2000-£5000 per vehicle (£43m up to 2012) Existing exemption of EVs from excise duty.	from 2011(to be reviewed in 2012)
Mayor of London, Electric Vehicle Delivery Plan for London (London as the EV capital of Europe) Includes the elements below		£60m estimated total cost (To be funded through national government incentive programmes)	May 2009 -2015
	25,000 charging points	unspecified	May 2009 -2012 (Phase 1)
	All Londoners within 1 mile of a charging point by 2015	Unspecified	May 2009 -2015
	1,000 EVs in GLA fleet	Unspecified	May 2009 -2015
	Congestion Charge discount	1,700 per year per person	May 2009 -2015

Additional initiatives suggested by the Committee on Climate Change (not committed)			
	For BEVs and PHEVs (£10,000 per vehicle cash incentive)	£ 250m	First 25,000 vehicles sold
	Initiative for projected number of 1.7 mil BEVs/PHEVs	Increase spending to £800m so total price support is up to £9 billion	Up to 2020

4.2.2 France

In 2009, a national plan for the development of EVs and HEVs in France was published, laying out the government's aims for its national EV programme (Secteurpublic, 2009b). The focus around consumer incentives in France involves familiarizing the general public with EVs by making them readily available for test-driving. The national plan involved making regional administrations responsible for ensuring collaboration and communication between all stakeholders, and in particular for driving forward EV market expansion projects in urban areas. In addition, a monetary incentive of €5000 (about £4200) is given to everyone who purchases an EV and €2000 (about £1700) is given for the purchase of an HEV. These incentives are based on CO_2 emission levels[13] and target "cleaner vehicles" (*véhicules propres*) in general, therefore including natural gas-powered vehicles (NGPVs) and liquefied petroleum gas vehicles (LPGVs).

These consumer incentives tie in with incentives for EV producers, as well as the public and the private sectors. These stakeholders have a part to play in developing and promoting incentive initiatives for consumers and, in particular, in increasing public awareness of EVs. The association *Espace Mobilités Electriques* (EME) (2010) was set up by Electricite de France (EDF) in 1997, the French electricity utility company, and the City of Paris, in order to provide information about all types of electric vehicles. According to EME's website (2010), the majority of EVs are currently used in commercial fleets or by other organised groups. La Poste, the French postal service, currently has the biggest EV fleet in France, supported by EDF. However, an agreement was signed on the 13th of April 2010 setting up EV pilot schemes in 12 municipalities, as described in Section 4.3.2, below.

A specific example of a pilot project currently underway is at Yvelines, which would receive €6.5m (£5.38m) funding from the French Environment and Energy Management Agency, in accordance with its 26 June 2009 request for proposals on zero (carbon) emissions vehicles. The main project partners, the Renault-Nissan Alliance and EDF, supported by the Île de France region and the Yvelines General Council, are collaborating with Schneider Electric, Better Place, and other partners (EDF, 2010). The project is under the coordination of EPAMSA, the public development authority for the Seine Aval area. Renault-Nissan would provide EVs to individual customers and professionals, while EDF would help set up the infrastructure, which Schneider Electric would help to build. Battery switching stations are to be installed and managed by Better Place.

[13] Any vehicle that has emissions less than 60g CO2/km (€5000), 61-95g (€1000), 96-115g (€500), 116-125g(€100).

The focus of French EV initiatives appears to be primarily monetary, focusing on acquainting potential users of EVs with the vehicles, and making sure that the necessary charging infrastructure is in place. There is cooperation between the public and private sectors, under the leadership of the government, to ensure that supply and demand of EVs goes hand in hand. It is hoped that this would increase the public profile of EVs, while at the same time making their production commercially viable (see, Table 7).

Table 7: Examples of incentives for EV increasing adoption in France

Initiative (name)	Funding	Time frame
Yvelines EV project Providing EVs to individual customers and professionals, putting necessary infrastructure in place	From Environment and Energy Management Agency (ADEME) (funding), public development authority for the Seine Aval area (EPAMSA)	June 2009 request for proposals on carbon-free vehicles
projet de loi Grenelle 2 Government focus on EV charging infrastructure deployment, support for requests and help for vehicle purchase. Car manufacturers aim to have 60,000 EVs for commercial use in 2011-2012 (with minimum range of 150 km) A group of about 20 public and private buyers, led by la Poste (the French postal service), has been assembled that will initially purchase 50 000 EVs	Everyone who buys an EV with CO_2 emissions equal to or less than 60g/km receives a bonus of €5000 for EV purchase	until 2012
	PHEVs with emissions less than or equal to 135g/CO_2/km could receive €2000	until 2012
"Super bonus" and "bonus" for low emissions vehicles	€2000-€5000 per vehicle, total unknown	Until May 2010 (start date unknown)
Revised "Super bonus" and "bonus" for low emissions vehicles, with more detailed vehicle classification	€100-€5000 per vehicle, total unknown	From May 2010 (end date not known)
Paris Autolib project Aimed at mirroring the current Vélib bicycle sharing scheme in Paris by providing electric vehicles for rent on a half-hourly basis.	By the City of Paris	To be introduced in 2011

4.2.3 Denmark

The Danish government has a four-pronged approach to the promotion of widespread EV use: tax rebates, pilot projects (i.e. the "test scheme for electric cars"), the Sustainable Energy and Open Networks (EDISON) project for developing EV infrastructure (see Section 4.3.3), and support for the private development of EV infrastructure (e.g. the Better Place programme). Similarly to the Committee on Climate Change in the UK, the Danish Commission on Climate Change Policy is tasked with providing guidance for the government in developing a plan to reduce the use of fossil fuels. One initiative aimed at achieving this goal is the national "test scheme for electric cars" (*Forsøgsordningen for Elbiler*), led by The Danish Energy Agency (DEA) (2008). The DEA, in a publication about the test scheme, directs interested parties to the Better Place Denmark website for general information about EVs, suggesting strong government support for the Better Place model (Danish Energy Agency, 2009b).

The "test scheme for electric cars" was set up in compliance with the government's Energy Agreement of 21 February 2008 on Danish energy policy for 2008-11. This states that DKK 10 million (ca. £1 million) per year for 2008-09, and DKK 5 mil. (ca. £0.5 million) per year for 2010-12 is to be designated for a "test scheme for electric cars". According to the Ministry of Climate and Energy, a total of DKK 35 million (ca. £3.89 mil) is being set aside for the scheme between 2008 and 2012 (Danish Energy Agency, 2009a). In the second round of applications for grants, in December 2009, the Danish Energy Agency allocated a total of DKK 10 million (£1.11 mil) of this fund to 16 different projects (Praëm, 2009). The aim is to discover the best uses for EVs and to elucidate any barriers to their widespread adoption. Support is provided in the form of a subsidy for the purchase of EVs and/or EV rechargers to be used in pilot projects to gather information about the practical use of EVs in fleets[14]. Measuring instruments are installed in all subsidised vehicles, collecting data about their use, to be analysed by the DEA.

The overall stated aim of this scheme is to promote the widespread use of EVs as a means of integrating the increasing production of renewable energy into the transport sector and reducing the use of fossil fuels in the transport sector. This will be done by gathering information about "technical, organisational, economic and environmental factors associated with using, operating and maintaining electric cars", which will be made publicly available. In addition, it is hoped that EV batteries could be used to store excess wind energy that could feed electricity back into the power grid during a shortage (Danish Energy Agency, 2009a). The information gathered from instruments in the vehicles involved in the scheme will help to determine the extent to which this will be feasible in the future.

Vehicles in Denmark are subject to a number of taxes each based on different measures, such as the price of the vehicle, its weight, and its fuel consumption. Because of the high taxes on vehicles in Denmark, tax exemption for low carbon vehicles is particularly important. Since 1984, the development of EVs has been supported by renewable periods of exemption from registration tax and this is currently set to continue until at least 2012 (Praëm, 2009). BEVs (not PHEVs or HEVs) and hydrogen-powered vehicles, weighing under 2000 kilograms/2 tons are exempt from registration tax (*registreringsafgift*), currently until 2012. The tax is based on the price of the vehicle. For 2010, it is set at 105% times the price of the vehicle for vehicles priced up to DKK 79,000 and 180 times the price of the vehicle for vehicles priced over DKK 79,000 (Skatteministeriet [Danish Ministry of Taxation], 2010). The registration taxation law (*Registreringsafgiftsloven*) is available in Danish on the government's legal information website (Retsinformation [Legal information], 2010).

The government has instituted a tax on cars with low fuel efficiency ratings. The more fossil fuel a car uses per km, the higher the tax. As they produce zero emissions, EVs are exempt from this tax. For 2010, the Owner tax law (*Ejerafgiftsloven*) imposes a tax on all owners of petrol or diesel powered vehicles based on the vehicle's fuel efficiency (km/l). For

[14] This subsidy is only for commercial fleets, and is not made available to the general public.

petrol vehicles, this is between DKK 260 (£29) (for at least 20 km/l) and 9230 (£1031) (for less than 4,5 km/l). For diesel vehicles, it is between DKK 80 (for at least 32.1 km/l) and DKK 12,530 (for less than 5.1 km/l). In addition, from 2010, diesel vehicles without particulate filters have to pay an additional DKK 1,000 (£112) per year (Skatteministeriet [Danish Ministry of Taxation], 2010). EVs are not subject to this law, as they do not run directly on fossil fuels.

Non-monetary incentives for EVs include free parking; in Copenhagen, EVs can park for free in zones where other vehicles have to pay. In Odense municipality, the third largest city in Denmark, EVs park for free as long as they have a valid, free parking license, renewed yearly. Monetary initiatives operate alongside non-monetary ones and appear to be aimed at making EVs easy for the general public to use, increasing their visibility, and gathering information about how EVs are and could be used in practice (Table 8).

Table 8: Example of incentives for increasing EV adoption in Denmark

Initiative (name)	Funding	Time frame
Test scheme for EVs, Administered by the Danish Energy Agency	DKK 10 mil/year	2008-2009
Test scheme for EVs, Open subsidy scheme, grants to projects implementing tests of the use of EV fleets for practical purposes	DKK 5 mil/year, in 2009, DKK 10 mil allocated to 16 projects	2010-2012
Tax exemption		1984 until at least 2012
Free inner-city parking for EVs, Copenhagen and Odense municipalities	Non-monetary incentive	Indefinite

4.2.4 Canada

Canadian provinces are likely to adopt the most stringent US environmental protection policies, usually exemplified by those in the US State of California. The Government of Canada announced in January 2008 (Transport Canada, 2008) that it would adopt as a minimum target the same fuel economy goal established by the United States. This required standards to be set, to be effective from 2011, in order to eventually achieve the goal for new vehicles in 2020 of an average fuel consumption of 35 miles per gallon (6.72 litres per 100 km) (Energy Independence and Security Act, 2007). The State of California has special status under the Clean Air Act and could apply to the Environmental Protection Agency (EPA) to set separate standards for vehicle emissions. This request was denied in 2007. Should California achieve the right to impose different standards to the rest of the US[15]again, other US states may choose to adopt Californian, rather than federal standards, as might Canadian provinces. The average Canadian car today consumes 8.6 litres of fuel per 100 km, less than the average US car (CBC News Canada, 2010).

The alignment of Canadian and US regulations is intended to provide a level playing field across North America, encouraging the production of more advanced vehicles and increasing competitiveness in regional and global markets (Government of Canada, 2010).

A number of EV programmes have been developed at the federal level as well as the provincial level, particularly in Ontario. These initiatives are discussed below.

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[15] This was previously allowed under the American Clean Energy and Security Act of 2009 (introduced as a draft in the House of Representatives on March 31 2009), but California currently has to adopt the federally dictated emissions standards.

ecoAUTO Rebate Program

This programme concluded its 2-year mandate to encourage Canadians to buy fuel-efficient vehicles on March 31, 2009. It ran from March 20, 2007 to December 31, 2008, and applications had to have been received by March 31, 2009. Eligible vehicles received rebates from $1,000 to $2,000 CAD (ca. £650-1,300).

Eligible new cars (2006, 2007 and 2008 model-year vehicles) received rebates under the ecoAUTO Rebate Program, based on their fuel consumption. The reason for the exclusion of newer vehicle models is not disclosed. Eligibility for a rebate was based on the vehicles' Combined Fuel Consumption Rating (CFCR): new cars that use 6.5 l/100km or less and new light trucks that use 8.3 l/100km or less. The list of eligible vehicles includes hybrid electric and highly energy efficient vehicles. In addition, new flexible-fuel vehicles with combined fuel consumption E85 ratings[16] of 13.0 l/100km or less were eligible (Growth Energy, 2009; Transport Canada, 2010b).

Regional initiatives

Because of the relative autonomy of Canadian provinces, they have considerable freedom to implement regional initiatives that are independent of federal programmes. As part of Ontario's Climate Change Action Plan, citizens of the province could apply for a Retail Sales Tax rebate of up to C$2,000 (ca. £1,300) when purchasing a hybrid vehicle (Ontario Ministry of the Environment, 2008). In addition, rebates of between C$5,000 and C$8,500 (ca. £3,000 – £5,200), based on the vehicle's battery capacity, are available for new vehicles purchased after July 1, 2010 (Ministry of Transportation, 2010).

EVs are given preferred access to the transportation grid. Plans are under way for a green licence plate that would allow single occupant EVs to use high occupancy vehicle lanes for a limited five-year period. Coordinated public education and the general promotion of electric vehicles for personal transportation are addressed in the Climate Change Action Plan (2009).

Canada seems to have comparably more non-monetary incentives. Of particular interest are the low speed vehicles (LSV) pilot projects, which differ significantly from any other incentives in place in that they take advantage of a niche opportunity to provide an EV for a specific purpose (i.e. short, local journeys). Other initiatives are aimed at the eventual replacement of all vehicles on the roads with EVs.

Table 9: Examples of incentives for EV increasing adoption in Canada

Initiative (name)	Funding	Time frame
Retail sales tax rebate for the purchase of a HEV	up to C$2,000 per vehicle	Unknown
ecoAUTO Rebate Program Encourages the purchase of fuel-efficient vehicles, based on Combined Fuel Efficiency, only for eligible model year 2006-2008 vehicles, included HEVs	C$1,000-2,000 rebate per eligible vehicle, issued over 169,000 rebates, totalling C$191.2 mil	March 20 2007 - December 31 2008 (applications by March 2009)
Ontario's Alternative Fuel Retail Sale	8% of tax saving	2000- June 2010

[16] E85 is a clean fuel blend with up to 85 percent ethanol and is a high-performance fuel with a 100+ octane rating compared to regular gasoline, which has an 87 octane rating. (Growth Energy, 2009)

Tax Rebate Programme	$750-$2000	
Ontario's Electric Vehicle Incentive Programme	$5000 to $8500, per eligible vehicle, expected to amount to $50-$85million	From July 2010 (first 10,000 qualified applicants)
Use of High Occupancy Vehicle lanes	N/A	5 year restriction
LSV pilot projects LSV use on public roads with speed limits of 50 km/hr or less in Quebec and Ontario	N/A	Restricted time pilot scheme

4.3 Developing infrastructure

It is impossible to consider the wider adoption of EVs in the absence of necessary infrastructure. Infrastructure development includes the development of sustainable energy sources for grid electricity, the provision of adequate charging points, and the incorporation of EVs into the existing or modified energy system. Of particular importance is the development of a standardised charging infrastructure (Arup-Cenex, 2008).

4.3.1 UK

A public charging infrastructure "can cost up to £40,000 per fast-charging point and another £50,000 if modifications to the local grid are required due to high load" (RAC Foundation 2010). The Committee on Climate Change estimates that introducing the necessary charging infrastructure for the UK would cost in the range of £150 million to £1.5 billion. The lower estimate only includes simple off-street charging, while the higher estimate includes dedicated off-street charging and fast-charging infrastructure (Committee on Climate Change, 2009).

Currently, £20 million of the £400 million allocated to low carbon vehicles would be earmarked for the Plugged-In Places Infrastructure Framework. In addition, £10 million from the low carbon element of the Strategic Investment Fund would also be used for the framework (Department for Transport, 2009b).

4.3.2 France

According to a white paper produced by the "Observatoire du Véhicule d'Entreprise (2010)" (OVE), translated as "the Observatory for Commercial Vehicles," run by BNP Paribas a working group of public sector stakeholders under the OVE, has identified a number of conditions along 3 axes, which would facilitate their engagement in the national plan for the development of EVs and HEVs (Secteurpublic, 2009b). These broad conditions are: better consideration of the life cycle cost of EVs in developing fiscal policies to incentivise EV acquisition, ensuring coherent global standards and regulations relating to EVs, and ensuring that the information available about EV initiatives is transparent and readily accessible.

Under the Grenelle 2 law, the French government has, in early 2010, announced a plan to encourage the deployment of public charging infrastructure for carbon-free vehicles in 11 French regions (République Française, 2010). This was announced by Jean-Louis Borloo, Minister of State for the Environment, Energy, Sustainable Development and the Sea. The French automobile manufacturers, Renault and PSA Peugeot-Citroën, aim to launch their first new generation BEVs and PHEVs by the beginning of 2011. In conjunction with this, the government is considering a launch of significant investments in EV infrastructure by the first quarter of 2011, and to have the conceptual and organisational infrastructure in place by autumn 2010.

4.3.3 Denmark

Because of its relatively small size and high proportion of renewable (wind) energy, the country of Denmark is seen as an appropriate initial model for the establishment of a widespread network of EV charging infrastructure. Denmark is also a test case for the Better Place model. Its main partner is DONG Energy (2010) (Danish Oil and Natural Gas) a public limited company, in which the state, the Kingdom of Denmark, is the principal shareholder. As of 2009, Better Place and DONG Energy had agreed to invest DKK 770 million (ca. £85.71 mil) in the Danish Better Place network for EVs (Danish Energy Agency, 2009a).

Independently of Better Place, EDISON (Electric Vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks) (2010), managed by the Danish Energy Agency, is looking at ways to integrate EV charging into the electricity grid and facilitating the incorporation of up to 400,000 EVs by 2020. A demonstration phase is being run on the island of Bornholm in 2011 to test charging stations, EVs and intelligent control of the charging system (Danish Energy Agency, 2009a). The project's total budget is DKK 43 million (ca. £4.79 million), of which DKK 32 million (ca. £3.56 million) is a grant from the ForskEL programme (Energinet.dk, 2009). The ForskEL programme, started in 1998, is managed by Energinet.dk and overseen by the Ministry of Climate and Energy. It provides DKK 130 million of annual funding for research and development into environmentally friendly technologies for energy generation. There are currently about 10 programmes funded by ForskEl.

Support for the rapid deployment of charging infrastructure in Copenhagen has taken the form of expediting the permitting process, allowing private operators to install charge spots throughout the city.

4.3.4 Canada

Investment in infrastructure for EVs seems to be in its early stages in Canada. Because of the highly decentralised nature of Canadian government, individual provinces appear to have the freedom to implement plans independently, without the need for an overarching federal plan (Ontario, 2009). Some provinces are therefore ahead of others in terms of developing EV infrastructure.

Discussing battery electric vehicles (BEVs), Transport Canada (2010a) considers one of the drawbacks of these vehicles to be that commercial refuelling infrastructure is not currently widely available. The Electric Vehicle Technology Roadmap for Canada (Electric Mobility Canada, 2008) suggests that it is necessary to harmonize North American standards and practices for charger interfaces, and that action plans for infrastructure readiness have yet to be developed. Fleet operators approached by Electric Mobility Canada suggest that one of the advantages of EVs is that they could use existing electrical infrastructure. The Roadmap also laments the current lack of investment by the Canadian Government in the national manufacture of EVs, related components and infrastructure, compared to the C$25 billion (about £15.6 billion) pool in the US.

The Electric Vehicle Charging Infrastructure Deployment Guidelines for the province of British Columbia (Electric Transportation Engineering Corporation, 2009), suggests that stakeholders are not currently familiar with the infrastructure requirements for charging EVs. The initial introduction of EVs in the early 1990s, while unsuccessful in leading to widespread EV adoption, led to general consensus among stakeholders regarding aspects of charging infrastructure such as building and electric codes. The need to collaborate with utilities in controlling EV load is highlighted, with the necessity of using a smart-grid system being discussed. A number of mechanisms exist through which utilities could control EV load, including control of the time of use of grid power for recharging, voluntary cutting back of electricity use in peak times, real-time pricing so that EV users could recharge when electricity is cheapest, and vehicle to grid transfers of electricity.

4.4 The Better Place Model

In terms of EV infrastructure development, a number of private initiatives exist, including car sharing clubs with BEV fleets such as Norway-based MoveAbout (Move About, 2010). There are also private companies specialising in charging infrastructure. Elektromotive is a UK-based company, which produces "Elektrobay" recharging stations (HM Gov (2009) Ultra-low carbon vehicles, p. 9). These are currently in use in London (City of Westminster) and elsewhere around the UK, as well as in Europe and the US. Elektromotive claims to have "developed the world's first truly generic electric vehicle refuelling network"[17]. However, the company that currently appears to have the widest worldwide reach and greatest amount of private investment is Better Place[18].

A significant amount of media attention has been paid to the Better Place model, which promotes the sale of pay-per-mile service contracts and battery leasing rather than on the conventional sale of cars and petroleum. Since its 2008 implementation in a number of core countries (Israel and Denmark, followed by Australia, the US, Canada and Japan), Better Place has grown dramatically. Within a year of its launch, Better Place was in discussion with more than 25 countries about national implementation (Droege, 2009). In January 2010, Better Place secured $350million (about £227 million) for its second round of new equity financing from an investor group led by HSBC.

The business model involves the provision of charging infrastructure for EVs in public places such as parking lots, and battery exchange stations for when batteries become worn out or are needed for longer journeys. The aim is to make the transition to EV use as practical and unproblematic as possible. Better Place needs to collaborate with local and national partners and have the support of local and national government in order to be operational. However, as Anthony Bernbaum, Global Head of Special Opportunities at HSBC points out, "One of the absolute beauties of Better Place, is that it allows for the build out of infrastructure to make electric cars a success without significant, maybe any

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[17] http://www.elektromotive.co.uk

[18] For a comparison of the Better Place model to some other existing models, see, for example: Lemoine, D. M. and D. M. Kammen (2009). "Addendum to 'An innovation and policy agenda for commercially competitive plug-in hybrid electric vehicles'." Environmental Research Letters 4: 039701.

government funding, and without consumers making a great sacrifice" (Better Place, 2010c).

The Better Place model is of interest because its initial focus sites are showcase areas for the model, and because its roll-out has been driven forward through a combination of political will and available private sector partners. Further expansion is based on investor returns. The characteristics of countries selected by Better Place for implementation are summarised in Table 10.

Table 10: Characteristics of initial focus sites for Better Place implementation

Country/City	Expected date of commercial launch	Positive Characteristics
Israel/ Jerusalem	End 2011	Nationally • Former Israeli President, Shimon Peres, is a champion of the project • Small country size • High petrol taxes Jerusalem • Support from the current mayor
Denmark/ Copenhagen	End 2011	Nationally • Small country size • Strong case for economics of transition • Progressive environmental policies mean extensive wind farms providing off-peak, clean electricity (20% of country's energy) • 2 million petrol-powered passenger vehicles • High international profile due to 2009 UN Climate Change Conference, COP15 • Tax differential on GPVs and EVs Copenhagen • Copenhagen aims to be the world's first carbon neutral capital by 2025 • City of Copenhagen support
Australia/ Canberra	Beginning 2012	Nationally The world's 6th largest country by geographical size, chosen to show that the model works in any country, irrespective of size. 15 million GPVs Canberra • Highly mobile population, commuters • Public support
US	Beginning 2012	Nationally • Blueprint for auto industry recovery California (San Francisco) • The world's 8th largest economy • 1.8 cars per household (one of the highest in the world) • Birthplace of innovation for last 50 yrs • Bay Area Climate Change Compact has action areas on increasing EV numbers and using clean energy Hawaii • Hawaii Clean Energy Initiative recently initiated (wind farms, photovoltaic arrays, geothermal, run-of-the-river, biomass energy) • Partnership seen as leading to job creation and economic growth • US blueprint
Canada	Beginning 2012	Nationally • World's 5th highest per capita rate of car ownership Province of Ontario • Leading petroleum-refining region • Ontario Climate Change Action Plan launched in 2007 • Big car-making region • Taken steps to sustainable transportation (e.g. the "Car 2.0" initiative)

Country/City	Expected date of commercial launch	Positive Characteristics
		• 7.3 million vehicles • 2nd largest province (over 1 million km^2/ 415,000 sq, miles)
Japan	Collaboration begun September 2009	Nationally
		• Funded by Japan's Ministry of Economy, Trade and Industry's Natural Resources and Energy Agency • Only foreign company participating alongside Japanese carmakers

Source: Better Place Website – Global Progress: http://www.betterplace.com/global-progress/

In February 2010, Better Place's first EV demonstration centre opened in Israel, in advance of commercial launch of the model in Israel and Denmark in 2011. The aim is to allow consumers to familiarize themselves with all aspects of the Better Place model, from EVs to charge spots, to the battery switching process (Better Place, 2010b). The first Better Place charge spots were installed in Israel in 2008, in the parking lot of Cinema City a shopping centre-theatre complex in Tel Aviv (Better Place, 2008). In April 2010, Better Place announced the signing of a memorandum of understanding with the Chinese car maker, Chery, involving collaboration to secure government funding for EV pilot projects in China (Better Place, 2010c). Also in April 2010, the Better Place battery switching station for BEV taxis opened in Tokyo. Three ICE vehicles have been converted to BEVs with switchable batteries, and the aim has been to trial them for 90 days, starting at the end of April 2010. The trial involves three operational EV taxis, with 12 batteries between them (Better Place, 2010f).

According to a case study developed at the William Davidson Institute (2010), the Better Place model has so far been greeted with both praise and condemnation. The company has been accused of monopolising the EV market, but insists that it supports the standardisation of EV equipment as a facilitator for the development of the EV market (ibid.). Formal evaluations of the first stages of implementation of the Better Place model have yet to be undertaken. The trial was completed at the end July 2010, and may be extended, following an initial examination of the data produced in the first three months. A similar trial is to be initiated in Israel at the end of 2010. The relatively limited range of the taxis, making it necessary to swap batteries after about 80-100 km, remains a concern for the taxi company, Nihon Kotsu, because they have had to turn away customers whose journeys were beyond the vehicles' range. Better Place aims to develop 50 – 100 battery swap stations in Tokyo, if the project goes ahead, but it is expected that 200 stations would be necessary to serve Tokyo, and that there would have to be 200 taxis per station in order for the model to break even. The implementation cost remains high.

CHAPTER 5 Examples of EV initiatives

Our review of EV initiatives seek to further highlight specific initiatives that are under way in a range of localities, some of which have been touched upon in Chapter 4, on policies and programmes to encourage wider EV adoption. Although all of these policies and programmes are in the early stages and it is too early to draw conclusions about what works, they may provide some useful lessons.

The example initiatives were chosen in order to provide additional information about electric vehicle initiatives in the countries that we have chosen to focus on in this review. Information about each of these emerged through a review of the particular literature for the country in question but, because they provide quite specific information that is not necessarily comparable between countries, we use them here as food for thought regarding certain aspects of EV initiatives to date. They serve to highlight points that could usefully be borne in mind when considering new or improved initiatives.

The case of Copenhagen illustrates the details of a Better Place model roll out, and the case of New York shows that a policy focus on early EV users may represent a more effective initial strategy than targeting immediate widespread use. The Quebec and Ontario cases highlight how low-speed vehicles (LSVs) could be used, while the London, Milton Keynes, and Cambridge cases show how national and regional coordination of efforts is intended to facilitate the widespread adoption of EVs.

5.1 London

A range of initiatives are under way in London to increase the number of EVs in the city, and thereby improve air quality, while reducing greenhouse gas (GHG) emissions (Greater London Authority, 2009). The Greater London Authority's (GLA) electric vehicle website (www.london.gov.uk/electricvehicles) has been set up for the express purpose of providing one easy to use source of up to date information about EVs in London, thereby allowing the general public and other stakeholders to make an informed decision about EVs. To this end, it provides links to a number of external websites for additional information on EVs: the Low Carbon Vehicle Partnership, the DfT, NewRide, WhatGreenCar.com, Green Car Site and Green-Car-Guide.com. These websites are the initiatives of groups of EV stakeholders such as local authorities, interest groups around environmentally friendly transport, and an environmental consultancy. The London Electric Vehicle Partnership (LEVP), formed in November 2008, is made up of a variety of EV stakeholders, including private and public sector partners such as Elektromotive, vehicle manufacturers, Transport for London (TfL), and the centre of excellence for low carbon and fuel cell technologies (CENEX). It is intended to provide leadership in the area of EVs by setting up an action plan, collecting information and promoting best practice examples, ensuring value for money and supporting EV users.

Funding for EV projects in London is to come from the UK government's £230 million fund for EV promotion, as well as from the GLA and private sector donations. Financial commitments have been made by a number of London stakeholders; Transport for London has issued a green vehicle tender worth £67 million for up to 1,300 zero and low carbon vehicles, while the transport authority has issued one worth up to £30 million for 25,000 EV charging points, both of which would run over four years (Greenwise Staff, 2010). 70% of TfL's tender is for EVs and HEVs with up to 8 seats. It is part of a move to establish EV procurement frameworks. The Mayor of London aims to install 1600 EV charging points by April 2011, 7500 by 2013 and 25000 by 2015.

In May 2009, the Mayor of London published his Electric Vehicle Delivery Plan to make London the "electric vehicle capital of Europe" (Mayor of London, 2009). The £60 million plan involves three main phases:

- 25,000 charging points rolled out by 2015
- 100,000 EVs on London streets as soon as possible, and to increase the share of EVs in the whole Greater London Authority fleet to 1,000 by 2015
- to promote EVs through incentives such as free parking and continued exemption from the London Congestion Charge (worth up to £1,700 per year).

Incentives for consumers to use EVs in London include exemption from the congestion charge, subsidised parking, and encouragement to car clubs to switch to EVs by providing them with dedicated charging infrastructure. Current financial benefits for using EVs are highlighted on the London electric vehicles webpage (Greater London Authority, 2009):

- exemption from the congestion charge, worth up to £1,700/yr
- no vehicle excise duty (VED), giving a saving compared to a Band D car of £125/yr
- reduced parking costs and free charging at a cost of £14 per day, worth £2,800/yr.

The City of Westminster, in London, was one of the first areas in the UK to exempt "alternatively fuelled vehicles" from congestion charges, and to give them reduced vehicle excise duty, as well as free parking in central London (the latter only for all-electric vehicles) (City of Westminster, 2010). People who work or live in Westminster are additionally eligible for free residential parking on qualifying vehicles.

In addition to private consumers, businesses are being encouraged to switch their commercial fleets to EVs, a variety of which are produced by UK-based companies. A group of 10 companies that already have EVs in their fleets are to work with the government to promote wider commercial EV use. While a number of barriers remain to the full electrification of public transport, primarily as a result of the requirement related to range, London eventually aims to find ways to incorporate EVs into the taxi, bus and private hire vehicle fleets in the city.

5.2 Milton Keynes

Milton Keynes Council and the Renault-Nissan Alliance have agreed to collaborate to roll out EVs and their charging infrastructure throughout the city. Four hundred and thirty EV charging points in public and private locations and up to 2000 charging points in homes are planned with funding from the UK government's Plugged in Places scheme. Local incentives for drivers include free parking and free charging at public charging points. The launch of the Nissan LEAF in March 2011 coincided with the opening of the first 50 charging points (Milton Keynes Council, 2011). The Renault-Nissan Alliance is planning to launch four models of zero-emissions vehicles, beginning in mid-2011.

According to David Hill, Milton Keynes Council's Chief Executive, the city is a showcase low carbon city, and this latest development ties in well with its Low Carbon Living agenda. Together with London and the North East, Milton Keynes was one of the first areas to secure government funding through the plugged-in-places scheme. It also joined the Joined-Cities Plan, which would create a national network of EV charging points (Sunderland, 2010). As such, the Milton Keynes EV charging scheme also allows its members to access charging posts in Oxford and Cambridge.

The Milton Keynes Sustainable Transport and Road Safety Forum is in charge of County Council initiatives to introduce EVs (Milton Keynes County Council, 2009). Milton Keynes has the advantage of Nissan's local EV research establishment and the long legacy of Aston Martin production. Steps are underway to involve schools and colleges in EV projects, as well as to provide charging facilities for a proposed fleet of electric buses.

5.3 Cambridge

A focus on the East of England Development Agency (EEDA) provides some interesting information about the context for EV roll-out in Cambridge.[19] EEDA's stated mission (EEDA, 2010a; Milton Keynes County Council, 2009) was to improve the economy of the East of England, which consists of 6 counties, including Cambridgeshire. EEDA's corporate plan for 2008-2011 was revised in June 2009 (EEDA, 2009), in part in response to the effects of the financial crisis. However, in the East of England, Cambridge has been least affected by the recession. EEDA groups Cambridgeshire with Peterborough Unitary Authority, but recognises the differences between the two areas, and addresses different issues in each. In Cambridgeshire, the focus is on "building on the innovation and knowledge economy, managing growth and making the case for infrastructure" (EEDA, 2010b).

EEDA invested a total of £86 million in the economies of the two counties in the last decade. EEDA's aim going forward was for the region to focus on strengthening its role as a leader in innovation. In support of the previous government's NEW Industry: New Jobs (NINJ) framework, there would be a focus on Cleantech innovation in the East of England (EEDA, 2009). This would include a CleanTech Innovation programme, focussing on the Built Environment, Low Carbon Vehicles and Renewable Energy. Projects similar to the

[19] EEDA will close by March 2012 as a result of policy changes by the coalition government

expansion of the Hethel Technology Park in Norfolk, focused on low carbon vehicles, do not currently appear to be planned for Cambridge. The bulk of initiatives appear to centre on improving the availability of renewable energy and transitioning to a low carbon economy. In a drive to improve coordination across regions, administrations, and with government, the revised EEDA corporate plan for 2008-2011 laid out how £625,000 has been pledged towards a pan-regional low carbon vehicle programme. In line with government reforms, EEDA will close by March 2012[20]. Transport and innovation strategic investments have stopped from April 2011, although EEDA continues to work with partners to complete existing innovation strategic projects and the Low Carbon Venture Capital Fund[21] will continue to develop innovative low carbon projects in the region.

As part of the Plugged-in Places, £30 million initiative, initiated by the former government, East of England's "EValu8" programme has been awarded £7 million over two years, from March 2011. The project aims to install 1,200 EV charging points in the region during this time. Eight key clusters have been identified for focused development of an electric vehicle charging network, to be linked to existing networks in London, Milton Keynes and the Midlands set up during the first phase of Plugged-in Places. These clusters centre on Bedford, Cambridge, Ipswich, Norwich, Peterborough, Luton and Hertfordshire (including St Albans, Stevenage and Watford), Thames Gateway South Essex (including Basildon, Harlow, Southend, Thurrock, Chelmsford and Colchester), and London Stansted airport. This area is considered to be ideal for this type of project because the major urban areas are within a range of 45-65 miles, which easily corresponds to EVs' ranges[22].

Although electric vehicle-related plans and interventions are not immediately obvious on the Cambridgeshire County Council website (Cambridgeshire County Council, 2011) it does include details of plans to improve the environment by prioritising sustainable travel (Onslow, 2011). This includes promoting the use of alternative fuelled vehicles, and links are provided to further information on the Energy Saving Trust, the Department for Transport's Cleaner Vehicles Task Force and the Green Fuel Company websites. Electric vehicles are not mentioned under the "car-sharing" or "car travel" headings.

Current initiatives appear to be focused on drivers' behaviour change with respect to transportation as a means of reducing traffic congestion and the environmental impact. This would appear to be at odds with the UK government's policy focus on improving technologies rather than on behaviour change. The latest Cambridge City Council Environmental Action Programme for 2010-2011 does not specifically mention electric vehicle related initiatives, but its overall aims are to tackle the causes and consequences of climate change, to minimise waste, and to protect the local environment. Nevertheless, the

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[20] Source: "Status update on projects and programmes" East of England Development Agency website, http://www.eeda.org.uk/6100.asp, accessed on 6 December 2011.

[21] Additional information from: Low Carbon Innovation Fund website, https://www.lowcarbonfund.co.uk/LCIF/, accessed on 6 December 2011.

[22] "EValu8's network coverage" on EValu8 website: http://www.evalu8-ti.org.uk/coverage, accessed on 6 December 2011.

City of Cambridge and Cambridgeshire County Council have plans for carbon reduction and improving "greenness" in the City, as well as the establishment of EV charging points and preferred EV parking spaces in the city centre (Cambridge City Council, 2010). The city is geographically well placed to benefit from regional roll-outs of charging infrastructure, including as part of the government's plugged-in-places scheme. Further links may be possible with EV initiatives in London and Milton Keynes, from where lessons and inspiration could be drawn.

5.4 Paris

The City of Paris is making a concerted effort to bring together EV stakeholders and to inform the general public about EVs. From 11-16 September 2009, it held "electric mobility days" at the city hall, allowing the public to discover and use more than 40 different types of electric mobility solutions, including EVs (Mairie de Paris, 2009). In particular, the "Autolib" scheme was also presented (Mairie de Paris, 2008).

"Autolib" is an electric vehicle sharing scheme, planned for introduction in Paris in 2011, to mirror the current "Vélib" bicycle sharing scheme in the city (International Herald Tribune, 2010). A recent International Herald Tribune (2010) special section on Green Business lays out the details of the scheme, which is being promoted by the Mayor of Paris, Bertrand Delanoë, and would be "the biggest of its kind in the world". There are plans to have 3,000 zero-emission EVs at 1,000 parking stations around the city and the Île de France region. Consumers would be able to subscribe to the scheme on a monthly basis (about €20 per month (£17)), and then pay a half-hourly rental fee of about €7 (£6).

The contractor to operate the program in a private-public partnership is to be chosen in December 2010, by the 31 local authorities of the Île de France region (Espace Mobilités Electriques, 2010). Although there is interest in the project, there are still problems to be overcome, including the prevention of vandalism, and the provision of sufficient charging infrastructure.

5.5 Copenhagen

The city of Copenhagen hopes to become the green capital of the world by reducing 20% of its CO_2 emissions by 2015, compared to 2005 levels, and to becoming completely carbon neutral by 2025 (Copenhagen Technical and Environment Committee, 2009). Regarding transportation initiatives, the city is setting up a hydrogen filling station and buying 15 hydrogen fuel-cell powered vehicles – 13 passenger vehicles and two lorries. As of December 2009, there should be about 60 climate friendly vehicles operating in the City of Copenhagen, which excludes EVs. There is a drive to green the City's municipal fleet so that all vehicles bought from January 2011 would be electricity or hydrogen-powered, in addition to 85% of the total fleet electricity or hydrogen-powered.

A number of initiatives were set in place in the run-up to the UN climate conference in December 2009, with a focus on teaching initiatives and user involvement, aimed at ordinary citizens and the youth, as well as collaborations with private businesses. The aim of the Copenhagen Climate Plan is to improve climate consciousness and to increase the

City's influence on the national and international climate agenda (Climate Capital Copenhagen, 2009).

EV users in Copenhagen could currently recharge their vehicles for free at public charging points around the city, but it is expected that a fee would be charged in the future. The municipality is one of currently 15 (out of 98) Danish municipalities that have an agreement with Better Place[23]. Not all charging points in the city are provided or owned by Better Place[24], but in order to use Better Place's charging points (Better Place, 2010a), EV users have to request a key card and electricity cable from the company by phone or e-mail (Copenhagen Municipality [Københavns Kommune]). There are currently Better Place smart charging facilities in 15 locations in Copenhagen, with 8 of these being fully accessible to the general public. In addition to free recharging, EVs park for free in public parking facilities where non-EVs have to pay. However, payment is also expected to be gradually introduced for EVs in the future (Copenhagen Municipality [Københavns Kommune]). Citizens who want to install a recharging point by their home or place of work could contact the municipality to discuss how to do this, with the condition that charging points on public roads must be available for general use.

The short-term agreements made between the city of Copenhagen and providers of EV charging infrastructure have been renewed for 10 years, with the possibility of renewal after this time (Copenhagen Municipality [Københavns Kommune], 2010a). Providers have permission to continue to install and run charging points until a total of 500 EV parking spaces have been established. In addition, the city is to make plans to install recharging facilities for curbside EV parking (i.e. not in designated parking spaces), and for how to proceed with the establishment of charging points beyond the initial 500 that have been approved.

A project currently underway at the Kolding School of Design is of interest regarding consumer attitudes to EVs (Kolding School of Design). Etrans is a three-year project, started in 2009, to investigate the electric car market in Denmark, including the Copenhagen area, and to determine how best to disseminate electric cars domestically (Etrans). To this end, an ethnographic field study was carried out in early 2009, the results of which are available on the Etrans website (Etrans, 2010).

As a purely qualitative study, it is not statistically representative of the population, but it provides rich descriptive material about lead EV consumers, users of conventional vehicles, and non-vehicle users. Emerging details regarding consumer attitudes to EVs include the role of an EV as the second car in the household, and how it may become the primary car once owners become familiar with its range and capabilities. Information about EV use includes generational differences in vehicle use through the life cycle, as well as differences in gender-based attitudes.

[23] See chapter 4.4 for a discussion of the Better Place model.

[24] Others are owned by the municipality of Copenhagen, Clean Charge, a Better Place competitor which also produces networked charging points, and MoveAbout, which runs EV car sharing clubs.

5.6 New York City

EV initiatives in the US tend to be associated with California, and particularly the San Francisco Bay area. However, significant initiatives are underway across the US. The city of New York, like all the regions reviewed in this chapter, has a comprehensive sustainability plan (PlaNYC) (City of New York, 2010a). The City aims to reduce GHG emissions by 30% in 2030, compared to 2005 levels. Because transportation emissions make up 22% of total GHG emissions, wider EV use is considered a key goal. New York has a unique transportation profile in that residents have a number of transport options and are not reliant on cars to the same extent as the rest of the country's population. Only 44% of households in the five boroughs of New York own cars, compared to 90% of households on a national level. Car ownership in Manhattan is less than 22%. About 40% of its electricity comes from clean energy sources.

In an attempt to address the shortage of information about consumer attitudes to EVs, McKinsey and co. are currently conducting studies in New York, Shanghai, and Paris (City of New York 2010a). The New York element of this study has found the following:

1. EV market expansion may benefit from an initial focus on "early adopters" rather than on the general public. Early financial investment may be best targeted toward charging infrastructure in homes and personal parking facilities, rather than in public spaces
2. Existing attitudes to technology and the environment would determine consumers' attitudes to EVs "Smart" charging in off-peak hours would facilitate a minimal impact on electricity availability
3. Government and industry cooperation, as well as across industries, would be necessary for success.

McKinsey and co. suggest that policies to encourage the general public to adopt EVs on a greater scale should involve a number of high impact, low cost initiatives. These include (City of New York, 2010a):

- The prioritisation of a "green" electricity service for EV recharging
- Differential pricing for on and off-peak charging
- Charging spots at central locations and in commercial garages
- A website dedicated to educating the public about EVs
- A free half-day EV school
- Training programs for mechanics to become certified in EV maintenance
- Planting one tree for each of the first 5,000 EV adopters.

McKinsey and co. is optimistic about the uptake of EVs, its forecast showed that 14-16% of the new cars purchased in New York by 2015 would be electric. However, the supply of EVs to the New York region is expected to be limited, meaning that demand would outstrip supply (City of New York, 2010a). After the early adoption stage, future developments such as the increased availability of different types of EVs on the mass market and a reduction of the price of batteries is expected to make EVs more attractive to the average consumer in years to come. Financial incentives in the form of tax rebates on EVs are not necessarily seen as the best way to increase their market penetration. Instead, a multi-pronged approach is needed which includes improving consumer awareness, making

EV drivers feel special, providing financial incentives, offering access to parts of the City via designated vehicle lanes, and reducing the perceived risk of EVs by guaranteeing resale and upgrade prices. These findings are consistent with those laid out in a 2008 report for the UK Department for Transport, carried out by Arup-Cenex (2008).

Many EV-related initiatives are underway in New York. One of these is the Coulomb Technologies' ChargePoint America program, which aims to install 4,600 free EV charging stations across a number of major metropolitan areas in the US by September 2011 (Foresman, 2010). This is comparable to the Better Place model, discussed above. The ChargePoint America website[25] provides an information video, showing how the charge points work and how they could be used to charge EV owners for their use. The stated aims of the programme are to reduce petroleum consumption, reduce GHG production and create jobs. The charge points would be in public spaces, businesses, and private homes. ChargePoint is a $37 million (ca. £ 25mil) project, partly funded by a grant from the American Recovery and Reinvestment Act. It is a partnership with the automakers Chevy, Ford and Smart, who would make their EVs (the Chevy Volt PHEV, Ford Transit Connect BEV, Ford Focus BEV and Smart ForTwo BEV) available in the regions covered. Businesses and private individuals could sign up to receive information about when charge points would be available in their region. Data would be collected from each charging point and analysed for future use.

In 2005, HEVs were approved for use as taxicabs and limousines in New York (City of New York, 2010b). Information was gathered and provided to stakeholders in order to assess the benefits and costs of adopting HEVs for commercial use (New York City Taxi & Limousine Commission, 2005).

5.7 Quebec and Ontario

Quebec and Ontario generally appear to be ahead of other Canadian provinces in their focus on increasing the number of EVs in use. In Ontario, forward-looking government procurement policies are in place to speed the incorporation of electric vehicles into government fleets, where appropriate. The aim is to have up to 500 EVs in the Ontario Public Service vehicle fleet. EV initiatives in Canada, and particularly in Quebec and Ontario, include the use of low speed vehicles (LSVs) as alternatives to ICE vehicles in urban areas, and deliberations regarding their suitability for use on public roads are ongoing. In Canada, all vehicles classed as LSVs are fully electric, also called battery electric, vehicles.

In 2001, a pilot project was carried out in the city of Saint Jérome, Quebec, in order to assess the integration of low speed electric vehicles (LSEVs) into urban traffic from a safety and reliability perspective (Transport Canada, 2002). Even with little previous awareness of LSEVs, 89 percent of road users felt that LSEVs had a place in the city, and 64 percent of test drivers were interested in possible purchases, even though a third would wait until improvements were made. Respondents felt relatively safe driving LSEVs. The assessment made recommendations regarding LSEV use for the federal and provincial government, as

[25] http://www.chargepointamerica.com/

well as for municipal authorities and manufacturers. These findings appear to have led to the implementation of a pilot scheme in Quebec, allowing LSEVs on 50 km/h roads. Quebec's pilot LSEV project was unique in Canada when it was set up. Other provinces only allow LSEVs on streets designated for 40 km/h or restrict them to parks, conservation areas, gated communities, and university campuses.

Transport Canada continues to raise safety concerns because of the small size of the low speed vehicles compared with typical cars and trucks with which they could potentially be sharing the roads. The safety of PHEVs remains a concern for policy-makers and the public (The Waterloo Institute for Sustainable Energy 2010), which is why there are as yet no commercially viable LSEVs on the Canadian market. In addition, it is claimed that these vehicles do not yet live up to consumers' expectations regarding range, performance, comfort, safety, and reliable operation. This would suggest that the Saint Jérome LSEV pilot project, while increasing public awareness of LSEV's, is unlikely to lead to their increased uptake by consumers, because they continue to compare LSEVs to the ICE vehicles of similar size.

In 2008, the Quebec Advanced Transportation Institute produced an assessment of the worldwide situation regarding LSEVs, in order to inform the Ministry of Transportation of Quebec's decision-making process regarding the integration of LSEVs into normal traffic. Some European countries have more stringent production criteria for LSEVs than those in Canada, while the US has stricter rules regarding their operation. The findings were that, while LSEVs are a small part of the overall transportation sector, their increased use would support the provinces' aims to reduce GHG emissions from vehicles. The recommendations of the report are that there is good potential for the use of LSEVs on public roads in Quebec, providing that stringent safety measures are put in place regarding their manufacture and their use.

A pilot project in Ontario was also initiated in 2006 and has recently been extended to the end of December 2014. The fact that Ontario's Ministry of Transportation encourages prospective LSEV users to become familiar with their local speed limits suggests that speed restrictions may be problematic. Other requirements for LSEV use include compliance labels, special plates and slow-moving vehicle signs, speed limits of 40 km/h, traffic control devices, towing and modification restrictions, and proximity warning signs that emit an intermittent noise when the vehicle is near pedestrians and cyclists. The Ontario Ministry of Transportation (MTO) has recently (2010) added information to its website, as guidance for Ontarians using "new and alternative vehicles", including LSEVs (referred to as low speed vehicles (LSVs) by the MTO). These guidelines make clear that different rules apply to LSVs, depending on where they are used, i.e. on what types of roads. The pilot project covers LSEV use in conversation areas, on public roads, and in controlled environments such as campuses in order to ascertain whether and, if so, how LSEVs should interact with ordinary traffic.

Interestingly, the Waterloo Institute for Sustainable Energy (2010), in its recommendations for the future development of PEVs in Ontario, suggests looking to the US for inspiration regarding the coordination of initiatives and policies. This once again underlines the Canadian focus on attempting to become a leader in the area of EV development, while maintaining coordination across North America. Specifically, the recommendation is to allow municipalities to drive development by allowing them to develop EV infrastructure, while ensuring coordination from the province.

CHAPTER 6 Conclusions

As part of a larger project which aims to build an understanding of the factors affecting electric vehicle uptake, the present paper is a review of the literature relating to the barriers to wider adoption and the interventions by governments. The objectives of this literature review have been to provide:

- an overview of what is known about the barriers to the wider adoption of EVs; and
- examples of policies and programmes that have been implemented or are proposed in different parts of the world.

There are many barriers to purchasing EVs, but also some facilitators

We have identified a number of barriers to EV market expansion: some are technological, some are social or perceptual, and some are institutional. We first provided a summary of these barriers and then moved on to discuss how policy interventions may serve to overcome some of them. The issues around battery technology include:

- limited all-electric drive range (typically, the range of EVs is only around 100 miles);
- long battery recharge time (typically 6-8 hours for a full charge); and

Limitations in battery technology drive the high cost of batteries; hence vehicle prices are at least £15,000 more expensive than typical (non-electric) UK household cars.

Central to the recharging issue is the lack of sufficient charging infrastructure and other infrastructure elements such as overnight parking dedicated to EVs. Additionally, there are safety issues related to collision safety, electrical safety and the lack of engine noise.

EVs are more fuel efficient than conventional vehicles, but fuel efficiency is not a feature that is highly valued by consumers, who generally put a low value on future savings. Some consumers misunderstand the benefits of fuel economy and some associate EVs with "cheap" design. Even those who see themselves as environmental-friendly do not necessarily back up this self-proclaimed attitude with the action of purchasing EVs.

Additional barriers to EV market expansion are institutional, in the form of resistance from industrial giants. We have reviewed the notable example of resistance from the automotive industry in the fierce campaign in California against the zero emissions mandate of 2001, resulting in an end to the mandate and a temporary halt in EV development by US carmakers. However, the landscape has changed dramatically here, as many major motor manufacturers are now developing EVs such as the Nissan Leaf and the Chevy Volt.

Despite the significant number of barriers, some factors could facilitate the transition of EVs to the mass market. These factors include the effect of incentives and low running costs as well as innovations in the supporting infrastructure. At a social level, the symbolic value of the EV could encourage consumer purchase, especially among early adopters. Further market penetration could be facilitated by the social process through which members of society influence each other as a result of direct communication about personal experiences with EVs. In addition, the entrance of luxury car makers, such as Lotus, Porsche and Ferrari, to the EV market may reverse the perception of electric vehicles as "feeling cheaply designed" and "slow".

A plethora of government interventions

Governments around the world have initiated a large number of policies and programme to overcome these barriers. We have chosen to focus on UK, Denmark, France and Canada, drawing examples from the initiatives currently underway in these countries. These government policies and programmes could be broadly classified into seven main categories:

- **Subsidy to purchase cost**: an approach taken by all the countries reviewed. The level of subsidy is typically around £4200-£5200 per vehicle. Eligibility for government support differs by country and by scheme, but there is a general tendency to focus EV interventions on 'grid-connected' vehicles, i.e. plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).
- **Subsidy to car manufacturers**: in the UK, for example, the Nissan Sunderland plant has received £20.7m in government grants and up to £220m from the European Investment Bank, with the expectation that this policy would lead to the creation of 350-600 new jobs.
- **Subsidy to research and development**: an example is the UK's Technology Strategy Board (TSB)'s £1.3m investment in the development of a new, lightweight battery for use in electric, small, city cars with the aim of improving their performance, functionality and range.
- **Infrastructure development**: installing fast charging points and reliable, readily accessible power outlets is seen as essential by governments. However, the funding committed to this development is significantly lower than the funding committed to subsidising purchase. Instead, there are substantial private sector efforts to provide such infrastructure. In particular, there is quite a lot of optimism around the Better Place model.
- **Introducing EVs to commercial/government fleets**: examples include La Poste, the French postal service, which currently owns the largest EV fleet in France; and the Greater London Authority which aims to introduce 1,000 EVs to its fleet by 2015.
- **Providing other preferential access**: in London, EVs are exempt from congestion charge; in central Copenhagen, EVs could park for free; and in Ontario, Canada, single occupancy EVs are allowed on high occupancy lanes.
- **Increasing public familiarity**: while most of the demonstration tests only engage a small segment of the society, the Autolib scheme in Paris (which aims to mirror the vélib bicycle scheme) would likely give different segments of the population the opportunity to test drive EVs.

Overcoming the upfront cost barrier

The subsidy to EV purchase is perhaps one of the most notable interventions. In the countries reviewed, the level of subsidy is typically around £4200-£5200 per vehicle, amounting to hundreds of millions of pounds of government funds (see Table 11 for a summary). Given the large difference between the price of a conventional car and that of an EV (currently at least £15,000), large subsidies on purchase are required if the government wants to make EVs more competitive in the car market. This policy can help overcome the demand-side barriers in a consumer environment where potential car buyers do not put a high value on future saving but are more sensitive to the upfront cost. However, the heavy reliance on government funding to sustain competitiveness brings many uncertainties, particularly given the huge budget deficits experienced by most governments in the developed world, which may subsequently result in political pressure to reduce subsidies.

More importantly, the EV's ability to expand its niche market to a mass market would depend on dramatic advances in technology aimed at lowering the cost of battery production while maintaining high vehicle performance. While government subsidies in research and development help in reaching this goal, technological breakthroughs are not guaranteed.

Table 11: Government subsidy to the purchase price of EVs

Country/ Province	Initiative	Subsidy per vehicle in local currency	Max. subsidy per vehicle in £[1]	Total amount of funding for programme	Time frame
UK	"Investment in ultra-low carbon vehicles"	25% of the purchase cost, capped at £5,000	£5,000	£43m	Jan 2011 to Mar 2012
		will be reviewed in Jan 2012	n.a	additional £187 million (previously announced)	2012 – 2014
France	"Super bonus" or "bonus" for low emissions vehicles	€2,000-€5,000	£4,200	Not known	until May 2010 (start date not known)
	revised bonuses, with more detail vehicle classification	€100-€5000	£4,200	Not known	from May 2010 (end date not known)
Denmark	Electric vehicles are exempt from a number of taxes	n.a.	n.a.	n.a.	n.a.
Canada	ecoAUTO Rebate Program	up to $2,000	£1,200	$191.2 million	Mar 2007 to Dec 2008
Ontario, Canada	Ontario's Alternative Fuel Retail Sale Tax Rebate Program	8% of tax saving $750 - $2,000	£1,200	$24 million	from 2006-Jun 2010
Ontario, Canada	Ontario's Electric Vehicle Incentive Program	$5,000 to $8,500	£5,200	$50-85 million	from July 2010 (first 10,000 qualified applicants)

[1]Note: August 2010 exchange rates, rounded to the nearest hundred.

Overcoming consumers' perceptual barriers is equally important for encouraging take-up of EVs

Consumers have not been taking full advantage of the capabilities of the current EV technology. Emerging findings from car trial programmes highlight the "range anxiety" issue, i.e. that drivers of EVs tend to be overcautious when planning their journeys. The longest journey made with an EV was only 25% of the average vehicle range, and almost all of the journeys (93%) involved a battery that was at least half full. In-depth interviews with EV owners in Denmark also revealed how initial unfamiliarity with the vehicle led to feelings that the vehicle was underperforming, relative to a conventional vehicle. It seems that programmes to increase familiarity with EVs would be a supplementary intervention to maximise the current technology in the short term.

Similarly, providing reliable and accessible information for potential EV customers, enabling them to understand and appreciate the benefits of fuel economy is relatively inexpensive for the government to support. In addition, the entrance of luxury car makers, such as Lotus, Porsche and Ferrari, to the EV market may serve as a catalyst to revert the perception of electric vehicle being "cheap" and "slow". It would be interesting to study how attitudes may change towards EV over time.

Wider transformations

BEVs and PHEVs have the potential to reduce direct, i.e. tailpipe, CO_2 emissions from the transport sector. However, it should be recognised that without a greener electricity generation sector, the net impact of the wider adoption of the EV could only be small. Therefore, the potential in integrating EVs with the use of renewable energy is an opportunity which excites many environmental policies researchers, practitioners and policymakers alike. Although this review has not explored the details of this integration, further research should look into the costs, benefits, potential barriers and the public's behavioural response related to such a large and transformative plan.

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