Electromobility in Sweden: Facilitating Market Conditions to Encourage Consumer Uptake of Electric Vehicles

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Abstract

Electric vehicles (EVs) are considered a major element of the trend towards cleaner transport fleets. Despite considerable interest in electromobility, consumer demand for vehicles in Sweden remains very low. Critical issues such as vehicle cost, range and infrastructure development function as blocking mechanisms that hinder consumer acceptance. This report details these critical issues, while also investigating the market conditions, inducement mechanisms and alternative business models that can be applied in order to stimulate consumer demand. The diffusion of innovations theory developed by Rogers (1995) is applied to the potential consumer market for EVs in order to determine the characteristics and primary motivations of those most likely to purchase an EV. Drawing on this research, a number of specific recommendations are proposed for the purpose of facilitating momentum in the market for EVs in Sweden.

Keywords: Sustainable development, electric vehicles, Sweden, consumer demand
Executive summary

Electromobility is here, and this time it looks set to stay. Nearly all major vehicle manufacturers as well as a growing number of new entrants are currently engaged in developing and releasing electric vehicles (EVs) on to the market. The renewed interest in EVs is the result of mounting concerns over the contribution of transport toward global emissions of CO$_2$, worsening local air pollution, rising fuel prices and dwindling oil supplies. EVs are also considered to have the potential to rejuvenate the automotive industry which has struggled in the wake of the global financial crisis. Support industries, battery and infrastructure development, are now areas of rapid growth that hold significant potential for new business opportunities and partnerships.

The European Union has implemented a number of directives and regulations aimed at supporting its commitment to achieving incremental improvements in CO$_2$ and pollutant emissions from road transport. At the same time, substantial resources are being directed towards increasing the competitiveness of the European car industry through the development of sustainable transport options, in which electromobility is expected to play a prominent role in the medium to long term.

The Swedish government has taken these initiatives one step further by announcing the ambitious vision of a fossil fuel free transport fleet by 2030. This vision, together with a host of positive local market conditions, suggest that consumer acceptance of EVs in Sweden may be high. This aligns with early political rhetoric that suggested Sweden would become an early lead market for electromobility. The reality however, is markedly different, with a relatively undeveloped electromobility industry and EV sales figures falling well below those reported in other European markets.

This research focuses on the critical issues affecting consumer demand for EVs, namely cost, battery range, infrastructure development and environmental performance. The motivational determinants of consumer demand are examined in greater detail by applying the diffusion of innovations theory developed by Rogers (1995). The theory attempts to determine the trajectory of a new innovation by identifying those consumer segments most likely to adopt, based on their individual characteristics. Furthermore, the rate of adoption depends heavily on the perceived attributes of the innovation. By applying these attributes to electromobility, it becomes clear that at the current stage in development, EVs do not meet the needs or expectations of the majority of the consumer market. Although demand for EVs does exist in Sweden, it remains confined to a small number of early adopters and niche markets. With sales figures remaining low, there is a risk that the market may fail to reach the hypothetical ‘tipping point’ at which an innovation achieves mainstream consumer acceptance and the market becomes self-sustaining.

At this early stage of development, the industry is dependent on government-backed stimulus and measures designed to increase the competitiveness of EVs. The Swedish government supports a number of initiatives aimed at developing and promoting the market, including the implementation of the ‘supermiljöbilspremie’ in January 2012 – a purchase rebate for EVs valued at a maximum of 40,000 SEK. Although this is a step in the right direction, these interventions have done little to influence demand for EVs. Analysis of other, more successful European markets for EVs reveal a number of strategies and interventions that have been instrumental in increasing the popularity of EVs among consumers.
The outcome of this research is a set of recommendations aimed at stimulating growth and creating momentum in the Swedish EV market. The key recommendations include:

- Develop a coordinated, strategic plan for the development, support and promotion of a sustainable EV market in Sweden;
- Offer better incentives to stimulate consumer demand – both financial and non-financial;
- Invest in infrastructure development;
- Instigate a public information campaign; and
- Encourage the development of new business models.

By implementing these recommendations, the Swedish government can send a clear message to consumers, industry participants and vehicle manufacturers, thereby creating a renewed sense of confidence in the EV industry and the future of electromobility in Sweden.
# Table of Contents

Abstract ........................................................................................................................................ i
Executive summary ................................................................................................................ i
List of figures .................................................................................................................................. ii
List of tables ...................................................................................................................................... v

1. Introduction ................................................................................................................................. 1
   1.1 Research objective and questions ......................................................................................... 3
   1.2 Scope ....................................................................................................................................... 3
   1.3 Methods .................................................................................................................................. 3
   1.4 Analytical framework ............................................................................................................ 4

2. Background ..................................................................................................................................... 7
   2.1 History ..................................................................................................................................... 7
   2.2 Technology ............................................................................................................................ 8
      2.2.1 Vehicles .......................................................................................................................... 8
      2.2.2 Batteries ......................................................................................................................... 9
      2.2.3 Charging infrastructure ................................................................................................. 9
   2.3 Critical issues ........................................................................................................................ 10
      2.3.1 Consumer demand ...................................................................................................... 10
      2.3.2 Cost .............................................................................................................................. 11
      2.3.3 Range ........................................................................................................................... 14
      2.3.4 Infrastructure .............................................................................................................. 16
      2.3.5 Environmental performance ...................................................................................... 18

3. Analysis ........................................................................................................................................ 20
   3.1 Regulatory environment ........................................................................................................ 20
      3.1.1 Sweden ........................................................................................................................ 20
      3.1.2 European Union ......................................................................................................... 22
   3.2 Incentives ............................................................................................................................. 24
      3.2.1 Financial incentives .................................................................................................... 24
      3.2.2 Non-financial incentives ............................................................................................ 26
   3.3 Dissemination of information .............................................................................................. 27
   3.4 Demonstration and procurement schemes ......................................................................... 28
   3.5 New business models .......................................................................................................... 28
      3.5.1 Leasing options ........................................................................................................... 29
List of figures

Figure 1: Selection of EV penetration forecasts to 2020 ................................................................. 2
Figure 2: Rogers’ diffusion of innovations adoption curve .............................................................. 6
Figure 3: Rogers’ cumulative adoption curve showing ‘tipping point’ ............................................. 6
Figure 4: Projected Li-ion battery costs to 2020 ............................................................................. 11
Figure 5: European Brent oil annual spot prices, 1987-2011 .......................................................... 12
Figure 6: Swedish petrol and diesel pump prices 1990-2011 .......................................................... 13
Figure 7: Sweden’s electricity generation mix in 2010 ..................................................................... 18
Figure 8: Percentage of renewable energy in electricity generation in EU member states, 2007 ...... 19
Figure 9: EV consumer categories applied to Rogers’ diffusion of innovations curve ................. 34

List of tables

Table 1: EV charging methods ........................................................................................................... 9
Table 2: Selected elements of EV strategies in Estonia and France ................................................. 22
Table 3: Consumer categories and Rogers’ diffusion of innovations model .................................. 34
Table 4: Perceived attributes of electromobility and proposed actions ......................................... 38
1. Introduction

The automotive industry is changing. The electrification of private transport – electromobility - is gaining momentum in the marketplace with nearly all major automotive manufacturers as well as a handful of new entrants currently engaged in the process of electric vehicle (EV) development and market introduction (Gyimesi & Viswanathan, 2011). Electromobility, together with alternative fuels such as ethanol and biogas, represents a broad transition toward cleaner transport fleets. Few EVs are evident on the streets today; however, this is likely to change in the near future as production ramps up. A recent survey of global automotive executives revealed that the majority believe electromobility to be the single most important trend affecting the automotive industry today (KPMG, 2012).

The resurgence of interest in EVs can be attributed to the interaction of a number of favourable environmental, political and technical conditions. Local pollution, global climate change, concern over the supply and security of fossil-fuels, rising fuel prices and an automotive industry struggling in the wake of global economic downturn, all combine to create conditions favourable for increased investment in electromobility. As a result of these issues, many countries have introduced legislation and implemented specifically targeted programmes designed to encourage the development and uptake of more efficient, alternative-fuelled vehicles. At the same time, advances in battery technology have enabled EVs to be considered a viable and promising alternative to the internal combustion engine (ICE) vehicle that dominates the passenger vehicle market today.

A broad range of stakeholders including vehicle and battery manufacturers, local and national authorities, utilities providers and research organisations are investing significant capital into electromobility research and development. Strategic alliances and collaborative partnerships are rapidly evolving between stakeholders in order to create supply chain efficiencies. There are however significant challenges to be overcome in order to ensure the development of a mature and sustainable market for these vehicles. Foremost among these are concerns over the high cost and limited performance of batteries. With the current level of battery technology, large-scale investment in charging infrastructure will also be required if EVs are to appeal to the mainstream consumer market. In order for EVs to become a viable alternative to conventional vehicles, cost reductions, battery advancement and infrastructure development not only need to continue in unison, but must be carefully managed and implemented to ensure that the needs and expectations of customers are met. Increasing demand for EVs may also require significant investment in renewable electricity generation if the full environmental benefit of electromobility is to be realised.

EVs represent a fundamental system change rather than a simple technical deviation from cars found on the market today. They have been described as a disruptive technology; one with the potential to bring about transformative change to industries and institutions, as well as creating opportunities for the provision of new services (Barkenbus, 2009). In order to realise this potential, demand for EVs needs to increase significantly. This may prove difficult given the long-established market and systems supporting conventional ICE vehicles.

Electric vehicles were for a brief time the lead technology among those vying for dominance in the passenger vehicle market. However, a series of technical, economic and political developments saw the early popularity of EVs soon eclipsed by petrol-powered vehicles, thus paving the way for technological lock-in and market dominance of the internal combustion engine. The popularity of these cars had a profound impact on society and was instrumental in promoting the growth of middle class suburban areas (Cowan & Hultén, 1996). Cars influenced where people were able to live and work, and how they were able to spend their leisure time. As society changed in response to the widespread diffusion of ICE cars, the capabilities of the internal combustion engine came to define
the modern motoring experience. Mainstream consumer acceptance of EVs will depend to a large extent on how well these vehicles meet expectations of performance and value in comparison to the conventional internal combustion engine.

Still in its infancy, the outlook for electromobility is characterised by significant uncertainty. Very little consensus is found among attempts to forecast the eventual global market size. Figure 1 represents recent forecasts made by a number of large consultancy firms regarding the predicted market penetration of EVs by 2020. Forecasts for EVs alone range from the pessimistic (2.5%) to the optimistic (15%), yet the figures become even more unclear when hybrid and ‘green’ cars are factored in.

![Figure 1. Selection of EV penetration forecasts to 2020](source: PwC (PriceWaterhouseCoopers), 2011; Bain, 2010; KPMG, 2012; BCG (Boston Consulting Group, 2010; Deloitte, 2009)

Forecasts for the Swedish EV market are equally inconsistent. In lieu of a clear government vision for the future market for EVs in Sweden, both the Swedish Energy Agency and electricity industry stakeholder group, Power Circle have released their own individual forecasts of 85,000 and 600,000 EVs respectively on the road by 2020 (Swedish Energy Agency, 2009). Four years on from these forecasts and a more realistic estimation would appear to be significantly lower than even the Swedish Energy Agency’s relatively modest figure (Henke, 2012).

Research suggests that interest in electromobility among potential consumers is high, however this interest has yet to be reflected in consumer purchasing behaviour. In Sweden, only 171 EVs were registered during 2011, less than one per cent of all new vehicle registrations, and a mere eight per cent of the total number of electric vehicles registered in neighbouring Norway over the same period (Norsk Elbilforening, 2012; BIL Sweden, 2012). Lower than expected sales volumes have resulted in a barrage of negative press coverage proclaiming the failure of the industry. This criticism is unfounded considering the market introduction of EVs is still in its infancy and the benchmarks for its success - or failure - have yet to be determined. Vehicle availability to date has been problematic, however supply is expected to increase steadily from 2012 as manufacturers prepare for the commercial release of electric models. Whether the increased availability of EVs for purchase will correspond to an equivalent increase in consumer uptake is unclear, for electromobility represents somewhat of a leap of faith for the consumer, particularly at this early stage in market development.

It is certain however that the transition to electromobility will be a gradual one that will begin in a small number of niche markets. These early adopters play a crucial role in building public familiarity

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1 No definition of green cars is supplied with the forecast, making its relevance questionable.
and interest around electric cars, effectively allowing time for EV technology and infrastructure to mature to the stage at which the needs and expectations of mainstream consumers are met. The appeal of EVs to the mainstream market is highly dependent on a number of factors including cost reduction, improvements in vehicle performance, the development of charging infrastructure and the provision of specifically targeted financial incentives; all of which must occur in conjunction with one another. In the meantime, EVs will not only have to overcome current technological limitations, but also compete with increasingly efficient internal combustion engines and a range of alternative fuels in order to gain the attention of potential consumers.

1.1 Research objective and questions
The purpose of this research is to outline a number of specific recommendations aimed at increasing demand-side momentum for EVs in Sweden. The content of these recommendations is based on the outcome of three specific research questions:

1. What are the critical issues influencing the consumer uptake of EVs?

The macro-level challenges affecting consumer acceptance of electromobility are common to all markets. By exploring the barriers and drivers of consumer acceptance at international and regional levels, the extent to which they are relevant to the Swedish market can be determined.

2. What is the role of consumer segmentation in promoting market growth?

The consumer market is not a homogenous group whose preferences and buying behaviour develop in unison. Understanding consumer market segmentation and the role that specific consumer groups play in encouraging the diffusion of an innovation or technology through society is critical to facilitating EV uptake.

3. What lessons are to be learned from observing the diffusion of EVs in other European markets?

The success of EV diffusion varies between markets depending on local conditions and the interventions applied to encourage uptake. There is no proven path to ensuring eventual success and sustainability of the EV market. Norway, Denmark and France are considered frontrunners in the transition toward electromobility, and other encouraging examples are emerging. Examining specific interventions and strategies in other European markets may provide valuable information for Swedish industry stakeholders.

1.2 Scope
A great deal has been written about the future of electromobility, although gaps in the knowledge base exist. In particular, few reports focus on the industry from the consumer perspective; nor is there sufficient insight into the dynamics of the consumer market itself. Existing research is often global or regional in scale, which although useful, does not adequately describe consumer market conditions within the Swedish context. This thesis attempts to address gaps in local market knowledge by exploring the macro-level factors affecting electromobility and the extent to which they impact the Swedish market.

1.3 Methods
The objective of this thesis is to provide a better understanding of the conditions necessary to facilitate consumer uptake of EVs in Sweden. It represents a piece of qualitative research consisting of data sourced from both literature reviews and personal interviews.

Literature reviews supply much of the background data for this report. Traditional sources of information such as peer-reviewed scientific papers and government agency reports are also incorporated, however the dynamic nature of the industry also requires the use of less conventional data sources in order to track the latest developments. Newspaper reports, automotive and
environmental blogs, as well as special interest groups on social networking sites are instrumental in providing up to date information. In addition, many of the large global business consultancies and investment banks are tracking electromobility as well as forecasting future industry developments, making their websites and reports useful sources of information.

These information sources have been supported by several semi-structured interviews conducted with key individuals from industry stakeholder organisations in Sweden, including the Swedish Energy Agency, the electricity industry group Power Circle and the Stockholm City EV procurement scheme, Elbilsupphandling. The purpose of these interviews is twofold: firstly to clarify certain issues pertaining to EVs; and secondly, to gain a subjective interpretation of current issues and developments. In addition to these interviews, a private tour was conducted of the Better Place information centre in Copenhagen, Denmark. This was particularly relevant to the research undertaken as it highlights the essential role that new business models will play in the future of electromobility. It also presented an opportunity to compare Denmark’s experience of electromobility development to that of Sweden’s. This research also draws on experiences from other European countries, specifically Norway, France and Estonia. These countries were selected for their innovative approach to electromobility and the relatively advanced state of market development there.

1.4 Analytical framework

A successful transition to electromobility is reliant on the underlying assumption that consumers will be willing to purchase electric vehicles. At this early stage in market development, it remains uncertain how successful industry stakeholders will be at fostering a high level of consumer demand for what is essentially a product for which the majority have little experience or reliable knowledge. Equally uncertain is the rate at which EV technology will be adopted by consumers. Early signs indicate that EV uptake in some European markets, including Sweden, has not been as rapid as anticipated, although this may be indicative of factors other than lack of demand, such as low vehicle supply and delays in establishing clear financial incentives for their purchase.

Numerous surveys have sought to measure consumer attitudes towards electromobility in order to gauge demand for EVs. Many of these utilise ‘stated preference’ analysis, a method which seeks to explain and predict preference and choice (Hidrue et al., 2011). Stated preference methods are widely employed in situations where actual preference data (i.e. that which is based on experience) is unavailable. In the case of EVs, stated preference methods study the respondent’s perception of electromobility, since low supply and the subsequent lack of vehicles on the road to date has meant that very few people have had any practical experience of electromobility. This raises a fundamental question concerning the validity of results obtained:

*How accurately can demand be forecast from stated preferences for a technology for which the respondent has limited knowledge and no experience?*

Attempting to predict consumer behaviour and the trajectory of new technologies is a well established research area. Diffusion research offers an alternative approach to determining demand by indentifying those consumer segments most likely to adopt an innovation based on the individual’s characteristics. The most widely applied diffusion theory is Rogers’ theory on the *Diffusion of Innovations* (DoI). This theory attempts to explain diffusion as the process through which an innovation spreads through a society over time (Rogers, 1995).

A number of variables determine the rate of adoption. Foremost among these are the perceived attributes of the innovation, specifically:
1. The **relative advantage** of the product compared to those which it attempts to replace. This is measured not only in economic terms, but also incorporates social factors, convenience and personal satisfaction.

2. The **compatibility** of product with the individual’s needs, values and experiences.

3. The perceived **complexity** (or simplicity) of the product.

4. **Trialability**, or the extent to which an individual is able to test the product before purchasing.

5. The **observability**, or visibility of the product an action.

According to the theory, innovations or products that are perceived as having greater relative advantage, compatibility, simplicity, trialability and observability will be more easily accepted by the individual, and therefore spread more rapidly through society. Other variables affecting the rate of adoption include the type of communication channels used to promote the product and the extent of promotion efforts.

Since individuals do not adopt an innovation at the same time, Rogers classifies them according to ‘innovativeness’, which is the rate at which an individual will adopt an innovation relative to others. Five standardised categories are utilised for differentiating adopters in diffusion research:

1. **Innovators**. Innovators are typically financially secure and have a high level of technical knowledge. As risk-takers, they are able to cope with a high level of uncertainty regarding the innovation at its time of adoption.

2. **Early adopters**. Early adopters are often successful individuals that are considered to be better integrated into social systems than innovators. Important drivers of trends, early adopters make discerning innovation-adoption decisions.

3. **Early majority**. Although adopting an innovation earlier than average, the early majority only do so after considerable deliberation. Unlike early adopters, they do not hold a position of opinion leadership.

4. **Late majority**. The late majority adopt an innovation later than average and often approach the innovation with considerable caution. Adoption often results from peer pressure, but only after most of the uncertainty regarding the innovation has been removed.

5. **Laggards**. The last to adopt an innovation, laggards tend to be suspicious of change agents and will often lag far behind in awareness of new innovations.

Plotted as a frequency distribution, adopter categories follow a standard distribution bell-shaped curve (Figure 2) which gives a general indication of the proportion of the population that lies within each category. All innovations follow the same curve, although variations in its shape do occur. Some products achieve mass market appeal relatively rapidly, while other more specialised products may never do so.

A possible limitation of the theory in the context of this research is that it does not acknowledge the dynamic nature of innovations. Continual improvement of technologies may have a dramatic impact on the rate of uptake. This research assumes that a technological breakthrough related to battery advancements is unlikely to occur within mid- to long-term scenarios, therefore application of the theory remains appropriate.
The DoI curve is particularly suitable for describing the attempted market introduction of a new technological platform within the automotive industry since EVs intend to appeal to the mass market. Furthermore, the automotive market is considered relatively conventional, with consumers thinking and acting more conservatively than they would in relation to other products (Etrans, 2009).

The trajectory of a new innovation in society, measured through cumulative consumer uptake over time is plotted as an S-curve (Figure 3). The rate of diffusion is slow to begin with as only a small number of innovators are willing to assume the risk involved in being on the cutting edge of adoption. The trajectory slowly gains momentum as early adopters make an astute decision to invest based on information obtained from innovators and observation of early implementation of the product.

As opinion leaders, the uptake of an innovation by early adopters functions as an indicator to remaining consumer groups that the product has utility, not only from a practical standpoint, but also in terms of social benefit gained through association. Rogers refers to the point at which enough individuals adopt an innovation so that its continued rate of adoption becomes self-sustaining as the ‘critical mass’. This can also be described as a tipping point at which an innovation becomes accepted by mainstream consumers as the benefits of owning the innovation have been clearly established by the early adopters. If the transition to electromobility is to become a reality, EVs must succeed in first winning over a core group of influential early adopters in order to drive future mass market adoption of the technology.
2. Background

Prior to discussing the determinants of consumer demand for EVs, it is useful to present some background information and a brief description of the main components of electromobility; specifically vehicles, batteries and charging infrastructure. Electromobility is an increasingly popular term used to describe the electrification of transport. More specifically, it describes vehicles which are partly or fully powered by an electric motor. In addition to zero tailpipe emissions, electric motors feature a number of other advantages over the internal combustion engine. They contain far less moving parts which contributes to reduced manufacturing costs and lower maintenance requirements. Electric motors are also far more efficient at converting primary energy into vehicular propulsion, with an on-board efficiency of up to 90 per cent compared to a maximum of 30 per cent for internal combustion engines, where much of the energy is lost in the form of heat (Barkenbus, 2009).

The major disadvantages of EVs – namely high cost and limited range – can be directly attributed to an immature battery market. Expensive to produce, battery costs are also negatively affected by low manufacturing volumes, and this in turn is reflected in the premium purchase price demanded of EVs. The disadvantages affecting today’s EVs are not expected to be an enduring feature of electromobility, as large amounts of capital is being invested into battery R&D in the hope of a solution. Steady improvements are being achieved in battery storage capacity and the anticipated scaling up of manufacturing volumes will effectively drive prices down. The length of time required for these developments to establish EVs as a competitive alternative to the ICE vehicle remains uncertain.

2.1 History

Far from being a recent technological innovation, electric cars have been in existence since the late 19th century. At that time, electric cars were one of three technologies competing for dominance of the car market; the other two being steam and petrol. Rapid advancements in battery technology were achieved within a short period of time and by 1900, fleets of electric taxi cars were operating in London, New York and Paris. The trajectory of battery improvements stalled in the early 20th century however and was soon overtaken by advances in the internal combustion engine. Electric vehicle manufacturers focused their sales strategy on the high-end market, with vehicles priced significantly higher than those of competing technologies. Before long, electric cars were being far outsold by cheaper, mass-produced petrol models, and had virtually disappeared from the market by the late 1920s. The dominance of the internal combustion engine was established through high sales volumes and consolidated through the construction of refuelling infrastructure in the form of a widespread network of petrol stations. (Høyer, 2007; Cowan & Hultén, 1999).

It was not until the 1970s that interest in EVs was revived due to growing concerns over environmental issues and pollution, the APEC oil crisis and associated fears surrounding the security of petroleum supplies (ibid). Despite interest from major car manufacturers and institutional support through research and development programmes, no electric cars were produced on a commercial scale. The general consensus being that battery technology was not sufficiently developed to warrant substantial investment in EVs. Interest remained high however and as a result of serious local air pollution in Los Angeles, the California Air Resources Board (CARB) passed the first legislation aimed at promoting the development of EVs in 1990 (Collantes, 2005). Known as the Zero Emissions Vehicle (ZEV) mandate, the stated goal of the legislation was that 10 per cent of all cars on the road by 2003 would be ‘zero emission’ vehicles. Although major car manufacturers produced electric models to comply with ZEV, they did little to promote the vehicles. At the same time, the automotive and oil industries combined forces to lobby against ZEV – eventually succeeding in having the legislation overturned. Car manufacturers subsequently focused attention on the far more lucrative sport utility
vehicle (SUV). The exit of major car manufacturers from the EV industry provided the opportunity for small, independent EV producers to gain a foothold in the market.

The global economic crisis of the late 2000s once again placed EVs within the sights of major manufacturers. Large, inefficient vehicles favoured by the industry (particularly in the US market) received criticism in light of rising fuel prices and the backlash against conspicuous consumption. At the same time, EVs were touted as a potential economic panacea to rejuvenate the struggling automotive industry.

2.2 Technology

2.2.1 Vehicles
EVs that are already commercially available as well as those which are slated for release onto the market in the near future can be divided into four main categories:

*Hybrid electric vehicles (HEV)*

HEVs incorporate an internal combustion engine as well as a small electric motor which is powered by a small battery pack. The battery is charged by energy that would normally be lost through braking and coasting – a process known as regenerative braking (EDTA, 2012). The purpose of the electric motor in HEVs is to extend the fuel efficiency of the internal combustion engine rather than directly power the vehicle. Currently, all commercially available HEVs use nickel metal hydride (NiMH) batteries, although it is anticipated that all manufacturers will switch to the lithium ion (Li-ion) batteries used in BEVs by 2018 (Hybridcars.com, 2012). Although 30 per cent more expensive, Li-ion batteries carry significant weight and power advantages over their NiMH counterparts. HEVs can be considered the first step in the transition toward electromobility as they were the first EVs to be released onto the market with the launch of the Toyota Prius, the world’s first mass-produced hybrid car in 1997 (Berman, 2007). Although some HEVs are able to propel the vehicle using the electric motor alone, they are only able to do so for very short distances owing to limited battery capacity. Since HEVs utilise an internal combustion engine as the primary means of propulsion, they are not considered as EVs for the purpose of this report.

*Plug-in hybrid electric vehicles (PHEV)*

PHEVs are in effect, a compromise between BEVs and ICE technology as they contain both an internal combustion engine and an electric motor. The Li-ion battery is much larger than that of an HEV and charged via plugging the vehicle into an appropriate outlet. PHEVs generally have an electric-only range of between 15 and 60 kilometres, after which the car continues to be propelled by the internal combustion engine (EDTA, 2012b).

*Battery electric vehicles (BEV)*

BEVs – commonly referred to simply as EVs – are propelled solely by an electric motor which is powered by a Li-ion battery pack. The battery requires regular recharging which can be performed using a cable connection to a standard electricity outlet or via specialised charging posts. How far an EV can drive on a single charge depends on the size of the battery and driving conditions. Most EVs available today have a driving range typically of 100-160 km on a single charge (Elbilsupphandling, 2012). The length of time required to charge the battery varies according to the type of connection used.

BEVs and PHEVs are occasionally grouped together and labelled simply as EVs in literature and industry forecasts. However from a consumer demand perspective, the divergent technologies have widely differing implications as they will likely appeal to different consumer segments.
**Fuel-cell electric vehicles (FCEV)**

Fuel cell technology combines hydrogen fuel with oxygen to produce the electricity required to power a motor. Although small numbers of FCEVs are on the road today, the commercial release of passenger vehicles using this technology is not expected until 2014 at the earliest (Going Electric, 2011). Fuel cells are expensive, complex and present a unique set of challenges involving hydrogen storage and the treatment of water produced by the electricity generation process. Due to the early evolutionary stage of this technology, FCEVs are not included for further discussion in this report.

### 2.2 Batteries

Advancements in battery technology have paved the way for growth in electromobility; whilst at the same time – batteries remain the most significant technical obstacle to continued growth in the EV market. Modern EVs utilise Li-ion batteries to store electricity from the grid that is subsequently used to power the vehicle. Li-ion batteries are currently the preferred solution for electromobility applications due to their high energy density (at least three times greater than the lead-acid batteries used in most ICE vehicles), high specific energy and sufficiently long lifespan (BCG, 2010; EvWorld Sverige, 2012). Although steady improvements in Li-ion batteries are occurring, the energy storage capacity of this technology is considered too low to meet the long-term demands of the transport sector (Bruce et al., 2012). Research into Li-ion and alternative battery chemistries is a competitive growth industry where substantial amounts of capital are being invested in anticipation of a technological breakthrough with regard to energy density, weight and affordability. This is a formidable challenge and carmakers are responding by developing close business relationships with battery manufacturers in order to gain competitive advantage. Preferred technology differs between manufacturers, with each consortium competing for a breakthrough in the hope of producing the industry standard on which future technology will be based.

### 2.2.3 Charging infrastructure

EVs are charged using a cable connecting the car to an electrical outlet. The length of time required to charge a vehicle is dependent on the method used and battery capacity. Charging methods can be divided into three main categories: levels 1, 2 and 3 which correspond to slow, medium and fast charging (Table 1).

**Table 1: EV charging methods**

<table>
<thead>
<tr>
<th>Power nomination</th>
<th>Mains connection</th>
<th>Power (kW)</th>
<th>Recharge range/hour</th>
<th>Approximate recharge time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>1-phase AC</td>
<td>≤3.7 kW</td>
<td>&lt;20 km</td>
<td>6-9 hours</td>
</tr>
<tr>
<td>Level 2</td>
<td>1- or 3-phase AC</td>
<td>3.7-22 kW</td>
<td>30-50 km</td>
<td>3-4 hours</td>
</tr>
<tr>
<td>Level 3</td>
<td>3-phase AC or DC</td>
<td>&gt;22 kW</td>
<td>&gt;110 km</td>
<td>15-20 minutes</td>
</tr>
</tbody>
</table>

*Source: Adapted from EurElectric, 2011; Svensk Energi, 2010; Gyimesi & Viswanathan, 2011.*

Level 1 charging involves a single-phase connection to a regular 230V domestic electricity outlet. Achieving full charge typically takes between 6-9 hours (Svensk Energi, 2010). Slow charging is – and will continue to be – the most common method as it fits with established household mobility patterns and most basic infrastructure already exists without the need for considerable capital investment. Many households have vehicle parking with access to an electrical outlet, either in a garage or via an engine block heater which is commonly used throughout the colder months.

Level 2 charging involves a 1- or 3-phase connection to a charging post developed specifically for EVs. Applications for this method of charging include specific locations outside the home where cars are parked for a significant duration, including workplaces or commercial areas such as shopping centres.
and car parks. One hour of medium power charging produces a driving range of approximately 30-50 km (ibid).

Level 3 charging posts are suited for longer journeys and when installed as a network along major highways, would function in much the same way as the network of petrol stations function today. Using a 3-phase connection, fast charging to 80 per cent of battery capacity can take as little as 15 minutes. Although fast charging is capable of extending the range and appeal of EVs beyond the urban market, cost however is significant barrier to the development of fast-charging networks, with a fast charging station costing up to 350,000 SEK (ibid). With costs of this magnitude, the profitability of rapid charging will only be realised when there is a sizeable user base.

Public and private charging options create challenges and opportunities for stakeholders – particularly utilities – in terms of service and payment options. Many are developing new business models to tempt customers in what is likely to be a competitive market area. In response to concern over incompatibility amongst diverging technologies, representatives of the European electricity industry signed a declaration in 2009 which pledged to apply cross-industry standards to EV charging hardware and software (EurElectric, 2009). Further progress was made on the issue in 2011 when the European Automobile Manufacturers Association (ACEA) approved a number of recommendations on specifications for standardised charging (ACEA, 2011). Although a uniform charging interface solution is not expected to be fully implemented until 2017, it appears that most market participants recognise the importance of standardisation as a driver of EV market penetration. A single agreed technical solution will enable economies of scale within manufacturing as well as encourage investor and consumer confidence. In the transition period until full standardisation, industry stakeholders have recommended the use of an ‘envelope’ or vehicle inlet that supports all current plug configurations.

2.3 Critical issues
Electromobility faces many challenges if it is to attract widespread public support sufficient to displace the internal combustion engine vehicle as the dominant passenger vehicle technology. There are critical issues to be addressed that act to constrain potential market growth, including financial barriers and technological limitations. Nearly all of the key issues influencing electromobility are common to all geographical markets. They are discussed here in detail, both on a general level and in the context of the Swedish market.

2.3.1 Consumer demand
Although the usefulness of stated preference analysis in producing accurate demand forecasts is questionable, the method is a valuable tool in highlighting broad trends in public opinion as well as key issues affecting demand.

A recent global survey conducted by Accenture (2011) using randomly selected participants, measured consumer attitudes and preferences toward EVs. The study found that 68 per cent of respondents were very much in favour of EVs replacing conventional cars over time. Furthermore, 60 per cent of those surveyed (53 per cent of Swedish respondents) indicated that they would consider either an EV or a PHEV for their next car purchase. A study of the Swedish market conducted by utilities provider Fortum in 2011 revealed that nearly 37 per cent of Swedes surveyed believed they would buy an EV within ten years (Fortum, 2011). A pre-study on market conditions for the introduction of EVs in Sweden concluded that swedes are considered early adopters of technology and that the general level of environmental awareness is high – both of which indicate potentially favourable conditions for high consumer demand for EVs (Stockholms Stad & Vattenfall, 2010).

While these results are encouraging, surveys regarding consumer opinions on EVs also highlight a significant gap between consumer expectations and the actual performance capabilities that EVs are able to deliver today (Deloitte, 2011). The capabilities that consumers expect from an EV are derived
from experience gained from our long relationship with ICE technology. A recent global Deloitte study concluded that when consumer expectations regarding driving range, charging time and price were compared to actual EV capabilities, a maximum of four per cent of respondents would have their expectations met by today’s EVs (ibid).

Consumer interest in electromobility may be high, but few appear willing to pay a premium price for a car that does not perform to the same standard as a conventional ICE vehicle with regard to driving range and convenience of recharging (ibid). Until these issues are addressed, it is unlikely that electromobility will present sufficient mass market appeal to encourage large-scale consumer uptake.

2.3.2 Cost

Perhaps the single most important obstacle to mainstream consumer uptake of EVs today is the significantly higher capital investment required compared to conventional vehicles – a key issue which is expressed in many consumer surveys on electromobility (Kley et al., 2011). In addition, the majority of respondents indicate that they would not be willing to pay a premium for EVs over an ICE vehicle (Deloitte, 2011). In Sweden, EVs cost on average 200,000 SEK more than a comparable conventional vehicle (Nandorf, 2012). The high premium currently paid for EVs is due to the cost of the Li-ion battery which accounts for up to 50 per cent of the cost of the vehicle (ibid). Battery costs have been gradually decreasing at a rate of around 6-8 per cent annually and this is expected to accelerate as economies of scale result from increased production volumes (Hensley et al., 2009). Research reports differ somewhat in current battery cost estimates, however all agree that these costs will decline significantly over the next decade (Figure 4).

The U.S. Advanced Battery Consortium’s minimum goal for long term commercialisation of EVs is $150 per kWh with a further long term goal of $100 per kWh, however forecasts (see Figure 4) indicate that it is highly unlikely that this price level will be reached within the mid-term outlook to 2020 (USCAR, 2007). Another aspect to consider with regard to battery costs is that each generation of batteries will need to be in production for at least four or five years in order for manufacturers to recoup R&D and investment costs (Gopalakrishnan et al., 2011). This implies that third generation
batteries will be under commercial production by 2020; the timeframe frame in which most reports suggest that a significant step-up improvement in battery technology will be realised.

Although all forecasts are in agreement over long-term battery price trends, the extent to which falling battery prices will be reflected in the purchase price of EVs is the subject of much debate. Some reports suggest that the eventual cost reduction may be offset as manufacturers look to increase energy density and storage with the aim of increasing driving range (Deloitte, 2011). In addition, economies of scale may be compromised as a result of rising costs and inflationary pressure on material components as battery production volumes increase.

The cost structure of an EV differs considerably to that of an ICE vehicle: high purchase costs and low maintenance costs of an EV are mirrored by the opposite being true of ICE vehicles. High capital investment required for EVs is mitigated to a certain extent by the elimination of costs associated with fuel consumption. Expected fuel savings are often cited as the primary reason for selecting an EV over a conventional vehicle (Accenture, 2011; Hidrue et al., 2011). At present however, advantages gained through fuel savings alone are not sufficient to overcome the purchase price premium of an EV. Comparative cost advantages between the two vehicle technologies can be determined by examining the total cost of ownership (TCO) for each type of vehicle, which can be described as the sum of fixed and recurring costs annualised over the life of the vehicle.

TCO is influenced by a number of factors including purchase price, taxes and subsidies, vehicle lifetime and resale value, distance driven and fuel (or electricity) prices (Kampman et al., 2011). The major determinants of the TCO of an EV relative to an ICE vehicle are purchase price and the cost of fuel. Electricity prices are relatively low and therefore have limited impact on the TCO when annualised over the lifetime of the car in comparison to fuel and purchase cost (Thiel et al., 2010). It should be noted that the anticipated increase in the penetration of renewable energy into national grid networks (in line with EU policy objectives) will likely lead to higher electricity prices in the future. This will result in electricity prices having a greater influence on the TCO of EVs. Currently, the TCO for EVs is more favourable in Europe compared to other regions as a result of high pump prices for petrol relative to both oil prices (due to local taxation) and electricity.

Improved access to cheap oil was one of the primary determinants that helped lock in the internal combustion engine as the dominant mode of passenger vehicle technology. These conditions are no longer applicable to the oil market today, as evidenced by the long-term trend in increase in oil prices (Figure 5).

![Figure 5. European brent oil annual spot prices, 1987-2011 (Source: USEIA, 2012)](image_url)
According to the IMF (2011), the combination of rapid growth in demand for oil, particularly from emerging economies and a negative trend in supply suggest that a downturn in long-term price trends in unlikely. The short-term outlook for crude oil also remains volatile. Continuing unrest in the Middle East, a planned embargo against Iranian oil imports by the EU in 2012 and the recent collapse of Swiss oil refiner Petroplus contributed to a 6.7 per cent increase in the price of Brent oil in the first four weeks of 2012 alone (Chazan, 2012; Terazono, 2012). In line with international developments in crude oil prices, Swedish fuel prices have also continued to increase over the last few decades (Figure 6). Record high petrol prices recorded in January 2012 have been directly attributed to the aforementioned volatility in oil markets (Gustafsson & Pålsson, 2012).

Figure 6. Swedish petrol and diesel pump prices 1990-2011 (Source: SPBI, 2012)

A significant proportion of the pump price paid for fuel in Sweden consists of taxation levied through an energy tax, carbon tax and value-added tax (VAT). The total taxation share of the final consumer sales price for petrol (60 per cent) and diesel (52 per cent) is among the highest in Europe (European Commission, 2012).

Research conducted into the TCO of EVs suggests that the high purchase price of the vehicle renders the advantages gained in fuel savings negligible and this will continue to be the case until technological advantages and economies of scale bring battery costs down (Thiel et al., 2012). A study conducted by Vliet et al. (2011) in Holland compared the TCO of EVs to PHEV, diesel and petrol passenger cars over three time scenarios: 2010, 2015 and a longer, unspecified term. Using battery price estimates in line with Figure 4 and International Energy Agency oil price forecasts, they concluded that the TCO for EVs remained higher than that for all other vehicles over all three scenarios. Although the difference in TCO reduces over time, costs for EVs are still 25 per cent higher than regular cars even in the long-term scenario. Longer range forecasts by BCG (2010) suggest that an EV purchased in Europe in 2020 could reach a TCO breakeven point relative to an ICE car within nine years, based on the assumption of the non-continuation of today’s government incentives. The inclusion of incentives (estimated at $US 7500) reduced relative TCO breakeven to as little as one year.
2.3.3 Range
The fear that the battery capability of an EV will not be sufficient to reach a planned destination, leaving the driver stranded without the ability to quickly and easily recharge is known as ‘range anxiety’. Most surveys of potential buyers as well as popular discourse on electromobility highlight range anxiety as one of the most significant barriers to the widespread adoption of EVs. Consumer expectations of passenger car driving range are built upon experience of the capabilities of the internal combustion engine. The average distance an EV can be driven before requiring recharging today is approximately 100-160 km. The manufacturers stated range is generally achieved under controlled conditions, and therefore the actual range performance of the vehicle under normal driving conditions may be considerably lower. The range of an EV is negatively affected by driving style (where aggressive or high speed driving increases the rate of battery discharge), use of in-vehicle temperature controls, battery age and road conditions (Nilsson, 2011). The range of an EV over a specific distance will therefore vary depending on a number of conditions and this uncertainty may exacerbate driver concern over the ability of the vehicle to reach its planned destination. This does not compare favourably to conventional ICE vehicles, some of which are able to cover a distance of 800 km without the need for refuelling (Matthies et al., 2010).

Range anxiety can be described as a product of four interrelated factors:
- The difference between perceived and actual mobility patterns
- Pre-existing performance expectations
- Limitations in battery technology
- Provision of a charging network

Surveys of consumer attitudes toward electromobility have revealed significant disparity between real and perceived mobility patterns. A recent global study by Accenture (2011) reported that 52 per cent of respondents would require an EV to have a driving range of at least 400 km before considering purchase even though the average respondent drove an average of only 52 km per day. A similar survey conducted by Deloitte (2011) among European respondents showed similar results, with 74 per cent expecting a range of 480 km, despite 80 km being the average distance driven by 80 per cent of survey participants. A comprehensive survey of Swedish travel patterns conducted by SIKA in 2006 found that the average daily distance travelled by car to be 27 km, this distance was further reduced for those living in cities (SIKA, 2007). Even though studies agree that the majority of journeys undertaken are well within the range currently offered by EVs, the range expected by consumers is in line with that associated with the conventional ICE vehicle.

A major advancement in battery technology is required in order to produce an EV range nearing that of an equivalent ICE vehicle. Forecasts vary, although most literature on the topic is in agreement that battery capacity and lifespan will continue to increase steadily. The Tesla Model S which is due for release mid-2012 already features a reported range of 480 km, although this range advantage is mostly due to a much larger battery pack which in turn is reflected in the premium pricing for these vehicles (Tesla, 2012).

Extremely hot and cold climates place extra demand on the battery due to interior air conditioning requirements, which further reduces the operating range of an EV. Unlike ICE vehicles, there is no waste engine heat which would normally be used to heat the interior. This issue is of particular relevance to the Swedish market, with its long, cold winters. Although further research into battery technology is necessary fully eliminate the problem, carmakers are addressing the issue by fitting vehicles with auxiliary heaters and heat pumps (Jung et al., 2011). The forthcoming Volvo C30 Electric for example, uses an auxiliary ethanol-powered climate system to provide interior heating and cooling without compromising battery range (Loveday, 2011).
Lithium-ion batteries represent a family of battery chemistries that utilise various combinations of cathode and anode materials (BCG, 2010). Although still at the experimental stage, certain alternative Li-ion chemistries indicate the potential for battery advancement. A high level of interest exists regarding the possibilities offered by lithium-air (Li-air) and lithium-sulfur (Li-S) combinations, which have a theoretical specific energy approaching ten times that of today’s Li-ion batteries (Bruce et al., 2011). While promising new materials exist, no major breakthrough is expected in the industry and technology featuring new battery chemistries is not expected to be available on any commercial scale until at least 2020 (BCG, 2010). In the meantime, battery energy density continues to improve at a relatively constant rate of 8-10 per cent annually (Boulanger et al., 2011).

Range anxiety is a significant concern for potential EV purchasers, however there is evidence to suggest that its relevance decreases significantly with experience of EV technology. The Ultra-Low Carbon Vehicle Demonstrator Programme is a UK based trial involving 340 EVs. Data collection is carried out by on board computers attached to all cars as well as through driver interviews. The aim of the trial is to test both EV capabilities and user driving habits and perceptions through everyday vehicle use. Final data collected during the 12 month trial will not be available until late 2012, however preliminary data gained after the first three months of the trial provides some insight into the relevance of range anxiety. Pre-trial, 100 per cent of participants expressed concern over the ability to reach a destination in an EV compared to their conventional cars, however this decreased to 65 per cent after three months (Technology Strategy Board, 2011). Respondents attributed the reduction in range anxiety to better knowledge of the car’s capabilities and careful journey planning. All participants however, continued to express a desire for increased driving range, even though the average daily distance driven was approximately 24 km – well within the capabilities of the EV.

Surveys and data collected from drivers involved in the 50 vehicle strong test fleet of Stockholm’s EV procurement scheme (Elbilsupphandling) revealed that 80 per cent of all journeys undertaken were less than 40 km in length (Sunnerstedt, 2012). Furthermore, data showed that distances driven became longer over time, a change in driver behaviour which is attributed to increasing experience and familiarity with the capabilities of the EV (ibid). A separate study involving French EV owners reported that the limited range of EVs was not a significant issue amongst owners as many had considered the commuting distance between home and work a primary consideration in the decision to purchase an EV (Pierre et al., 2011). It should be noted that most participants in the study already had an ICE vehicle in the household. The EV became the primary transport means except when its limited range made it unsuitable for an anticipated journey, in these circumstances, the ICE car was able to compensate for the shortcomings of the EV, whose limited range was therefore not considered a serious issue. These and other studies indicate that although range anxiety may decrease with familiarity of EVs, a high value is still placed on the ability to drive long distances on a single charge. Careful journey planning to take advantage of charging opportunities during longer journeys mitigates range anxiety, although it represents a significant modification to ingrained patterns of driver behaviour. Vehicle owners place far greater value on a car that is capable of meeting all their journey requirements rather than the majority of them.

Perhaps most significantly, range limitations threaten the fundamental values we associate with car ownership. The idea of ‘freedom’ was an essential marketing idea that helped foster widespread demand for cars as they became increasingly popular in the early decades of the 20th century (Urry, 2004). A car enabled its owner the freedom to travel where they wanted, when they wanted. The limited range of an EV reduces the applicability of the vehicle with regard to longer journeys, particularly those not involving mains roads or an urban centre as a destination. This change in driving habits is at odds with the freedom that people associate – perhaps subconsciously – with the passenger car. Until technological advancements in EVs can achieve a performance range
approaching that of ICE vehicles, mainstream appeal will mostly be limited to the second car market, where an ICE vehicle is used for longer journeys.

An obvious solution to the range limitations of EVs is provided by plug-in hybrid vehicles (PHEVs) which are often described as a transitional technology on the evolutionary path to full electromobility. Although the electric-only range of a PHEV is limited to approximately 50km, the combustion engine activates automatically once maximum electric range is reached, giving a PHEV the equivalent range to a conventional ICE vehicle (Hybridcars.com, 2012b). PHEVs offer many of the benefits of EVs, while mitigating many of the drawbacks – particularly limited driving range. Minimal modification to established patterns of driver behaviour is required – thereby removing range anxiety. For this reason, consumer acceptance surveys often indicate a much higher level of general support for PHEVs than EVs. Accenture’s (2011) global survey showed 71 per cent of respondents preferred PHEVs – a decision based on range anxiety and concern over insufficient access to charging infrastructure.

The dual-fuel optionality of PHEVs means that they will likely appeal to a different consumer segment than EVs. Until a public charging infrastructure network is established, the appeal EVs will largely be confined to urban areas, where driving distances are shorter and charging opportunities more widespread. Unlike more compact EVs, PHEVs will more likely be better suited as larger cars, suitable for longer journeys. Their appeal will therefore extend beyond urban areas. With two separate propulsion systems, PHEVs are both more complex and more expensive that EVs, which may limit their affordability to the high-end market.

PHEVs represent somewhat of a fork in the road for the electromobility. Some manufacturers have invested in hybrid development while others have focused directly on pure electric powertrains. To what extent demand for PHEVs will influence the market for EVs is unclear. The critical role of PHEVs in paving the way for wider consumer acceptance of electromobility cannot be underestimated. PHEVs ostensibly represent a viable option for those that are interested in the advantages offered by an EV but are unwilling to compromise on performance expectations. Through ownership of a PHEV the consumer becomes accustomed to the behavioural adjustments required of EV ownership (i.e. regularly charging the vehicle), while still able to enjoy the performance capabilities of ICE technology. Familiarity with an electric motor, combined with continued advancements in battery technology and infrastructure development could feasibly see subsequent vehicle purchasing decisions directed toward a full EV.

2.3.4 Infrastructure

Often described in the media as a ‘chicken or the egg’ dilemma, the debate over the extent to which the uptake of EVs is dependent on a network of public charging stations – or vice versa – continues to be a divisive one. Convenience, cost and timing indicate that the majority of EV charging will take place primarily at home overnight or in the workplace. Although this is a viable solution for the EV when used as part of a regular daily commute, it is not sufficient for longer journeys, nor for consumers that may lack the ability to charge at home or work. In order to eliminate range anxiety and extend the appeal of EVs beyond a small group of urban enthusiasts or those looking for a second car, the provision of a public fast-charging infrastructure network is essential. However low revenue potential and high capital investment requirements combined with a high risk of obsolescence due to continued technological advancements, do not make a compelling business case, particularly from a utility providers perspective.

Preference for home charging, together with a lack of EVs on the streets to date, means that public infrastructure facilities are likely to be under-utilised, which further detracts from their financial viability. The issue of who takes responsibility for the implementation and funding of public infrastructure is widely debated. The high cost of public charging points and the poor business model proposition they currently represent requires a high degree of collaboration amongst stakeholders in
order to support development. Infrastructure development provides an opportunity for new actors to enter the market and increasing numbers of private organisations and businesses have indicated their intention to install fast charging points. Despite the economic risks involved, competition in the market remains high as stakeholders seek potential revenue streams.

Current infrastructure development in Sweden is driven by local municipalities, often in partnership with utility companies. Development is somewhat fragmented, which can be attributed to the absence of clear guidelines regarding implementation, support and payment services. Charging posts cost from 3000 SEK up to 350,000 SEK for fast charging stations yet there is however no general financial support for their installation (Svensk Energi, 2010). Furthermore, it is as yet unclear who has the right to set up public charging stations; where they are permitted to be located; who receives payment; and the actual cost to the consumer (ibid; Högenberg, 2012). With so much uncertainty involved, it follows that potential consumers may be discouraged from using public charging facilities. The lack of momentum behind infrastructure development may well be related to differing perspectives on the importance of infrastructure at this early stage in the EV market. In Sonnenschein’s (2010) study of Sweden’s EV market preparedness, a number of stakeholder representatives interviewed referred to the ‘symbolic value’ of public charging points, i.e. that the presence of charging stations is of greater psychological benefit to consumers that actual practical value. Even with a fully developed public infrastructure network, the majority of charging will still take place at home or at the workplace. It is however the visibility of public charging points that will act as both a way of increasing awareness and familiarity of EVs and their associated technology, as well as a means of providing reassurance against range anxiety.

The small-scale regionalised approach to infrastructure development in Sweden contrasts considerably from other nations who are investing heavily in national charging networks. Estonia has begun work on installing a nationwide network consisting of 200-250 fast charging stations (Estonian Ministry of Economic Affairs and Communications, 2011). The goal is to provide access to fast charging in all urban areas of more than 50,000 inhabitants and at 50km intervals along national highways (ABB, 2012).

It is becoming increasingly popular for private businesses and retailers to install EV charging stations. In 2009 McDonalds Sweden announced the opening of the first public charging post at one of its restaurants outside of Stockholm, the first stage in a long-term plan to install charging access at a number of its restaurants along main national highways (McDonalds, 2012). There are now five charging posts in total and more are expected to be installed as the market for EVs expands. The implementation of charging infrastructure was carried out in partnership with a combination of other industry stakeholders, including utility companies, payment solution providers and research institutions. EV infrastructure implementation involves a number of benefits for the participating stakeholders: the full cost (and investment risk) is shared, while the association with electromobility fosters a visible ‘green’ reputation which may provide leverage and competitive advantage in the marketplace. Moreover retailers hope to attract eco-conscious, high-income customers – typical EV early adopters – into their stores.

Sweden is home to a number of companies which are active in developing products and services associated with EV infrastructure. The level of technical knowledge and experience is high which presents an opportunity for Swedish industry to compete successfully on the international market for these products. In early 2012, the Swedish-Swiss power and automation technology conglomerate ABB won a contract to develop Estonia’s fast-charging network which will be Europe’s largest when completed (ABB, 2012). Public charging infrastructure also opens up opportunities for the provision of value-added services from utility and service providers which offer both new revenue streams and a means of attracting more customers. Examples include smartphone applications that identify nearby charging points with real-time updates on their availability; remote car diagnostic services
and the ability to download extra content such as navigational aids or entertainment directly into the car (Bain, 2011).

An exception to the highly urbanised nature of current infrastructure development in Sweden is the Green Highway project, a collaboration between Sundsvall and Östersund municipalities in northern Sweden and Trondheim in Norway, in partnership with a number of energy and infrastructure providers. The scheme aims to develop and promote both renewable energy and green transport along the E6 and E14 highways which form an axis between Sundsvall in the east and Trondheim in the west (Green Highway, 2012). Inaugurated in 2009, numerous projects have already been completed as part of the scheme, most however – like the establishment of electric bus and taxi services - are concentrated in the urban centres. The establishment of an EV charging network along the Green Highway is a planned commitment of the scheme, although work on this has not yet begun. Once established, the network will be the first scheme of its kind in Sweden that addresses infrastructure requirements for electromobility outside of urban centres. A similar project to develop a charging infrastructure along the E6 highway between Oslo and Gothenburg was approved for funding in March 2012 (Länsstyrelsen Västra Götaland, 2012).

2.3.5 Environmental performance
EVs are commonly described as zero-emission vehicles, which reflects the standard practice in the automobile industry of only taking into account the emissions created by the vehicle itself when determining environmental impact. A more appropriate measure of environmental impact – especially when applied to EVs – is the so-called ‘well to wheel’ calculation which takes into consideration the carbon intensity of the electricity required to power the vehicle. In other words, EVs are only as clean as the electricity used to power them. On a regional level, Europe is ideally placed to benefit from the CO₂ reductions obtained from substituting EVs for ICE vehicles owing to the high proportion of renewables and nuclear energy in electricity generation. Within this context, less than one per cent of Sweden’s electricity was generated through the combustion of fossil fuels in 2010, and the proportion of electricity generated from renewable energy is the second highest among EU member states after Austria (Figures 7,8) (Energimyndigeten, 2011; European Commission, 2010).

![Figure 7. Sweden’s electricity generation mix in 2010 (Source: Energimyndigheten, 2011)](image-url)
The environmental impact of EVs is not however limited to the electricity mix used to power them; swapping dependence from oil to another finite resource – lithium – involves a new set of environmental considerations and consequences. Lithium, in the form of lithium chloride is commonly found in brine lakes and salt pans. The largest known deposits are located in the vast salt pans of Bolivia, Chile and Argentina (Gruber et al., 2010). Lithium is extracted from brine which is pumped into shallow lakes and evaporated under controlled conditions (ibid). Observations of lithium mining suggest that it is considerably less hazardous and contaminating than other forms of mineral extraction (Friedman-Rudovsky, 2009). While this may be the case now, if demand for lithium increases as expected in line with anticipated production volumes for Li-ion batteries, detrimental environmental impacts are likely to increase.

Most EV manufacturers plan for a 10 year battery lifespan, although recycling and end of life options for batteries is an area in which considerable gaps exist in knowledge and contingency planning (BCG, 2009). Lithium is relatively plentiful and recycling costs up to five times more than extraction, therefore few manufacturers have recycling contingency plans in place (Neslen, 2011). This is an issue that will need to be addressed in the near future as production volumes increase. Failing to plan for recycling could be potentially damaging for the ‘green’ reputation of EV manufacturers.

The relatively benign environmental impact of Li-ion batteries compared to cadmium and lead based batteries, has created opportunity for manufacturers to explore options for in-house end of life recycling. Renault-Nissan have signed a joint venture agreement with French investment and energy authorities to manufacture up to 100,000 Li-ion batteries per year (Renault-Nissan, 2009). With a focus on advanced research, manufacturing and recycling, production at the French facility is expected to begin in 2012, with batteries available for sale to any vehicle manufacturer. It is uncertain at this point in time whether other manufacturers will follow suit and recycle in-house or outsource this process to specialist recycling facilities. Umicore, a global materials technology group based in Belgium, opened an industrial-scale battery recycling facility in late 2011 in anticipation of the need for such a facility. At present, Tesla is the only EV manufacturer to have announced a recycling agreement with the company (Tesla, 2011).

There is currently considerable interest in secondary battery applications. The automotive end of life is reached when battery capacity is decreased by 20 per cent or peak power is decreased by 25 per cent, therefore the remaining capacity can theoretically be used for another purpose before recycling is required (Gopalakrishnan et al., 2011). A number of EV manufacturers have formed business partnerships to explore secondary applications as an alternative to battery recycling. Nissan is investigating the second life utilisation of batteries as storage for renewable energy sources such as wind and solar, while GM is researching the use of batteries as backup sources in the event of power failures (Kanter, 2011).
3. Analysis

EVs are not a natural progression on the development trajectory of internal combustion engine vehicles. As previously discussed, they are a disruptive technology that will lead to transformative change at all levels. Electromobility will require conducive market conditions, specific interventions and new ways of thinking in order to compete with conventional vehicles, at least in the early stages of market development.

3.1 Regulatory environment
Local authorities, national and regional governments play key, specific roles within electromobility. National governments are responsible for creating an institutional climate that promotes and encourages cleaner transport systems, as well as providing for the development and implementation of EV-specific policies and instruments. Furthermore, central governments maintain an essential role in the coordination of all stakeholders and activities. Local and regional authorities function to implement and promote policies on a smaller scale, with projects usually involving a small number of vehicles and localised infrastructure development.

3.1.1 Sweden
In 2009 the Swedish government presented two bills which proposed an integrated climate and energy policy. The bills outlined an ambitious strategy aimed at reducing both dependence on fossil-fuels and greenhouse gas emissions. Among the proposals contained within were a number of targets to be achieved by 2020, including a 40 per cent reduction in greenhouse gas emissions from 1990 levels, applied to all sectors not already covered by the EU Emissions Trading Scheme, including transport (Sveriges Regering, 2009).

In addition, three broad action plans were outlined with the intention of contributing to the government’s long-term vision of a sustainable, resource-efficient and emission-free energy supply by 2050 (ibid):

- A fossil-fuel independent transport sector;
- Increased energy efficiency; and
- Promotion of renewable energy

With regard to the transport sector, the current political focus is on increasing energy efficiency, breaking dependence on fossil fuels and drastically reducing greenhouse gas emissions, with a specific target of achieving a fossil fuel independent transport fleet by 2030.

This ambitious goal assumes a transport fleet that has the technical potential to operate independently of fossil fuels. Electricity is just one of the fuel source means of achieving this goal. Considerable research and development is also taking place within the biofuels sector which includes ethanol, biogas and methanol. The overall vision allows for the continued use of certain fossil fuels in transport to 2030, limited to those which are anticipated to be climate neutral (i.e. free from harmful emissions) by 2050 (Sköldberg et al., 2010). A combination of taxation-based instruments and increased investment in renewable fuels and alternative technologies is the intended route by which the Swedish government hopes to achieve this target. Taxation instruments are two-fold, consisting of levies imposed on fossil fuels as well as tax incentives for ‘green’ cars (see Section 3.2.1).

Sweden has had a system for the environmental classification of cars since 1993 (Transportstyrelsen, 2009). Following its inception, the basic requirements for the environmental classification of new cars has gradually been tightened in line with more stringent EU emissions regulations. There is still
however no single definition of a ‘green’ car (miljöbil) according to Swedish law. As of 1 January 2011, all new cars sold must fulfil the requirements of one of the following environmental categories:

- Euro 5 (limits of non-CO₂ vehicular emissions)
- Miljöklass el (electric vehicles)
- Miljöklass hybrid

These categories do not however specify any limits on vehicular CO₂ emissions. An additional criterion for green cars was presented by an amendment to the Road Traffic Tax Act in 2010 which included a provision for a tax break to encourage the purchase of cleaner cars (Sveriges Riksdag, 2006). Under the new criteria, CO₂ emissions from petrol and diesel powered vehicles must not exceed than 120g/km. Electricity consumption for electric vehicles is set at a maximum of 37 kWh per 100km (Transportstyrelsen, 2010).

In 2011, the Swedish government approved a 200 million SEK budget, distributed over five years, directed toward facilitating the large-scale introduction of EVs in Sweden (Energimyndigheten, 2011b). Named the Demonstration Program for Electric Vehicles, the programme hopes to achieve its goal through:

- Promoting electromobility through the demonstration of EV and infrastructure use
- Identifying and eliminating barriers to the large-scale introduction of EVs in Sweden
- Establishing an independent information channel by which to communicate both research findings and questions regarding electromobility

Under the programme, independent researchers and electromobility projects are able to apply for a share of funding. Data from participating projects will be stored in a national database in order to evaluate results and determine the most effective means of achieving the programme’s goal.

The government’s fossil fuel free ambitions create substantial scope for Sweden to assume a leading role in global efforts to reduce emissions from transport. Recognising this, in 2009, the Swedish Energy Agency (2009) identified the opportunity for Swedish industry to become world leaders in the field of electromobility. Little has been done to capitalise on this opportunity however, and both sales figures and industry development now lag well behind that of other key European countries. Although low EV sales figures can be attributed to a certain extent to the lack of vehicle availability, the situation is in fact a reflection of domestic market immaturity as international automotive manufacturers are increasingly down-prioritising EV launches in Sweden in favour of other countries due to poor market development (Högenberg, 2012). Experience in other European countries suggests that EV manufacturers prioritise markets where clear signals exist regarding governmental commitment to the long-term sustainability of the market and sufficient incentives to ensure that demand remains constant (Stockholms Stad & Vattenfall, 2010).

Although the Swedish regulatory framework encourages the transition to cleaner transport through the application of financial instruments and specifically allocated funding, noticeably lacking are clear goals and benchmarks for success. The long-term vision of a fossil fuel free transport fleet by 2030 may be ambitious, yet it lacks both definition as well as a clear roadmap regarding how it is to be achieved. In contrast to Sweden’s approach, other European countries have adopted a more proactive, coordinated strategy for creating a market for EVs. Two notable examples are Estonia and France (Table 2).
### Table 2: Selected elements of EV strategies in Estonia and France

<table>
<thead>
<tr>
<th>Estonia: Electric Mobility Programme for Estonia</th>
<th>France: National Electric Vehicles Plan</th>
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<tbody>
<tr>
<td>• Funding achieved through trading emissions allowances</td>
<td>• EUR 1.5 billion 10 year plan to achieve 2 million EVs and PHEVs on the road by 2020</td>
</tr>
<tr>
<td>• Provision of attractive financial incentives for private and commercial buyers up to 18,000 euros per vehicle</td>
<td>• Government appointed EV coordinator to liaise between stakeholders and coordinate all aspects of EV development</td>
</tr>
<tr>
<td>• Issuance of green certificates to ensure EVs use renewable energy</td>
<td>• Subsidies to manufacturers</td>
</tr>
<tr>
<td>• Development of a nationwide fast charging infrastructure</td>
<td>• Financial rebate for private buyers up to 5000 euro per vehicle</td>
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<tr>
<td>• Financial support for the installation of private charging points</td>
<td>• Development of a nationwide network of 4 million public and private charging stations</td>
</tr>
<tr>
<td>• Purchase of more than 500 EVs for use by government agencies</td>
<td>• Support for public and private EV procurement scheme</td>
</tr>
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</table>


### 3.1.2 European Union

When discussing the drivers of electromobility in Sweden, it is necessary to consider the market within the broader political context of the European Union (EU). As a signatory to the Kyoto Protocol which aims to combat climate change through the reduction of greenhouse gas emissions, the EU implemented a number of measures intended to achieve its target of reducing greenhouse gas emissions by eight per cent below 1990 levels between 2008 and 2012 (European Union, 2010). A progress report published in 2009 claimed that although total greenhouse gas emissions from the European Union had reduced by 12.5 per cent compared to 1990 levels, those produced by the transport sector had increased by 24 per cent over the same period (ibid). Road transport accounts for approximately 20 per cent of total CO$_2$ emissions within the European Union (European Commission, 2011). Unlike many other sectors, greenhouse gas emissions from transport have continued to rise. Significant reductions in emissions from the transport sector are necessary if the EU hopes to achieve its long-term climate goals and this issue is addressed by a range of EU policies and initiatives. Electric vehicles are considered a promising technology through which significant progress in reaching climate and emissions targets can be achieved. The EU’s commitment to a cleaner vehicle fleet also provides an important impetus for the market development of EVs in Europe.

The EU strategy to reduce CO$_2$ emissions from passenger cars and light commercial vehicles adopted in 2007, aimed to reduce average emissions from new cars and vans to 120 grams CO$_2$ per km by 2012, with a limit not exceeding 130g/km by 2015 (European Commission, 2007). These targets were to be achieved through supply-side improvements in vehicle technology. A review of the strategy published in 2010 concluded that the original target would not be reached by 2012 as some of the measures were not due to be implemented until after 2012 and the strategy’s supporting regulation (Regulation (EC) 443/2009) would not be fully enforced until 2015 (European Commission, 2010a). The regulation sets a further target of average new vehicle emissions not exceeding 95g CO$_2$ per km by 2020.
As part of its commitment to air quality objectives, the European Union has introduced successively stricter limits on pollutant emissions from new cars registered and sold in member states. Regulation (EC) 715/2007 introduced the Euro 5 and Euro 6 standards which place strict limits on pollutant emissions, particularly nitrogen particulates and oxides, from diesel and petrol vehicles as well as those running on natural gas and LPG. Euro 5 has been applied to new car registrations and sales from 1 January 2011, while Euro 6, which further restricts emissions of nitrogen oxides and hydrocarbons from diesel vehicles will be enforced from 1 January 2015 (European Union, 2010b).

In addition to tight restrictions on vehicle emissions, EU climate and energy policy also actively promotes increased use of renewable energy sources through the implementation of the Renewable Energy Directive 2009/28/EC. Under the Directive, member states are required to establish national action plans that support the overall EU objective of achieving a 10 per cent share of renewable energy sources in the transport sector by 2020 (European Commission, 2010b).

Electric propulsion systems alongside alternative fuels technologies such as biofuels and hydrogen fuel cells, form the research core of the European Green Cars Initiative adopted by the European Council in 2008. With a funding package of €5 billion, the initiative is a Public Private Partnership (PPP) introduced as part of the European Economic Recovery Plan that aims to increase the competitiveness of the European car industry through taking the lead in the manufacture and development of sustainable transport technology (European Commission, 2010c). Although often described as competing technologies, electromobility, biofuels and hydrogen fuel cells are intended as complementary measures to help achieve climate and transport goals. The electrification of road and urban transport forms the main goal of the Initiative, with an emphasis on battery development, cost reduction and grid connectivity. Research on biofuels from sustainable sources is focused on developing second generation biofuels for use in buses and heavy urban transport such as rubbish collection trucks. The initiative supports hydrogen and fuel cell technology through R&D investments, acknowledging the very early developmental stage of these alternatives.

While acknowledging the potential of electric vehicles in helping to achieve emissions and renewable energy targets, much of the attention given to electromobility within the context of EU policy, centres on expanding the market as a means of creating economic growth in Europe following the global financial crisis.

Building on the European Green Cars Initiative, the European Commission released a communication entitled “A European strategy on clean and energy efficient vehicles” in 2010 which recognises the importance of a well-structured and coordinated approach to the introduction of new vehicle technologies (European Commission, 2010d). At this early stage in market development, insufficient coordination could place the competitiveness of the industry at stake through fragmentation and a lack of standardisation. The strategy also acknowledges the importance of sufficient consumer demand to the long term viability of green vehicle technologies and proposes the use of financial incentives to foster this demand. Although recommending the use of financial incentives to generate demand, the strategy report suggests that the uncoordinated approach to the introduction of CO2 emission-based vehicle taxation schemes by individual member states and the significant variation that exists between these schemes is detrimental to the successful functioning of the Europe-wide market for green vehicles. The strategy is due for review in 2014 to assess progress and make further recommendations.

In March 2011 a four-year project, Green eMotion was launched with the aim of promoting electromobility and enabling the large scale rollout of electric vehicles across Europe. The project hopes to address coordination issues by bringing together a range of participants involved in 12 existing pilot programmes across Europe. The project partners comprise stakeholders from industry, electric vehicle manufacturers, utilities, municipalities and academic and research institutions. By developing a transferable best practice framework it is intended that information and experience...
gained can then be applied to new test regions. The resulting development of Europe–wide standards and protocols are intended to aid the mass deployment of electric vehicles across the European Union.

As a result of increasingly tighter EU emissions standards and programmes that actively support the transition to a cleaner transport fleet, Europe looks set to become a global leader in EV uptake, accounting for an estimated 62 per cent of the global market by 2020 (J.D. Power, 2010) – growth which is driven by increasingly tighter emissions regulations.

3.2 Incentives
Targeted incentives and inducement mechanisms are an essential component of the early market development of electromobility. Financial and non-financial incentives can be applied to all phases of the EV value chain, from battery research and development to infrastructure development. Sustained governmental financial backing is critical to the successful introduction of a disruptive technology such as electromobility.

For the purpose of this report, the incentives discussed in this section are those specifically targeting the end user, or consumer. In this context, inducement mechanisms must be carefully targeted and implemented as means of increasing the cost competitiveness of EVs in a market dominated by conventional ICE vehicles.

3.2.1 Financial incentives
Although cost reductions will be achieved through economies of scale and manufacturing efficiencies, they will not be sufficient to compensate for the pricing differential between EVs and conventional cars in the short or mid-term. Government backed subsidies and financial incentives are therefore necessary to help stimulate early market demand for EVs. Many countries currently offer a financial incentive in the form of a rebate for the purchase price of an EV, supported by tax offsets for recurring costs such as registration and vehicle tax.

In Sweden, all new cars that meet certain environmental criteria (see Section 3.1.1) are exempted from motor vehicle tax for five years. In practice, this incentive is worth between 1000 - 3000 SEK per year (Stockholms Stad & Vattenfall, 2010). In addition to time-limited tax exemptions, EVs purchased in Sweden are eligible for a cash rebate known as the ‘supermiljöbilspremie’, or super green car rebate. New vehicles with CO₂ emissions further restricted to a maximum of 50g/km are classified as so-called ‘super green cars’ (‘supermiljöbilar’). In practice, it is only electric cars that meet the rebate criteria. All eligible vehicles registered after 1 January 2012 receive a fiscal rebate of up to 40,000 SEK, which represents approximately 35 per cent of the price difference between a green car and the nearest comparable car (Sveriges Regering, 2011). The rebate is limited to a total of 5000 vehicles and a budget of 200 million SEK paid out over three years as follows:

- 2012: 20 million SEK
- 2013: 80 million SEK
- 2014: 100 million SEK

Financial incentives designed to encourage the uptake of cleaner vehicles have met with a high level of success in Sweden. Statistics from BIL Sweden show the number of new green car registrations to have risen steadily over the last five years. 40 per cent of all new cars registered in 2011 were classified as ‘green’ (miljöbilar), with a total of 122,400 cars registered in this category – a record high (BIL Sweden, 2012). These figures however are misleading, especially when considered in conjunction with the Swedish government’s target of a fossil-fuel free transport fleet by 2030. Although the total number of green cars sold has increased steadily in recent years, the proportion of vehicles powered by renewable fuels (i.e. electricity, ethanol or biogas) has dropped markedly over the last six years. 62 per cent of all green cars sold in 2011 were diesel-powered, an increase of 520 per cent compared
to 2005 figures (ibid). Although diesel cars represent an improvement in terms of both fuel-efficiency and CO₂ emissions when compared to petrol vehicles, diesel combustion results in significantly higher emissions of pollutants such as particulates and nitrogen oxides which contribute to local air pollution and human health problems. These issues can be reduced or mitigated through the substitution of diesel with biodiesel, either 100 per cent or as a low-blend (generally between 5-15 per cent for passenger vehicles). Complete substitution is however mostly limited to specially-modified heavy vehicles rather than passenger vehicles (Statoil, 2012).

Furthermore, as a fossil fuel technology, the increasing number of diesel powered vehicles on the road appears to directly contradict government targets concerning fossil fuels in the transport sector. It is too early to predict how successful the supermiljöbilspremie will be with regards to increasing sales of EVs in Sweden, however recent growth in the diesel car market suggests that a refocusing of government strategy and incentive structure is required to steer the passenger car market toward achieving set targets. A new green car definition is currently under assessment and although it is yet unclear how diesel vehicles will be classified, the environment minister Lena Ek has already inferred that diesel should be re-evaluated with reference to its long-term impact on air quality (Gustafsson, 2012).

Despite the success of incentives in increasing the popularity of environmentally friendly vehicles, the introduction of the supermiljöbilspremie in January 2012 has not had the anticipated positive impact on EV demand. Statistics from BIL Sweden (2012a) indicate that EV sales in the first three months of 2012 actually represent a 13 per cent reduction compared to the corresponding period of the previous year.

A company car tax rebate is applicable to both EVs and PHEVs in Sweden. The taxable value of the vehicle is determined to be 60 per cent of that of a comparable conventional vehicle. The maximum reduction in taxable value cannot exceed 16,000 SEK per year (Skatteverket, 2012).

The scope of mechanisms supporting EV uptake in Sweden have received criticism for having markedly lower ambitions in comparison with measure implemented in other countries (Swärd, 2011). The neighbouring countries of Norway and Denmark are well advanced in terms of EV uptake in comparison to Sweden, which can be attributed to the significantly higher financial incentives applied in order to encourage consumer uptake.

In 2011, EV sales in Norway accounted for 1.6 per cent total vehicle sales – far ahead of Denmark, the nearest competitor with 0.21 per cent of total car sales (Grønnbil.no, 2012). Norway has established a comprehensive fiscal incentive scheme for the purchase and use of EVs, encompassing:

- exemption from non-recurring vehicle registration tax (based on weight, engine power and CO₂ emissions),
- exemption from sales tax,
- exemption from annual road tax, and
- exemption from taxation for company car tax benefit
- exemption from vehicle import duty

These tax benefits are offered in conjunction with a range of non-financial incentives for EVs (cars21.com, 2011). At the same time, the Norwegian government has confirmed its on-going support for electromobility through the continuation of incentive instruments and large-scale investment in a public infrastructure network. The resulting demand for EVs is very high as evidenced by the registration of 322 new EVs in March 2012 alone; equivalent to 2.5 per cent of all vehicle sales (Grønnbil.no, 2012b). High demand and clearly defined government support for the industry have made Norway an attractive prospect for EV manufacturers who have responded by selecting it as a priority market for new vehicle releases (Grønnbil.no, 2011). A larger selection of vehicles promotes
competition in the market and lower prices, thereby reinforcing market momentum. According to Bernt Jessen from Motor Gruppen, a Norwegian vehicle retail network, financial incentives in the form of tax benefits form the basis for the success of EVs in Norway and their continuation is critical for the future of electromobility (ibid). At present, financial incentives in Norway are mandated until 2015, however there seems little doubt that government support for the industry will continue beyond this if necessary.

Taxation-based support for electromobility is also particularly effective in Denmark. EVs are exempt from registration tax, VAT, and road tax. Considering VAT is levied at 25 per cent and registration tax as high as 180 per cent, the exemptions represent substantial savings – estimated to reduce the cost of an EV by more than 60 per cent (European Parliament, 2010; Shankar, 2010). Encouraged by these measures, many EV manufacturers consider Denmark a priority market for EV releases.

Exemption from registration tax is a particularly effective means of significantly reducing the purchase price of EVs to a level that is competitive with conventional vehicles. There is however no scope for its use as an incentive in Sweden as there is no comparable tax applied to vehicle purchases. An alternative strategy for incentive funding is employed in France via a bonus malus taxation regime. A financial penalty (malus) applied to the purchase of new vehicles with high CO₂ emissions is subsequently used to fund the rebate system (bonus) used to encourage the purchase of vehicles with low CO₂ emissions (International Energy Agency, 2010).

The longevity of government-backed financial incentives in Sweden is a potential cause for concern. The super green car rebate is mandated until 2014, however the government has been somewhat forthright than Norway in declaring its long-term support for the industry. It is therefore uncertain what – if any – financial support will be available for the purchase of EVs after the current mandate period. As the purchase price and TOC of EVs is not expected to become competitive with conventional vehicles until at least 2020, the presence of long-term financial support is critical to the success of the industry.

Valuable lessons regarding the impact of financial incentives can be gained from the example of ethanol fuelled vehicle sales in Sweden. As recently as 2008, sales of ethanol cars reached nearly 60,000 per year, comprising 66 per cent of all green cars sold, however by 2011 this figure had dropped to just over 15,000 (BIL Sweden, 2012b; Carlén, 2012). The dramatic decline in sales can be partially attributed to a reduction in the price advantage of ethanol over petrol and diesel, however the primary reason is a removal of economic stimulus supporting ethanol vehicles. In 2011 the Swedish government announced the removal of company vehicle tax benefits for ethanol cars. Previously, it had been advantageous to retain ethanol fuelled company vehicles since they had a lower taxable value and hence a lower duty (Carlén, 2012). With an estimated two-thirds of new car sales in Sweden comprising company cars, this had a dramatic effect on the sales figures for ethanol cars. The Swedish environment minister Lina Ek has defended the decision to remove ethanol stimulus measures by stating that all subsidies need to have an end date (ibid). According to the minister, subsidies are applied for as long as considered necessary in order to drive a technology across a threshold into the market place, and ethanol vehicles were considered to have reached the level at which they are able to sustain increasing sales independent of economic stimulus. This assumption is not supported however by the decline in ethanol car sales since the removal of financial incentives was announced.

### 3.2.2 Non-financial incentives

Non-financial incentives to stimulate consumer demand for EVs include for example:

- free use of public car parks,
- allocated priority parking areas,
- free electricity for public charging
- use of lanes reserved for buses and taxis, and
- exception from tolls and congestion charging

All of these feature in Norway’s EV incentive structure (Cars21.com, 2011). User feedback in Norway indicates that non-financial incentives have had a greater than anticipated impact on consumer acceptance and the decision to purchase an EV (ibid). This agrees with the research of Pierre et al. (2011) who found that benefits such as free parking increased the attractiveness of EVs for those living in the centre of large cities. For this particular group, EVs would otherwise remain unattractive due to the scarcity of parking and availability of public transport as an alternative.

The Swedish government has not specified any standardised non-financial incentives to promote electromobility. The provision of reserved or free parking for EVs is handled by local municipal authorities. Currently 70 of Sweden’s 290 municipalities charge for parking and approximately half of these offer free or discounted parking for environmentally friendly vehicles (Sunnerstedt, 2012).

At present, only EVs registered prior to 31 December 2008 are exempt from congestion charges in Stockholm City until 30 June 2012 (Elbilsupphandlingen, 2012b). Similar charges will be introduced in Gothenburg in 2013, although no exception has been scheduled for EVs. This is however widespread support for an exemption for EVs. A motion was announced to parliament in late 2011 which suggested a three to five year exemption for EVs in both Stockholm and Gothenburg (Sveriges Riksdag, 2011). The motion highlighted that such a move would only marginally impact congestion during that period, owing to the relatively slow uptake of EVs. The economic loss would also be relatively minor, however the value gained in signalling clear support for electromobility would be considerable. No decision has been reached on the motion to date.

In addition to encouraging private EV ownership, exemption from congestion charging is particularly advantageous for commercial fleet vehicles that need make frequent journeys through city centres. Similar to Oslo, EVs in London qualify for exemption from the city’s congestion charge. A recent study on the use of EVs in fleets calculated the saving to be worth £2,250 (24,000 SEK) per year for a vehicle that travels into London’s charging zone five days a week (The Climate Group, 2012). This favourably impacts the TCO of EVs which has helped encourage greater uptake from the commercial sector.

3.3 Dissemination of information

Many consumer studies regarding EVs have highlighted another potential roadblock to electromobility – specifically that consumer knowledge of EVs is low and misconceptions regarding the technology abound (Gyimesi & Viswanathan, 2011; Deloitte, 2011). In addition to low product knowledge, consumer uptake of EVs is also hampered by inconsistent and often negative information regarding the performance, cost, safety and availability of EVs that circulates in the media today. The reputation of electromobility has suffered from previous market entry failures. Substantial effort must be devoted to public education and marketing campaigns in order to disseminate correct and positive information regarding modern EVs and their advantages. Carmakers and stakeholders alike will need to capitalise on well-publicised vehicle launches in order to capture and sustain public interest.

The enduring popularity of the Toyota Prius, one of the first generation hybrid vehicles is the result of a massive education effort by a few automotive manufacturers, estimated to have cost in the range of more than $US1 billion over ten years (Deloitte, 2010). Although awareness of the concept of electric propulsion systems in vehicles is more widespread today, full EVs represent an even greater departure from traditional vehicles and public acceptance will depend to a large extent on the dissemination of information about the issues such as performance and charging. This information will need to be carefully packaged to not only promote the EV driving experience, but also to deal with negative preconceptions that many may associate with electromobility.
Although public awareness of electromobility may be high, few people have had the experience of actually driving one to date. For those that have, feedback from drivers is resoundingly positive (Matthies et al., 2010). The sensation of driving an EV differs considerably to that of a conventional vehicle, most notably in terms of silent operation, lack of gears, smooth handling and rapid acceleration – all of which contribute to a pleasurable motoring experience according to driver studies (Technology Strategy Board, 2011; Pierre et al., 2011). Silent operation which although is sometimes highlighted as a safety concern from a pedestrian perspective, is a feature which is appreciated by many EV drivers. Interestingly, a study of French EV owners found that many considered EVs to be far safer in traffic than ICE vehicles due to their ease of operation which has a calming effect, allowing the driver time to pay greater attention to their surroundings (Pierre et al., 2011). Also noted were the driving habits that developed through efforts to conserve battery charge, namely reduced speed and earlier anticipation of braking. Responses obtained in the UK study consistently referred to the relaxing effect of low vehicular noise.

Despite overwhelmingly positive responses to the overall driving experience, little of this has been communicated to potential EV buyers, where the focus generally centres on environmental performance and reduced running costs. Emphasising the positive features of driving an EV – those which differentiate them from conventional cars - is a marketable aspect of electromobility that remains underutilised to date.

### 3.4 Demonstration and procurement schemes

Demonstration and procurement schemes are a crucial component in the early market introduction of EVs. As well as encouraging the uptake of electromobility, demonstration schemes also provide stakeholders with vital information on the utilisation of both vehicles and infrastructure. Sweden’s largest procurement of EVs, Elbilsupphandling, is a collaboration between Stockholm City Council and Vattenfall. Initiated in 2010, the project aimed to facilitate early EV market development, helping enable Sweden to become a leading electromobility market and reap the associated benefits to local industry, employment and the environment (Stockholms Stad & Vattenfall, 2010). The scheme began with a fleet of 50 vehicles available for purchase or lease and now includes approximately 300 participants from both the private and public sectors. The goal is to expand to 5000 vehicles over a four year period. Partially funded by the Swedish Energy Agency, participants in the scheme are eligible for funding for up to 25 per cent (maximum 50,000 SEK) of the difference between the cost of an EV and the nearest equivalent ICE vehicle, although this financial support is currently limited to the first 1000 vehicles purchased under the scheme (Elbilsupphandlingen, 2012).

### 3.5 New business models

The transition to electromobility requires a systematic change to the way in which vehicles are manufactured, serviced and sold. The high purchase cost of EVs and uncertainties regarding issues such as residual value and battery lifespan have created opportunity for the delivery of alternative business models centred around EV ownership which represent a radical departure from the traditional concept of car ownership. These models are aimed at mitigating the major obstacles to EV uptake by minimising financial risk and uncertainty, while at the same time creating a new value proposition for the consumer through the provision of innovative value-added services and benefits. New mobility concepts and business models are critical in increasing consumer acceptance of EVs and are likely to maintain a central role in the roll-out of electromobility.

A notable feature of electromobility is the transition away from classic product-oriented business models that are commonly applied to the automotive market. Under the classic model, manufacturers focus on the vehicle as a core product, with services generally regarded as a supporting mechanism designed to help sell the vehicle (Kley et al., 2011). By contrast, electromobility centres round delivery of a service-oriented business model where the core focus is no longer on the vehicle alone, rather the acquisition of an EV is accompanied by a service guarantee.
whose products continue to be delivered well beyond the point of purchase. Acquisition of the vehicle does not necessarily require it to be purchased, instead it becomes part of a package of connected services which can include for example, vehicle and battery leasing packages, car sharing concepts, mobility guarantees and mobile technology applications.

3.5.1 Leasing options
From a business perspective, interest regarding leasing alternatives for EVs is high. Leasing allows for the offsetting of the high purchase price as well as the application of flexible payment terms. Although leasing arrangements are primarily aimed at commercial fleet markets, several car manufacturers have indicated that they will offer a leasing model for private customers as well.

Vehicle leasing is nothing new within the automotive industry, however alternative leasing models are being developed with specific applicability to the EV market; including, structured leasing models that separate the battery from the vehicle. Leasing – whether the entire vehicle or just the battery – removes much of the risk associated with full EV ownership. Uncertainties regarding battery obsolescence, maintenance and residual value as well as purchase price premiums can all be mitigated through leasing. Despite this, surveys reveal a strong reluctance on behalf of consumers to lease vehicles. Accenture’s global survey revealed 73 per cent of respondents preferred purchase over leasing; whilst in a European survey conducted by Ernst & Young, the figure rose to 86 per cent (Accenture, 2011; Ernst & Young, 2010). It is unclear however whether this preference for the purchasing of EVs would have remained so high if information regarding the effect of leasing – particularly on purchase price – had been communicated in the survey.

Renault will be the first manufacturer to offer several of its EV models for sale with a leased battery component. By removing the battery from the EV ownership model, the consumer has the option of purchasing an EV which is competitive in price to that of an ICE vehicle. British press coverage has indicated that the Renault Fluence ZE EV will be the cheapest electric car on the market when it goes on sale later this year – a cost advantage realised through battery leasing. Customers will pay a monthly fee in order to lease the battery, which is tailored to the anticipated mileage. Monthly fees in the UK start at £75 (approximately 750 SEK), which amounts to roughly the same amount a conventional car owner would pay for petrol to cover the same distance (Sunday Times, 2011).

It is uncertain at this stage whether battery leasing will provide an appealing value proposition for potential customers. While it does offer a solution to the high purchase price of EVs, the financial advantage is simply transformed to a recurring cost over the lifetime of the vehicle, with the overall impact on TCO being negligible. The benefit to the consumer of battery leasing is not therefore economic, but serves rather to remove the perceived risks of battery ownership – particularly those of obsolescence and limited lifespan – from EV ownership.

3.5.2 Car sharing
Car sharing is a means of efficiently utilising vehicle capacity. Users benefit from the lower operating costs of EVs, while at the same time the high capital cost of the vehicles are spread over a broad user base. Car sharing schemes have become increasingly popular in recent years, particularly in heavily urbanised areas as they provide members with the flexibility of a car on demand without the disadvantages associated with full car ownership, such as capital cost and difficulties in locating a parking space. Sharing differs from traditional car rental in that the car is only used for a short period of time (normally a matter of hours), with billing based on the duration of use. Schemes work on a membership basis, with customers paying a small upfront fee to join. Vehicles are parked (and charged) on the street at specially marked locations where users are able to collect the car and return it after use.

Car sharing brings with it a number of benefits to the urban environment in terms of both congestion and local pollution. The widespread popularity of these schemes suggests that they will play an
important role in increasing the public profile of electromobility. Furthermore, in providing an alternative to car ownership, consumers are encouraged to re-evaluate their travel needs and options. In a recent survey of car share scheme members in the UK, 32 per cent reported a reduction in the number of cars owned in their household since joining the scheme, while 30 per cent indicated that they would have bought a car had they not joined the scheme (Harmer & Cairns, 2011). When questioned about the effect of scheme membership on future car purchasing decisions, 60 per cent responded that they were less likely to purchase a car. Overall, results indicate that car sharing may have a measurable impact on levels of car ownership within the scheme catchment area. At first, this does not appear encouraging for the rate of uptake of EVs, however electromobility appears set to play a key role in the expansion of car sharing schemes. Decoupling ownership from the car driving experience gives consumers the freedom to choose the most appropriate vehicle for their intended journey. Very low running costs combined with short driving distances indicate a high potential for the use of EVs within the context of urban car sharing.

Several European cities have launched or are planning ambitious car share schemes comprised wholly or partially of electric vehicles. The largest of these is Autolib, a collaboration of 46 local authorities in the greater Paris area. Inaugurated in 2011 with 250 EVs and allocated parking spaces with charging facilities, the scheme plans to expand to a total of 3000 EVs and 6600 charging stations in 2014 (Autolib, 2011). According to Autolib’s estimates, the 3000 EVs will represent a reduction in private ownership of 22,500 vehicles, thereby reducing CO₂ emissions by approximately 260,000 tonnes per year and easing traffic congestion. The scheme has received positive feedback from users, with 92 per cent indicating that they would recommend the service to friends and family (ibid).

Car2go, a subsidiary of Daimler, provides car sharing services in a number of cities throughout the US and Germany. In November 2011, the company announced the launch of its service in Amsterdam, the first European city within its operations to offer an all-electric fleet comprising of 300 vehicles (EV World, 2011).

Car sharing schemes do exist in Sweden, although on a much smaller scale than those in operation in other countries. Sunfleet is Sweden’s largest car share company, offering approximately 600 vehicles from many locations throughout the country. In April 2012 the company announced the incorporation of nine Volvo C30 EVs into their fleet, distributed between Stockholm, Malmö and Gothenburg (Sunfleet, 2012). The Norwegian company Move About operates EV car share fleets in Oslo, Copenhagen and Gothenburg, with a total fleet size of approximately 60 vehicles. Although the company operates a public car share network in Oslo, with vehicles available from a number of locations around the city, Swedish operations are considerably smaller, with only 13 vehicles currently available for rent from two locations in Gothenburg and Helsingborg. Demand for these vehicles has been high, with equal interest from both private and corporate customers. Encouraged by a high level of interest in the scheme, Moveabout hopes to incorporate 300 EVs into their Swedish fleet by the end of 2014 (Kilter, 2012). The popularity of car sharing schemes abroad indicates an opportunity for significant growth of such schemes within the Swedish market.

3.5.3 Better Place
Another variant of the battery leasing model is battery swapping, a technique pioneered by Better Place, a global provider of EV networks and services. Operating according to a similar concept to that of a mobile phone subscription, the Better Place model involves customers buying an EV at a discounted price and entering into a subscription agreement involving a monthly fee for the battery which covers charging, replacement and running costs according to a pre-agreed mileage plan. The company plans to develop a network of battery switch stations, where subscribers are able to swap a depleted battery for a fully charged one in as little as three minutes – thereby avoiding the need for a lengthy recharging process (Better Place, 2012). Designed to complement regular EV charging, customers charge their vehicles by plugging in at home or work, while using the network of battery switching stations for longer journeys. The procedure is fully mechanised and operates in a similar
fashion to a drive-through car wash, with the occupants able to remain in the vehicle throughout the switching process. Pilot schemes for the battery swapping model are being rolled out in Israel and Denmark, followed by Australia, with further pilots planned for Japan, China, Canada and the US (Better Place, 2011). In Denmark, the company plans to install 25 switching stations at regular intervals along the main highways, supplemented by a network of 300 charging stations for the exclusive use of Better Place customers (Better Place, 2012). The first of the battery swapping stations is scheduled to open in mid-May 2012.

A long-term aim of the company is to supply the network with 100 per cent renewable energy, a goal which although not possible in the short term, due to dependence on the energy mix of grid supplied energy in target markets – further underlines the importance of renewable energy to the environmental sustainability of electromobility.

Although having received widespread attention in the press and acclaim for its innovativeness, the business case for Better Place model has also been received with a degree of scepticism from within the electromobility sector. Foremost among concerns is the large amount of capital investment needed to develop and install a network of switching stations – a costly undertaking with each switching station estimated to cost $US 500,000 to install (Yarrow, 2009). Better Place does not appear short of investment capital at this stage, with aggressive marketing of the concept having attracted widespread investor interest. In a recent round of equity financing, the company secured a further $200 million in funding which it intends to use to expand operations in Western Europe beyond the Danish market (Better Place, 2011).

Vehicle compatibility with battery swapping technology is also a potential issue. Better Place and Renault have entered into a strategic partnership under which Renault has produced the Fluence ZE model to be compatible with Better Place’s switching stations. As part of the agreement Better Place has pre-ordered 100,000 vehicles from Renault to be sold with a leased battery component primarily to customers in Israel and Denmark (Taylor, 2011). The switching stations will not be accessible to all compatible vehicles - only to those who have purchased their vehicle through Better Place. At present, Renault Fluence is the only vehicle compatible with the battery swapping system.

As with conventional EV infrastructure development, there is a risk that obsolescence due to ongoing battery advancements will result in significant financial loss and render the eventual network of switching stations inoperable. This risk is mitigated to some extent by the ‘captive market’ achieved through the collaboration with Renault, however uncertainties remain over the ability of the business model to remain sustainable if EV uptake remains sluggish. Both Renault and Better Place have committed substantial investment capital to the project in the hope that its eventual success will create an industry standard by which other manufacturers will have little reason to deviate from (Swedish Energy Agency, 2009).

Despite uncertainty regarding its business model, consumer and commercial interest in Better Place has been high. The company operates a high tech information centre in each of its target markets where members of the public are able to sign up for free tours which explain the philosophy and technology behind the business model. These have proved extremely popular, with the Copenhagen Better Place centre having received in excess of 11,000 visitors in little over a year – resulting in the sale of 150 vehicles on subscription and more than 1000 pre-orders (Better Place, 2012; 2011). According to company estimates, purchasing an EV and subscription through Better Place in Denmark, results in a 16 per cent reduction in TCO compared to a comparable diesel vehicle. In Better Place’s other key market Israel, more than 400 companies have signed agreements to begin switching their fleets to Better Place as the vehicles and service become available (Better Place, 2011). These figures indicate not only the high potential of new business models as a means of encouraging consumer demand for EVs, but also highlight the importance of the dissemination of
information. The Better Place information centres have been instrumental in transforming interest in EVs into willingness to purchase.

3.5.4 Mobility guarantee
Limited range and lack of a developed charging network limit the usage potential of EVs, making them unsuitable for longer journeys in many cases. This limitation can be overcome by offering what Kley et al. (2011) have coined a “mobility guarantee”; an example of which is tailoring the EV purchase package to include the rental of a conventional vehicle when required for longer journeys. Although no EV manufacturers have incorporated a mobility guarantee into sales agreements to date, the model holds significant potential in avoiding the likelihood of consumers choosing a vehicle to meet their ‘peak’ needs over an EV which covers the majority of their needs. The concept could also be easily combined with other value added extras such as a vehicle service if the EV is left at the dealership whilst the conventional vehicle is in use.

3.5.5 Mobile applications and software development
Although not strictly a new business model, the development of mobile applications and software connected to electromobility is an area of rapid growth aimed at delivering value-added services for the customer. Carmakers and utility providers are particularly active in this area, developing applications that not only locate the nearest charging point and indicate its availability, but also communicate information regarding the state of charge of a vehicle’s battery, allowing for certain functions to be controlled remotely. Carwings, an application developed by Nissan for use with their Leaf EV, provides the owner with an update on the state of the vehicle’s systems and allows for remote operation of both climate control and charging (Nissan, 2012). Through the application, users are able to speak directly with a Nissan service representative in the case of any questions or problems.

Mobile applications have also been developed in conjunction with car share schemes, enabling users to reserve, locate and unlock vehicles. OSCAR, the intelligent navigation system developed by Better Place, allows user to input their intended journey and receive information on the most suitable charging locations along the route, determined by real-time information on the state of the battery’s charge (Better Place, 2012). These applications form part of concerted efforts on the behalf of certain key stakeholders – particularly EV manufacturers - to market electromobility as more than just driving an electric car. Value-added extras and personalised service options are helping repackage electromobility as a full-service driving ‘experience’.

3.5.6 Build-to-order
Ford Motors plan to release their Ford Focus Electric model onto the US market in April 2012, with the first production run destined to fulfil pre-orders from corporate partners and commercial buyers (Murray, 2012). For public orders, Ford plan to use an innovative ‘build-to-order’ model, similar to that developed by PC manufacturer Dell. According to the model, EV dealers will feature a single demonstration vehicle. Customers will be able to order an EV which will be delivered approximately six weeks later following its construction. The approach is unique among EV manufacturers and reduces the financial risk inherent in large production volumes where demand is uncertain. According to Ford, the business model also provides a higher degree of flexibility, allowing the manufacturer to respond rapidly to changing market conditions by ramping up production if necessary (ibid).
4. Discussion

In this report, the critical issues affecting consumer demand for EVs today have been highlighted. Consumer interest is strong, however significant obstacles exist which work to prevent the transformation of this interest into actual willingness to purchase. Limited performance and high purchase price mean that the appeal of EVs will – at least in the beginning of their sales trajectory – be limited to a relatively small number of niche market buyers. Correct identification of those most likely to buy an EV and their motivation for doing so is essential for establishing a market entry point. Early adopters and niche markets are critically important for the future prospects for electromobility and EV uptake among them must be encouraged in order to create sufficient market momentum to guarantee that the sales trajectory of EVs will continue into the hesitant mainstream consumer market.

Urban areas

Urban areas represent the obvious starting point for the diffusion of EVs. Problems caused by large volumes of conventional passenger cars, particularly CO₂ emissions and local air quality issues are felt most acutely in cities. Driving distances are generally short and journeys often undertaken on relatively set routes (i.e. commuting between home and the workplace) which provide opportunities for routine battery recharging. In other words, the requirements of urban driving are easily fulfilled by the current capabilities of EV technology, and it is in urban centres that the benefits of electromobility will be most apparent. Conversely, the shortcomings of EVs – particularly limited driving range – are less acute within the urban environment, where opportunities for charging are more abundant. Urban centres are generally home to the largest number of people who consider themselves early adopters of a technology or innovation.

Demographic studies

Demographic research is frequently used by EV manufacturers and other industry participants to identify those consumers most likely to purchase an EV. Most studies agree that the profile of an early adopter is most likely to be a male, well-educated, urban, high-income earner that already owns at least one car (Accenture, 2010). While demographics may provide useful insights into the characteristics of potential EV purchasers, it ignores other factors such as functional need and consumer attitude toward electromobility which are more useful contributors to a buyer’s decision.

In 2009, Etrans, a Danish electromobility stakeholder group, conducted an extensive qualitative anthropological study of EV and conventional car owners. By analysing the participants’ values, attitudes and consumer behaviour, the researchers determined seven main consumer categories, each of which occupies a specific location on Rogers’ adoption curve (Figure 9 and Table 3). The final category identified as ‘status seekers’ by Etrans, has not been included for further discussion in this report as it relates exclusively to Rogers’ ‘laggards’ category. Laggards constitute those consumers who are highly unlikely to purchase an EV, therefore attempting to encourage this segment wastes resources that are better spent on those consumers more likely to purchase.
Table 3: Consumer categories and Rogers’ diffusion of innovations model

<table>
<thead>
<tr>
<th>DoI phase</th>
<th>Market share</th>
<th>Etrans category</th>
<th>Description</th>
</tr>
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</table>
| Innovator | 2.5%         | Technology enthusiast            | Technology enthusiasts have often been active in electromobility for some time. They may have converted convention cars into EVs or purchased an EV in the 90s from small (now discontinued) production runs.  
As technology enthusiasts, innovators have a high level of technical knowledge about the innovation and form peer networks with those who share similar interests. Unperturbed by the risks or costs involved, innovators are willing and able to pursue electromobility (often as a hobby) in a very immature market defined by lack of infrastructure and technical support. |
| Early adopter | 13.5%   | City bohemian (ca. 8.5%)          | Research suggests that the primary motivation of early adopters is divided into two main categories: desire to own the latest technology and environmental conviction (Pierre et al., 2011; Dütschke et al., 2011).  
City bohemians view EV ownership as symbolic of being an urban trendsetter. EVs are a visual reminder of their individual, modern and eco-friendly tastes.  
The environmentalist has often already invested in green technology around the home and considers personal mobility an area that must become ‘greener’.  
Early adopters are willing and able to pay a price premium for EVs while compromising on range and performance. Considered opinion leaders, acceptance of an innovation by early adopters legitimises it in the eyes of remaining (more hesitant) consumer groups. |
According to the Danish study, many of the early majority are attracted to the aesthetic qualities of EVs, although awareness of sustainability and ecological concepts still play a role. While this may be true, the willingness to purchase among this category remains limited by concern over the high price of vehicles.

The late majority take a very conventional view of the car as a work tool. They will not adopt an EV until its purchase can be rationalised primarily in the form of financial savings. Pragmatists among this group would only find EVs appealing if they were able to outperform conventional cars while at the same time providing financial benefit.

Source: Adapted from Etrans, 2009 and Rogers, 1995

At present, demand for EVs is driven by the innovator and early adopter consumer segments. Always the first to adopt a new innovation, these groups are differentiated from the mainstream consumer market by their willingness to pay a price premium for a product that has not yet reached developmental maturity or for which supporting mechanisms may be lacking. In the case of electromobility, this lack of market maturity is reflected in EVs which are limited in performance when compared to conventional vehicles and the lack of a fully developed support framework in the form of widespread public charging opportunities.

Economic factors

Economic factors represent the single most important blocking mechanism to the mainstream consumer uptake of EVs. Applied to Rogers’ diffusion curve, the economics of EVs is an issue which divides the consumer market into two distinct groups. The first consists of innovators and early adopters whose motivation to purchase an EV stems from either a technological or environmental interest. Both groups are usually high income earners who are not deterred by high purchase prices or limited capabilities in order to own the latest technology. Their willingness to pay a price premium for an innovation involving considerable uncertainty differentiates them from the remaining consumer groups (the ‘hesitant majority’) who are primarily motivated by economic factors when making purchasing decisions. Surveys suggest that not only are the hesitant majority unwilling to pay a price premium for a car that essentially does not perform to the standards they have come to expect from an ICE vehicle, but many would not consider purchasing an EV until it is able to demonstrate an economic advantage (achieved through fuel savings) over other transport options².

Demand for EVs exists. The issue for the industry however is whether innovators and early adopters constitute sufficient demand to ensure market growth and sustainability. Convincing the hesitant majority will require carefully implemented inducement mechanisms that address the high purchase price of EVs and a coordinated effort on behalf of governments and other industry stakeholders in order to reach the tipping point required to facilitate mainstream market penetration.

² A significant number of visitors to the Better Place information centre in Copenhagen have expressed this sentiment: that they would be willing to purchase an EV only if doing so would result in a net economic benefit compared to owning a conventional car (Better Place, 2012)
Niche markets

Certain niche markets can be identified as key drivers of demand for EVs. Foremost among these are commercial fleets. It is estimated that commercial vehicles account for around 50 per cent of new car sales in Sweden (Stockholms Stad & Vattenfall, 2010). The commercial market operates differently to the consumer market in that far greater consideration is given to the total cost of ownership (TCO) of each vehicle. With sufficient mileage, fleet managers are able to take advantage of the cheaper running costs of EVs, thereby lowering the TCO, which makes EVs a tempting value proposition. Fleet vehicle workloads often match the capabilities of EVs, particularly as vehicles are often utilised over fixed routes in urban centres and parked overnight at a central facility where they are able to be recharged. Commercial utilisation of EVs complements corporate sustainability goals, while at the same time creating a visual indicator of a company’s green credentials to customers and the public alike. EV fleets offer companies an opportunity to reduce operating costs while at the same time strengthening their image and brand through association with electromobility. Demand for environmentally friendly products and services is high and many consumers show a preference for brands with strong environmental credentials. Car manufacturers also benefit from a steady demand and revenue stream for EVs at a time when public demand for EVs remains low. The commercial market also exerts a significant influence on the composition of the national vehicle fleet as vehicle turnover is frequent with most sold on to private buyers at the end of their commercial service period (Henke, 2012).

The incorporation of EVs into rental and car share fleets has also created the opportunity for consumers to gain practical experience with EV technology. Multi-national vehicle rental firms including Hertz, Europcar, and Avis have all entered into partnerships with car manufacturers to incorporate EVs into their vehicle rental fleets (Loveday, 2010, 2010b). This is part of a wider strategy of improving environmental performance through providing greener vehicle alternatives to customers. The 50-strong EV component of Hertz’ U.S. fleet has proven popular with customers. According to Rich Broome, Hertz head of communications, consumer demand for EVs has been steady, however corporate demand has exceeded expectations (Voelcker, 2011). In line with commercial fleet owner motivations, many businesses choose to rent an EV over an ICE vehicle as a means of meeting their sustainability targets. The popularity of EV rentals to date has also highlighted another issue affecting the market – that of supply-side delays. Broome has estimated that another 2000-3000 EVs could be successfully incorporated within the Hertz fleet in order to meet demand, however supply-side issues mean that this will not be possible for some time (ibid). Despite their popularity overseas, EVs have yet to be incorporated into the Swedish fleets of the large rental companies. OKQ8 and Statoil who both operate a network of petrol stations throughout Sweden, have purchased EVs which are now available to rent through four of their outlets in Stockholm and Gothenburg.

Public authorities represent a key early market for EV uptake as procurement requirements often favour environmentally friendly vehicles. Approximately 88 per cent of vehicles acquired through the Stockholm procurement scheme to date have been purchased by municipal or public authority buyers (Sunnerstede, 2012). According to a recent survey, a quarter of all Swedish municipalities had purchased EVs as at May 2011, and more than half planned to invest in the near future (Grönabilister, 2011). Through investment in EVs and charging infrastructure, local authorities play a key role in encouraging growth in electromobility.

Several car manufacturers have indicated that they expect the majority of their EVs – at least in the initial manufacturing run – to be sold or leased to private and public fleet operators. According to Volvo’s estimates, 80 per cent of their V60 plug-in hybrids which will begin production in late 2012 will be sold to corporate customers (Lejland, 2011). Recognising the importance of commercial fleets to the evolution of electromobility, Renault have been targeting marketing efforts toward large corporate clients since 2009 in the form of a Europe-wide marketing road show. As a result, the
company expect 70 per cent of their Fluence ZE EV sales and leasing agreements to be comprised of corporate customers (Taylor, 2011).

Although EVs have a number of advantages as fleet vehicles, particularly in terms of branding opportunities and reduced operational costs, high purchase price still represents a significant obstacle to their uptake. Taxation instruments, purchase rebates and leasing options all help to strengthen the business case for these vehicles, however the longevity of government-backed incentives that legitimise the business case for buying EVs today instead of waiting for market maturity is an on-going concern raised by fleet owners (Ernst & Young, 2009). This further highlights the need for far-sighted political strategy that not only encourages initial uptake, but also supports long-term market sustainability.

*Second car market*

Another key area for EVs is the second car market, which can be regarded as a subset of the early adopter segment since the majority of surveys suggest that many early adopters will already own a vehicle at the time they purchase an EV (Accenture, 2011; Deloitte, 2010). The term ‘second car’ is somewhat misleading as the incorporation of an EV into a household already containing a conventional car usually results in the EV becoming the primary household vehicle, being used for all routine journeys that fits within its range. This supports the findings of Pierre et al. (2011) who conducted a study of French EV users and concluded that the ICE vehicle was only used when required for longer journeys or spontaneous trips where the distance and duration was unknown. The limited range of the EV was therefore no longer viewed as a problem by those owners surveyed. The study also found that the existence of an EV as a second car generally encouraged more rational car use among owners as greater consideration of the intended journey was required, resulting in the selection of the most appropriate vehicle for the task. Although an EV as an additional car may not have the same impact on reducing overall vehicle emissions that replacing the ICE vehicle would have, it does offer a significant opportunity for EVs to gain a foothold in the consumer market. This is particularly important for the first generation of EVs whose shortcomings will certainly elicit a ‘wait and see’ response from the majority of consumers.

There is evidence to suggest that several carmakers have recognised the value of the second car market and plan to market their EVs to appeal to this segment. The Think City for example – a compact EV – is being marketed specifically as a car for urban dwellers (Berman, 2010). Rather than a replacement for the conventional car, Think City is aiming to appeal as a second (or third) car for urban families in ‘green-leaning’ cities across the US. Think’s take on consumer segmentation strategy is potentially a clever one. By not claiming to be a replacement for the conventional car, Think can focus on establishing brand loyalty among a small, yet influential group of urban enthusiasts.

*Celebrity endorsements*

Electromobility has received a somewhat unexpected boost in the form of unofficial celebrity endorsement. A recent article in the Guardian described EVs as “the latest celebrity must-have”, noting a number of high-profile EV owners as well as the emerging trend in the use of EVs to convey celebrities to award ceremonies (Rowley, 2011). Celebrity interest in EVs may be indicative of an underlying broader social transition away from conspicuous consumption stemming from the global economic downturn which began in 2008. This behavioural change has been coined ‘conspicuous conservation’ and it is part of a trend toward the diversification of status indicators (ibid; Sexton & Sexton, 2011). While celebrities may easily be able to afford luxury sports cars, selecting an EV implies a level of environmental awareness and empathy – qualities not attained through money alone. Although celebrities themselves represent only an extremely small buyer group, the influence of celebrity endorsement on current consumer choice cannot be underestimated. Thanks in part to
widespread internet access and social media networks, celebrities today maintain global influence, extending far beyond the bounds of the entertainment industry (Choi & Berger, 2009). Popular magazines and online media regularly feature celebrities pictured with electric cars and the impact on mainstream consumer perception of EVs must be considered positive, particularly if the sales trajectory of the Toyota Prius serves as an indicator. Toyota’s initial marketing strategy for the Prius specifically targeted innovators and early adopters; and as members of these groups, celebrities were considered a “key ally” in determining its market success (Ranchhod & Gurău, 2007:144; Rodrigues & Page, 2004). Cumulative global Prius sales exceeded three million vehicles in early 2011 (Loveday, 2011b).

Consumer perceptions

Ultimately it is the consumer’s perception of how well an EV meets their expectations and needs that will determine their willingness to purchase one. Rogers refers to five different perceived attributes of an innovation: relative advantage, compatibility, complexity, trialability, and observability. By examining the relationship of each of these attributes to electromobility a clearer picture emerges of the areas in which EVs meet consumer perceptions and expectations, and those in which they fail (Table 4). Through identifying these issues, a number of basic actions are proposed for the purpose of suggesting ways in which the advantages of EVs can be maximised and the disadvantages minimised. These actions form the basis for the specific recommendations detailed in Section 5.

Table 4: Perceived attributes of electromobility and proposed actions

<table>
<thead>
<tr>
<th>Perceived attribute</th>
<th>Relation to electromobility</th>
<th>Proposed action</th>
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<tbody>
<tr>
<td>Relative advantage</td>
<td>Environmental: Potentially very high depending on the energy mix used to produce electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Economic: Low due to high costs associated with battery production. From a TCO perspective, EVs will not be competitive with ICE vehicle until at least the medium-term outlook.</td>
<td></td>
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<tr>
<td></td>
<td>Social: High, EVs offer individuals and companies the opportunity to display their green credentials</td>
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<tr>
<td></td>
<td>Promote environmental benefits of EVs</td>
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<tr>
<td></td>
<td>Increase financial incentives for EV purchase</td>
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<tr>
<td></td>
<td>Invest in innovative design</td>
<td></td>
</tr>
<tr>
<td>Compatibility</td>
<td>Values/beliefs: EVs complement increasing public awareness of environmental and fuel supply issues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experience: EVs require a wholesale shift in ingrained behavioural patterns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Needs: EV range is sufficient to meet the majority of users requirements, however most users demand range similar to that of an ICE car</td>
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<tr>
<td></td>
<td>Engage potential customers in a public information and marketing campaign</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Promote new business models</td>
<td></td>
</tr>
</tbody>
</table>

38
<table>
<thead>
<tr>
<th>Complexity</th>
<th>EVs are simpler to operate than conventional vehicles</th>
<th>Promote the EV driving experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trialability</td>
<td>Vehicle availability is low with little opportunity to test drive outside of urban areas</td>
<td>Invest in EV demonstration and sharing schemes</td>
</tr>
<tr>
<td>Observability</td>
<td>Low – very few EVs are visible on the streets today</td>
<td>Develop a national EV strategy that promotes Sweden as a promising market for EV manufacturers</td>
</tr>
</tbody>
</table>
5. Conclusions and recommendations

Most of the issues covered in this report regarding electromobility and consumer perception of EVs are common to all markets. However, the rate of EV uptake differs considerably between markets due to local conditions which work to drive or constrain EV diffusion. In Sweden, a number of conditions exist that suggest that the country will be well positioned to support a transition toward electromobility. The government has declared its intention for a fossil fuel-free transport fleet by 2030 and has implemented a number of policies aimed at achieving incremental improvements in vehicular emission standards. These measures are reflected in the popularity of vehicles classed as environmentally friendly. Fuel prices are high due to a combination of geopolitical developments and government imposed taxation levies, which drives interest in- and demand for alternative-fuelled vehicles.

Biofuels and ethanol already feature prominently within the Swedish transport fleet, indicating a generally positive attitude towards alternative-fuelled vehicles. Furthermore, the energy mix used to produce electricity is virtually carbon free, ensuring that the environmental benefit of an EV fleet is maximised. Despite these favourable conditions and early political rhetoric, Sweden has not fulfilled its ambition to become an early lead market for EVs. By contrast, it lags well behind many comparable European countries in terms of nearly all aspects of industry development – from consumer demand to the deployment of infrastructure.

The vision of a fossil fuel free Sweden by 2030 has certainly attracted attention on the world stage, however efforts to achieve this goal have been somewhat fragmented and lacking in political commitment. Policies regarding environmentally friendly vehicles have seen a rapid increase in new diesel car registrations, a development which is potentially counter-productive to achieving the long-term vision, depending on the proportion of biodiesel utilised. The enduring popularity of fossil-fuels in the passenger transport fleet must be addressed with urgency, particularly if the potential lifespan of a vehicle sold today is taken into consideration. Despite this, transport policies do recognise the key role that EVs and alternative fuels such as ethanol and biofuel will play in reducing the emission of CO₂ and other pollutants from the sector.

Although a generally supportive political climate exists for the introduction and growth of electromobility – as is evidenced by the Swedish Energy Agency’s Demonstration Program for Electric Vehicles, purchase incentives and significant amounts of R&D by various agencies and industry groups - the consumer market for EVs in Sweden remains very low. Existing demand is confined to a handful of early adopters and specific niche markets such as the commercial vehicle sector. Despite the interest among these key early segments, EV sales figures for the first three months of 2012 have revealed a reduction in demand compared to the corresponding period of 2011, a strong indicator that government interventions designed to stimulate the market for EVs are not working. Without suitable measures applied to correct this issue, there is a risk that EVs will fail to reach the critical ‘tipping point’ where the level of consumer acceptance is sufficient to ensure that market for these vehicles becomes self-sustaining.

5.1 Key recommendations

Encouraging growth in the EV market is not simply a matter of producing more vehicles. EVs challenge many of the perceptions we have regarding passenger vehicles, which in turn creates significant obstacles to market growth and vehicle demand. Creating market growth requires considerable effort on behalf of all industry stakeholders. Central governments in particular take a
central role in coordinating and promoting efforts. Although electromobility and its associated services continue to develop in Sweden, the industry lacks the momentum that is apparent in other European markets. The following recommendations are intended as a means of addressing this issue.

**Develop a coordinated, strategic plan for the development, support and promotion of a sustainable EV market in Sweden**

It is critically important that Sweden develop and implement a coordinated, multi-stakeholder strategy outlining the pathways through which a sustainable market for EVs will be achieved. Even more important is the political will and commitment to ensure that the plan reaches fruition. The Demonstration Program for Electric Vehicles is a step in the right direction, however the program is significantly underfunded and is oriented as more of an information gathering facility rather than a driver of market momentum.

It is not within the scope of this report to outline the specific features of the strategy, but rather to emphasise its importance. The remaining recommendations can however be considered as essential components of such a strategy.

**Offer better financial incentives to stimulate consumer demand**

EVs are too expensive! Financial incentives must be improved in order to address the considerable pricing differential between EVs and conventional vehicles which is the single most significant obstacle to consumer acceptance. Natural cost reductions achieved through technological advancements and economies of scale within the battery sector are not expected to significantly impact the TCO of EVs until at least the mid- to long-term outlook. The industry will therefore be reliant on government-backed stimulus to increase the competitiveness of EVs in the market for some time.

Current purchase rebates available in Sweden — through Elbilsupphandling or the ‘supermiljöbilspremie’ amount to a maximum of 50,000 SEK, which although represents a substantial saving, has little impact on the overall competitiveness of EVs. A clear reduction in EV sales since the introduction of the supermiljöbilspremie in January 2012 indicates that it is not an effective mechanism in increasing consumer demand.

The popularity of EVs in Denmark and Norway can be attributed to the wide range of incentives applied to encourage uptake, particularly the exemption from non-recurring registration tax which effectively reduces the cost of an EV by up to 60 per cent. No such tax exists in Sweden and implementing one would attract widespread opposition, perhaps even proving politically fatal for its proponents. A potential option for Sweden is a bonus-malus taxation system similar to that operated by the French government as part of its environmental framework. Using a sliding scale, high CO₂ emitting vehicles are subject to a fee paid at the time of registration. This is subsequently used to fund a rebate for new vehicles with very low CO₂ emissions. Applied correctly, a bonus-malus scheme should be economically neutral, thereby making it relatively easy to introduce from a political perspective. Such a scheme could be used either to boost or replace those rebates currently available, with the ultimate aim being to substantially increase the size of the rebate on offer to EV purchasers.

**Offer a range of non-financial incentives to stimulate consumer demand**

Extending the range of non-financial incentives available is another means of increasing demand for EVs that has proven popular in Norway. In Sweden however, the few non-financial incentives on offer - which are mainly related to parking - vary considerably according to the municipality one lives or travels in. Parking is a key area through which specialised advantages can be offered to EV drivers. Free, reserved parking bays combined with the option of recharging for free is a tempting
proposition for many drivers, particularly those in heavily urbanised areas. The larger cities of Stockholm, Gothenburg and Malmö should follow the lead of Oslo by installing a centralised park and charge area reserved for the use of EVs.

Exemption from congestion charging for low emission vehicles has been successfully applied in Stockholm in the past and could easily be reinstated, both in Stockholm and in Gothenburg where congestion charging is set to be introduced next year. There is widespread support for such a move and if were to be confined to EVs alone, neither revenue nor congestion would be significantly impacted owing to the very small number of eligible vehicles at present.

Incentives – particularly financial ones – are designed to be finite in nature; applied until the tipping point of market penetration is achieved. It is not possible to predetermine when this critical mass will be reached, nor is it likely that it will coincide with a point at which cost reductions associated with battery production will result in EVs naturally reaching a price level comparable to conventional vehicles. With this in mind, the government will need to be prepared to financially support the industry for longer than initially intended.

**Invest in infrastructure development**

Current EV infrastructure and home charging options may be sufficient for early adopters, however a developed public charging network is a necessity if EVs are to expand beyond urban niches and into the mainstream market. The two most successful European markets for EVs to date – Norway and Denmark – have both invested heavily in the development of nationwide charging networks. Although strong demand for EVs in these countries cannot be directly attributed to infrastructure development alone, it does factor as a major component of their national electromobility strategies. Existing infrastructure in Sweden is somewhat fragmented due to the regional nature of development. The poor value proposition presented by fast-charging stations means that development has been slow. Advancement is hampered by a lack of clear guidelines regarding installation, support and payment – and this is a situation that needs to be resolved. Interest in the provision of charging facilities by retailers and private businesses is high and this should be encouraged by the provision of subsidised financial support.

**Develop a public information campaign**

A significant roadblock for the industry is that potential consumers simply do not know enough about EVs. In addition to the lack of knowledge surrounding electromobility, the reputation of EVs has also suffered as a result of previous unsuccessful attempts to enter the passenger vehicle market. Both issues can be readily addressed through the development of a public marketing campaign aimed at reducing misconceptions and capitalising on the benefits of EVs – particularly low running costs, environmental performance and positive driving experience. EVs need to be marketed as an appealing and viable option for consumers. Producing a large-scale marketing campaign is likely to be expensive, although total costs could be distributed among industry stakeholders. In any case it is likely to be money well spent.

**Encourage new business models**

Advancements in battery technology are achieving steady cost and performance improvements in EVs, however these will not approach the levels set by conventional ICE vehicles for some time. Until then, new business models will play a critical role in increasing the competitiveness of EVs.

Electromobility is characterised by the development of service oriented business models where the key focus is a package of connected services rather than the vehicle itself. Particularly promising are subscription-based battery leasing models such as those offered by Renault and Better Place, and
membership-based car sharing schemes, both of which address issues connected to the high capital cost of vehicles. There is no proven winning strategy yet, therefore innovative ways of increasing the value proposition presented by EVs should be actively encouraged.

5.2 Final thoughts

The recommendations outlined in this report are intended to facilitate growth in a market that is lacking momentum. Instead of building on favourable market conditions and striving to become an early lead market for electromobility, the Swedish government has instead embarked on a far more cautious ‘wait and see’ approach. Experience from other European countries has shown that with the right inducement mechanisms, considerable market growth and demand for EVs can result. Now is the time for the Swedish government to adopt a more proactive approach to supporting and promoting the industry. Strong political commitment evidenced by a comprehensive electromobility strategy and adequate funding will send a clear message to consumers, industry participants and vehicle manufacturers, thereby creating a renewed sense of confidence and momentum in the industry.
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### List of interviews and communication

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Position</th>
<th>Communication</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henke, Magnus</td>
<td>Swedish Energy Authority</td>
<td>Program manager, Demonstration program for electric vehicles</td>
<td>Interview</td>
<td>12 April, 2012</td>
</tr>
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<td>Johansson, Olle</td>
<td>Power Circle</td>
<td>Project leader</td>
<td>Interview</td>
<td>12 April, 2012</td>
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<td>Kilter, Mikael</td>
<td>Move About AB</td>
<td>Managing Director</td>
<td>Email communication</td>
<td>6 May, 2012</td>
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<td>Sunnerstedt, Eva</td>
<td>Elbilupphandling (Stockholm City/Vattenfall EV procurement program)</td>
<td>Project leader</td>
<td>Telephone interview</td>
<td>10 April, 2012</td>
</tr>
<tr>
<td></td>
<td>Better Place</td>
<td></td>
<td>Private tour of Better Place information centre, Copenhagen</td>
<td>17 April, 2012</td>
</tr>
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</table>