TØI report 1261/2013

Randi Hjorthol

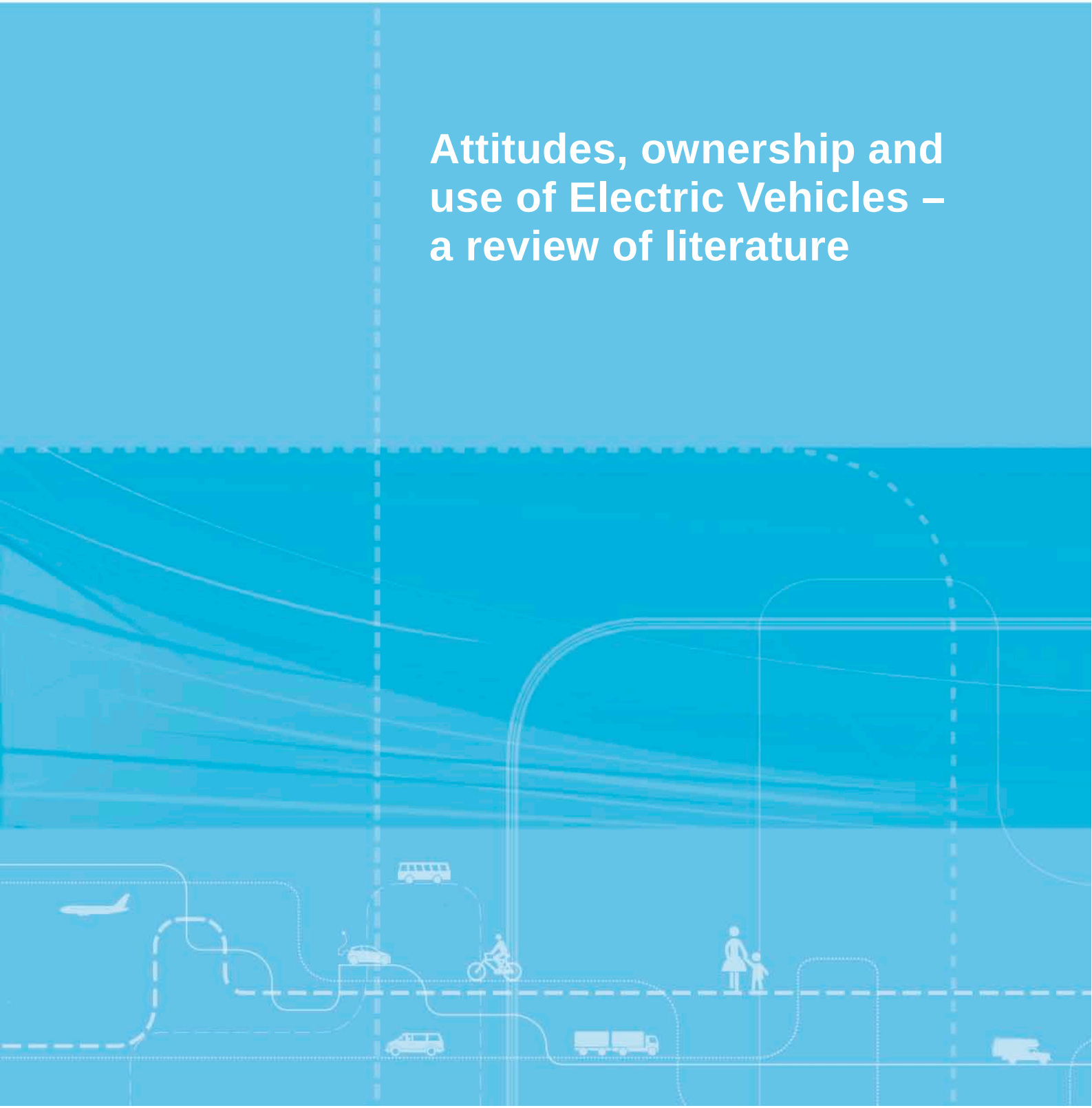
COMPETT

Institute of Transport Economics
Norwegian Centre for Transport Research

Vejdirektoratet
Danish Road Directorate

AUSTRIAN ENERGY AGENCY

# Attitudes, ownership and use of Electric Vehicles – a review of literature



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# Attitudes, ownership and use of Electric Vehicles – a review of literature

Randi Hjorthol



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**Summary:**

The early adopters of EVs are middle aged, 30-50 years, a majority are men, they have high education and income, live in the vicinity of cities and belong to households with more than one car. Early adopters of HEV are also men, in the age of 50-60 years. The studies show that the EV is mostly used for commuting as a complement to the conventional car. This is especially typical for Norway where we have favourable incentives: no VAT, free parking, driving in bus lanes, free driving on toll roads, reduced annual vehicle tax and reduced tax on company cars. In some studies car use increased after the purchase of EV, it replaced previous trips by public transport

**Sammendrag:**

De som først tok i bruk El-biler var relativt unge, menn, bosatte i eller i nærheten av større byer, folk med høy utdanning og inntekt og tilhører hushold med mer enn en bil. El-biler blir først og fremst brukt til arbeidsreiser. Dette er typisk i Norge, der fordelene knyttet til eie og bruk gjør dette spesielt gunstig. En del studier viser at bilbruken har økt etter at El-bil ble anskaffet. Bruken har erstattet reiser med kollektivtransport. De som kjører El-bil planlegger reisene bedre med tanke på begrensingen i batteriet og kjører jevnere for å spare batteriet. Motiv for å kjøpe El-bil er knyttet til spesielle fordeler, som i Norge, til miljøhensyn, lavere driftskostnader og fordi den er behagelig å kjøre.



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# Preface

This report is a part of the project COMPETT (Competitive Electric Town Transport), which is a project financed by national funds which have been pooled together within ERA-NET-TRANSPORT. The report is written by Chief Research Sociologist Randi Hjorthol, and quality assured by research director Frode Longva.

In January 2011 ERA-NET-TRANSPORT initiated a range of projects about electric vehicles under the theme ELEKTROMOBILITY+ concerning topics from the development of battery and charging technology to sociological investigations of the use of electric vehicles.

20 European project consortia have now been initiated including the COMPETT project. COMPETT is a co-operation between The Institute of Transport Economics in Norway, The Austrian Energy Agency, The University College Buskerud in Norway, Kongsberg Innovation in Norway and the Danish Road Directorate. The objective of COMPETT is to promote the use of electric vehicles, particularly with focus on private passenger cars. The main question to answer in the project is "How can e-vehicles come in to use to a greater degree?"

Read more about the project on. **www.compett.org**

**The COMPETT project is jointly financed by Electromobility+, Transnova and The Research Council of Norway, FFG of Austria and The Ministry of Science, Innovation and Higher Education (Higher Education Ministry) in Denmark.**

Oslo, April 2013
Institute of Transport Economics

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| *Gunnar Lindberg* | *Frode Longva* |
| Managing director | Research director |

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Institute of Transport Economics
Norwegian Centre for Transport Research

**Summary:**

# Attitudes, ownership and use of Electric Vehicles – a review of literature

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*Early adopters of Electric Vehicles (EVs) are middle aged,between 30 and 50 years of age; a majority are men, they have high education and income, live in the vicinity of cities and belong to households with more than one car. Early adopters of Hybrid EVs are also men, but in the age range 50-60 years. Studies show that the EV is used by commuters mostly as a complement to the conventional car, especially in Norway where favourable incentives include: no VAT, free parking, permitted driving in bus lanes, free driving on toll roads, reduced annual road tax and reduced tax on company cars. Some studies show that EV drivers are, for the most part, former public transport commuters.*

## Owners, use and motives for buying an EV

Studies of early adopters of electric vehicles (EVs) indicate a large number of common socio-demographic characteristics across countries. They are relatively young, a majority are men, they have high education and income, and belong to households with more than one car. The majority also live in, or in the vicinity of, larger cities.

Travelling from one's home to place of work is the most often cited reason for using EVs in most countries, and in Norway the special conditions that apply (no VAT, free parking, permitted driving in bus lanes, free driving on toll roads, reduced annual vehicle tax and tax on company cars) have a major bearing on the decision to buy.

Adjustments drivers have to make when driving an EV include better planning of journeys – due to battery limitations – and adoption of a smooth (non-erratic) driving style. Motives behind the purchase are the special regulatory advantages (such as in Norway), environmental considerations, lower operation costs and simply the convenience and fun it is to drive these vehicles.

## The potential of EVs and incentives for purchase

Since electric vehicles are a relatively new technology under continuous development and with greatly reduced GHG emissions, studies have been carried out to evaluate the potential ownership and to promote initiatives that would increase their number on the roads. The methods and data used to calculate or evaluate this potential are very different, and so the results cannot be compared

directly, although in Paris and Birmingham a potential of about 10 percent has been estimated. In the USA (California), the share of owners who could recharge at home has been estimated at about one-third. Surveys of people's interest in buying an EV also vary between countries, i.e. between those with and without knowledge of the technology and survey method.

Reduced taxes, other benefits (parking), appreciated convenience over public transport and environmental benefits were areas of interest. Knowledge of the technology and practical experience of driving an EV are likely to raise one's interest in buying.

## Positive and negative attitudes

Attitudes towards and perception of EVs, both positive and negative, vary by experience, knowledge and the everyday context. In many of the surveys and studies of people's opinions of different aspects of EVs, there is little or no information about the respondent's level of knowledge and experience. Questions can vary and therefore answers can be difficult to compare. However, two negative aspects of the EV mentioned in many studies are: range and battery charging. "Range anxiety", i.e. the fear of being stranded due to a depleted battery, is not uncommon. Size, price, security and distrust of the technology are also mentioned as negative factors. Praiseworthy aspects of the EV found in several studies are that it is environmentally friendly, easy to park, low on noise, is well regarded and economically advantageous.

# 1 Introduction

This review of the literature is part of the Competitive Electric Town Transport (COMPETT) project funded by ERA-net transport. COMPETT's objective is reduction of $CO_2$ emissions by increased use of electrified vehicles – this to be done through better knowledge of the barriers against and potentials for electrified vehicles, including reduced road traffic noise. Fully electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell hydrogen vehicles and electric two-wheelers have different functionalities and may face different barriers and potentials. Austria, Denmark and Norway are participating in the project with a total of five partners representing research, local authorities and businesses. COMPETT will shed new light on the appropriate role of the government in the take-off stage and on the creation of a self-sustainable market for e-vehicles.

Electrification of road transport combined with low-carbon electric sources is an appropriate instrument on the policy agenda for reducing emissions of greenhouse gases (GHGs). In most countries, however, lack of renewable electric energy is one of two important arguments making electric charging of batteries into a disputable global warming reduction action. The other argument is the batteries themselves. They are expensive, large and heavy and make fully electric passenger cars about twice as expensive to produce as corresponding combustion-engined cars.

Electrification of the car fleet means a further introduction of different types of EVs on to the market. Countries with a high share of renewable electric energy and can afford the high costs of EVs are able to reduce their emissions of GHG. Small vehicles for commuting purposes and limited need for heating and cooling represent a segment of the market where electrification is competitive with conventional vehicle technology (Hagman et al. 2011). The following questions are important in whether and to what extent the introduction and spread of EVs will be a success or not:

- To what degree can EVs satisfy the everyday transport needs of different groups of the population and their various travel purposes?
- What are the attitudes toward ownership and use of EVs (of different types)?
- Do potential owners and users have sufficient knowledge of the different types of EV?
- What is the potential ownership and what are people willing to pay under which conditions (incentives)?

On the basis of the available literature, this report illuminates these questions and points to the need for further research. Since EVs constitute a very small share of the total car fleet (in Norway around 0.5 percent), research on their use, on the potential users and on attitudes is carried out using different methods and perspectives, thus making it difficult to compare results across countries and studies.

Even though EVs have existed for some decades, the term is still thought of as "new" technology. It might therefore be useful to take a look at theories of the

diffusion of new technology in society before presenting the results from this review of the literature.

There are several theories about how innovations and new technology are widespread and diffused in society and adapted by users (e.g. Rogers 1995, Schelling 1978, Gladwell 2000). To give a very short introduction to the different perspectives, we present a paper that discusses the different ways an EV can be adapted.

Axsen and Kurani (2012a) have explored the processes of interpersonal influence implied in the question of how and why consumers buy new vehicles that offer societal benefits. They present five perspectives (including some critiques) that can be useful when discussing adaption of EVs:

1) *Contagion*: Point-to-point flow of information, e.g. a) Diffusion of innovations (DOI) (the process in which an innovation is communicated through certain channels over time among the members of a social system); this means a unidirectional communication from 'innovators' and 'early adopters' to other consumers. This perspective has been criticized as being unsuitable for prediction, with a lack of focus on symbolic attributes and underlying motivation. b) Social network analysis (having the same limitations as DOI).
2) *Conformity*: An individual's perception of the thoughts and actions of others. It may best be applied to symbolic benefits. Conformity includes threshold models (threshold may vary according to the strength of ties with other individuals (Granovetter 1978), physical proximity and structural equivalence).
3) *Dissemination*: Diffusion directed and managed by an organized group (the provision of societal benefits). Collective action approaches look for the appearance of a critical mass (Schelling 1978, Granovetter 1978).
4) *Translation*: Treats innovations as dynamic, socially constructed artifacts. A newly introduced artifact has a high degree of interpretive flexibility; different social groups may have differing interpretations of its meaning and content, which influences further technological development.
5) *Reflexivity*: In modernity (Giddens 1984), individuals must create their self-identity, taking on 'a reflexive project'. Reflexivity is the dynamic, continuous, self-aware process of defining and expressing oneself. As a part of this project, an individual seeks a lifestyle as a package of practices associated with their particular lifestyle, fashion, eating and other 'means of symbolic display'.

Used on the empirical material (a plug-in hybrid electric vehicle (PHEV) demonstration project) the results show:

*Contagion, conformity and dissemination* are useful concepts in regard to interpersonal processes that involve functional, symbolic and societal PHEV benefits. Contagion assumes a unidirectional flow of information between groups; conformity describes only the current pressures and norms of a given social system; dissemination is focus on a core group of pro societal lifestyle practitioners.

*Translation and reflexivity* provide language and theoretical depth when describing observed perception and motives and also when addressing dynamics in these perceptions and in consumer values. These terms acknowledge the ongoing negotiations and development of interpretations, values and lifestyle practices associated with evaluating an innovation.

There are three factors that support development of the new societal interpretation of vehicle technology:

(i) A basic understanding of functional aspects of PHEV technology has been achieved
(ii) Lifestyle practices in a transitional state
(iii) Pro societal values supported within a social network

To capture value change, behaviour models should account for perceptions of functional and symbolic benefits, as well as identity and lifestyle practices.

This report is organized in five sections. Section 2: studies about owners of EVs and use of the vehicles; section 3: studies of potential owners; section 4: papers about attitudes towards EVs; and section 5: some concluding remarks.

A summary of the refereed references is given in Appendix 1.

The data sources for the review are ISI web of knowledge – multi-disciplinary – peer reviewed, Science direct – Elseviers Publishing records, Springer link – Springer Publishing records, Taylor Francis online – Publishing records – multi-disciplinary, Google scolar and Bibsys –Database for Norwegian university and college libraries.

Since this vehicle technology is relatively new in use, the respondents in the different studies will not represent the population as a whole and generalization of attitudes and adjustments will therefore be difficult.

# 2 Owners and use

## 2.1 Profile of users

Examinations of the early adopters of EVs indicate a large degree of common socio-demographic characteristics across countries. They are relatively young, a majority are men, they have high education and income, and belong to households with more than one car.

Several surveys of Norwegian EV owners have been carried out during the past decade. Econ analyse (2006) carried out a survey in Norway in 2006. This was a combination of postal questionnaire and online survey with private EV owners as respondents. A sample of 703 respondents was drawn from the total population of EV owners with a response rate of 71 percent and 103 companies with a response rate of 51 percent.

The survey suggested that the typical owner is a man (65 percent), between 30 and 60 years of age, married or cohabiting, having high education and income, and living in or in the vicinity of a large city. The results show that only 9 percent have an EV as the only car. A majority of EV owners, 89 percent, live in Akershus, Oslo, Hordaland, Rogaland, Sør-Trøndelag and Buskerud, which are areas within commuting distance of the three biggest cities in Norway; Oslo (approx. 600 000 inhabitants), Bergen (approx. 260 000 inhabitants) and Trondheim (approx. 175 000 inhabitants).

Rødset (2009) carried out a survey in cities in Norway in 2009 interviewing two groups of respondents by telephone; 600 owners of an EV and 600 randomly sampled driving licence holders in Oslo, Bergen and Trondheim (the three largest cities in the country).

The survey shows that owners of EVs differ from the random sample in the following ways: More are men (68 percent male vs 32 percent female), the age groups between 30 and 50 years represent 60 percent in the EV sample compared with 38 percent in the random sample. Eighty-four percent of the EV sample has education at university level compared with 65 percent in the random sample. In the EV sample, 72 percent live in a household with more than two persons compared with 43 percent in the random sample. Nearly all (93 percent) EV owners also own a car with a combustion engine. Twenty-three percent of the random sample has two cars (10 percent have no car). More of the respondents in the EV sample work full time than in the random sample (73 percent vs 62 percent).

Transport for London (2010) carried out a study with a combination of qualitative and quantitative methods of EV owners and EV drivers in small and medium-sized enterprises (SME); in-depth interviews were used. It was found that current users were affluent and car dependent, and have an EV in addition to another car to facilitate driving in central London and take advantage of no congestion charge.

In other international studies, too, the early adopters of electric vehicles are young, and have a high income and education (Pierre et al. 2011; Campell et al. 2012).

Hagman et al. (2011) carried out a postal questionnaire among owners of hybrid electric vehicles (HEVs) in Norway in cooperation with the Toyota Motor Company. The number of respondents was 991 and the response rate 60 percent.

The survey showed that the owners of HEVs are men (70 percent); 54 percent are over 60 years, they have at least six years of higher education and live in the eastern parts of Norway (where the capital is located).

Ozaki and Sevastyanova (2011) also did research in cooperation with Toyota (GB), but involving a survey of owners of the Toyota Prius. Similar to the Norwegian study, they found that the majority of Toyota Prius owners were men aged 50 years or older who had relatively high income and owned more than one vehicle.

## 2.2 Use of electric vehicles and the motives for purchase

Commuting is given as an important purpose of travel in both Norwegian and international studies. The Norwegian national travel survey shows that commuting constitutes about 20 percent of daily trips (Vågane et al. 2011).

A Norwegian study of the travel behaviour of EV owners in 2006 found that commuting was the most frequent purpose of EV use (Econ analyse 2006), with 90 percent having one recurrent trip per day (95 percent commuting). The study found that travel time with an EV was a bit less than with an ordinary car over the same distance due to permitted driving in bus lanes. Time-use was much shorter than with public transport. The special conditions for EVs in Norway (no VAT, free parking, permitted driving in bus lanes, free driving on toll roads, reduced annual vehicle tax and tax on company cars) had a great impact on the decision to buy an EV in this study.

The study from Oslo, Bergen and Trondheim with two groups of respondents (600 owners of an EV and 600 random sampled licence holders in the three cities) also demonstrated that commuting was an important travel purpose of the EV (Rødseth 2009). On trips to work, 83 percent of the EV owners went by car (16 percent ordinary car and 67 percent EV) vs 47 percent in the random sample. EV owners increased their car-use after they had acquired the EV. In this case there had been a change from public transport to use of the EV. Forty-one percent of the EV owners passed a toll ring daily compared to 14 percent of the random sample. (In Norway, drivers of EVs do not pay a fee when passing toll rings.) In this study the three most important factors of buying an EV stated by EV owners were: being able to use bus lanes, driving an environmentally friendly vehicle and lower operating costs than ordinary cars. For the random sample, access to charging stations, the range of the battery and lower operating costs were the most important motivating factors for buying an EV.

HEVs are used differently from EVs. The Norwegian study of Toyota Prius owners found that the annual distance of the HEV was a little further than the average for cars in general (Hagman et al. 2011). The HEV was used mostly for commuting and leisure activities (not for shopping, chauffeuring children or others) and for different types of service trips (e.g. visiting the doctor, dentist, going to the bank or post office). Environmental reasons were the most important considerations when buying a HEV, and also the low use of fuel. These are also said to be the most important

advantages of the HEV. Next time the respondents were to buy a car, 60 percent said they would want a HEV (35 percent a plug-in HEV). The respondents in this study were also asked about buying an EV, with 40 percent saying they could accept a distance of 120 km between each battery charge.

To find out more about how users adapt to the new car technology, some in-depth studies and demonstration projects have been carried out.

In France, Pierre et al. (2011) interviewed 30 EV owners/users in 2006 and 10 in 2008 to try to trace the different stages in adaption of the use of an electric car (awareness, purchase, first steps, daily practice, breakdowns, maintenance, etc.) The owners/users in this study lived in or near large cities or in medium-sized towns and characterized as middle class, with children. All had a conventional car which they used most of the time. The EV was used primarily for commuting and was complementary to other modes of transport. Many of the owners worked in places where they had been sensitised to such innovations – even as electricians or in a municipality using a fleet of EVs – and where they could learn to drive the vehicle. Among owners of EVs, there is both the exclusive motorist (only the electric or the petrol car) and the multimodal user (who uses their car in combination with other modes). "... the use of an electric car encourages a more rational use of the car and sometimes multimodal behaviour" (p. 514). "Users are multimodal rather than convinced ecologists", but they also show an interest in cutting-edge technologies.

Owners who use the EV on a daily basis appreciate its comfort and quietness – low running cost is also an attribute. Driving range is not mentioned very often, mainly because the distance between home and work is a prerequisite to purchasing an electric car. The car can usually be recharged at the end of the cycle. People with both a conventional car and an EV use the vehicles selectively depending on the journey they are about to set out on.

Two important aspects of driving style of drivers of EVs in the French study:

- Their anticipation of the journey ahead due to recharging, which is mostly done at home or at work (planning, which is often not necessary when there is access to a conventional car). The EV is less used for leisure activities because of the uncertainty regarding recharging of the battery
- Their adoption of a smooth driving style in order to save battery power

EV owners say they use public charging terminals infrequently. They find them unreliable, difficult to locate, sometimes reserved for professional fleets, and poorly maintained. The reliability of public charging terminals is fundamental if they are to become established use.

An in-depth study of EV users in Norway found that two specific changes, corresponding to the French study, occurred when changing from a traditional car to an EV, i.e. more planning of the daily travel and more eco-friendly driving (less acceleration/braking and non-erratic/slower driving) (Gjøen and Hård 2002).

Turrentine et al. (2011) studied 50 users of MINI E (BMW converted MINI Coopers into high performance battery electric vehicles with about 100 miles of range) in the United States. As methods they employed interviews, focus groups, surveys and driving diaries.

Turrentine et al. describe the MINI E learning process as follows:

| | Discovery → | Translation → | Application |
|---|---|---|---|
| Definition | Drivers learn about the vehicle's unique attributes | Drivers form opinions about discoveries | Drivers apply translated discoveries in their routine |
| Adaptation route example | Driving fast reduces the vehicle's range | "Driving slower to get more range is worthwhile to me" | Driver now routinely drives more slowly |
| Exploration route example | Regenerative braking allows for one-pedal driving | "I like driving with one-pedal because I feel more in control" | Driver now drives with one pedal and rarely uses the mechanical brake |

Three significant lifestyle values emerged among drivers' responses to the field of new attributes of BEV:

- The intersection of Clean and Fun – the MINI E meets drivers' desire for a vehicle that is both environmentally friendly and fun to drive
- Expanding Mastery of Energy Use: Drivers find value in using electricity as a fuel and mastering their energy use through driving behaviour, regenerative braking and charging
- Developing their Electric Vehicle Territory: Drivers *adapt* to and *explore* limited range through better understanding of their activity space, and seek to expand their clean driving territory through the use of available tools.

Over a six-month period, Cocron et al. (2011) carried out a field study of 40 people with an EV in the household. They were interviewed before receiving the car, after three months of use and upon return of the car. Participants lived in the metropolitan area of Berlin. They were willing to take part in scientific surveys over a defined period, willing to pay the monthly leasing rate, had available garage space, sustainable electric power supply and satisfied other technical conditions. The study examines whether electric mobility systems are useable and satisfactory in daily life in their present form. A travel diary was used (three times), with the participants reporting that a range of less than 100 km was insufficient, more than 200 as sufficient and 250 km as optimal. About 80 percent of daily trips could be made with an EV. The result indicated that, after 3 months, 97 percent wanted to drive an EV in the future, 75 percent indicated that more eco-related issues would be considered when making future car purchases, 95 percent believed that renewable energy should be used for charging EVs, 33 percent approved of nuclear energy for charging and 8 percent would accept charging with energy from coal-fired power plants.

Caperello and Kurani (2012) followed up on 36 households participating in a PHEV demonstration project in northern California over a period of 4-6 weeks. In-depth interviews with respondents were carried out four times during the period and the most important themes from the narratives were:

- *Confusion about PHEVs* – the relationship between electricity and petrol. The user could not see the energy level of the battery on the display; did not know when it should be recharged; and did not understand the information being displayed.
- *Recharging habits and etiquette* – the extension cord was experienced as a nuisance and few drivers found an appropriate outlet away from home. Many did not know how often and when they should recharge. Several respondents

would not ask permission to recharge at the houses of friends or family because they were unsure whether or not this would be appropriate. Those who understood that the greatest benefits were achieved by maximizing the use of the battery were recharging almost every night.

- *Changing driving behaviour* – seeing the miles per gallon (MPG) on the energy display made some of the participants change their driving behaviour, but most women continued to drive as before.
- *Pay back* – the participants had difficulty finding out the costs and benefits of the car. Secondary themes – saving money? Prior expectations and the future – PHEV – a car for the future, not for today?

Over the course of four weeks, Davis and Kurani (2010) studied the recharging behaviour of 40 households in California participating in the PHEV demonstration project. They found a large variation, with average households plugging in their PHEV conversions about once per weekday and less frequently on weekend days. Those who lacked both a home and a workplace base for recharging rarely recharged, and households that could recharge both at home and at the workplace did so more often than others.

Williams et al. (2011) spent a year following up on 12 households in northern California that used an early (nickel-metal battery) Toyota Plug-In HV (one of the first manufacturer-provided plug-in hybrids available), mainly to study recharging behaviour. All households could charge at home and at work and their average trip lasted 14 min (about 7 miles). Trips ranged up to 2.4 hours and were 133 miles long. Total distance 35 miles/day on weekdays and 21 miles/day at weekends. Compared to the NHTS (national travel survey), the study participants had a higher percentage of travel days exceeding key distances (10–50 miles). Charging events lasted on average 2.5 hours, peaking between 7 p.m. and 11 p.m. and 8 a.m. and 10 a.m.

- Early adopters of electric vehicles (EVs) are relatively young, a majority are men, they have high education and income, and belong to households with more than one car. The majority also live in, or in the vicinity of, larger cities.
- Commuting is the most often cited reason for using EVs in most countries
- Adjustments drivers have to make when driving an EV include better planning of journeys – due to battery limitations – and adoption of a smooth (non-erratic) driving style.
- Motives behind the purchase are the special regulatory advantages (such as in Norway), environmental considerations, lower operation costs and simply the convenience and fun it is to drive these vehicles.

# 3 Potential owners and incentives for purchasing

Since the EV in its present form is relatively new technology, continuously under development and, simultaneously, appropriate for reducing GHG emissions, several studies have been carried out to evaluate the potential of ownership and initiatives that would lead to increased demand. The methods and data used are very different. The review in this section provides information about potential data sources and helps in the choice of methods for this type of analysis.

Campell et al. (2012) used census data from Birmingham in 2001 to find potential EV owners in an urban area. They employed hierarchical cluster analysis – a method by which to group a set of objects in such a way that objects in the same group (called cluster) are more like each other (in some sense or another) than those in other groups (clusters) – to identify geo-demographic clusters that fit the profile of an anticipated alternative fuel vehicle driver (input variables to the cluster analysis were based on a review of the literature on EV owners). The results of the cluster analysis show that the 'early adopter' cluster constitutes 8 percent of the (geographical) output areas. Within the areas of this cluster there are 32 000 households and 85 000 residents, which equates to 9 percent of the total population. They were concentrated in four areas. Early adopters have a large proportion owning two or more cars and show high car-use.

A research group in Germany (Peters et al. 2011) has carried out an online survey of four different consumer groups with regard to potential adoption of EV: 1) users of EVs; 2) consumers intending to adopt EVs in the future; 3) consumers interested but with no concrete intent to purchase; and 4) consumers not well informed about/not interested in EVs. These groups differed in age, gender, type of household and number of cars. Group 1: average age 45 years, low female rate 5.4 percent, household with children, 2.2 cars; group 2: average age 43 years, 9.4 percent female, fewer children, 1.4 cars; group 3: average age 39 years, 18 percent female, fewer children, 1.3 cars; and group 4: average age 39.5 years, fewer children, 32 percent female, 1.4 cars.

A regression analysis of the total sample shows that compatibility with own values, experiences and needs is the most important variable predicting intention to purchase and use of an EV. In addition, significant effects are observed for relative advantages with regard to operational costs of EVs and driving characteristics.

In the analysis of the four consumer groups, compatibility was an important variable showing that the more interested respondents are in EVs, and the more experience they have, the more they evaluate the various dimensions in their favour.

Examining the required range for a day's driving, Pearre et al. (2011) monitored 484 vehicles (liquid fuel) with GPS for up to three years; 470 were monitored for more than 50 days. The selection of vehicles (households) was random (in the USA, Atlanta, Georgia greater metropolitan area). Whenever the ignition of the instrumented vehicles was turned on, a GPS data logger would record the position,

time and several operation variables once per second until the vehicle was switched off. Results of the study:

- *Daily driving distance*: During one year, the daily range of a vast majority is anything up to 50 miles, excluding days of zero driving; the mean 44.7 miles, the median 29.9 miles. When days without driving are included, the mean is 32.6 miles and the median 18 miles. One hundred miles or more occurs on average 23 days in the year and 150 miles less than nine times a year. This information can be used when addressing questions about the number of days per year the average driver would have to adapt his behaviour by, for instance 1) switching to a petrol-engined car; 2) battery charging during the day; 3) planning the day's trip to cover less total distance?
- *Days of vehicle use and mileage:* There is low correlation between number of days in use and travel distance, 0.18.
- *Maximum daily travel distance:* 50 percent of the fleet have one day of 313 miles.
- *Days requiring adaptation:* Meaning 1) use another car in the household or rent a petrol-driven car; 2) recharge during the day or en route; 3) delay part of the trip until the next day; 4) choose a different mode of transport. If drivers are willing to adapt two days a year, the 100-mile EVs would meet the needs of 17 percent of drivers, or if willing to adapt six days a year, the same 100-mile EV would meet the needs of 32 percent of drivers.
- *Segmenting by average daily driving distance*: Four groups of drivers: to satisfy 95 percent of the lowest quarter of the days of driving requires only a 56-mile range, an 86-mile range for the second quarter, a 116-mile range for the third quarter and a 171-mile range for the highest quarter. For the lowest group, an EV with 100-mile range would be sufficient for 32 percent of drivers, without requiring any adaptation. If a period of two days per year of adaptations is tolerable, this vehicle could satisfy 56 percent of these drivers – with six days adaptations, 83 percent of the lower mileage vehicles could be replaced with 100-mile range EVs.
- *Time-of-the-day driving patterns*: On an average weekday at 5 p.m., only 15 percent of the vehicles in the sample are on the road. Eighty-five percent are parked at any given hour of the average day, and in a year never less than 75 percent of the cars are parked. "Also, because the return trip home is widely spread in time, even if all cars plug in and begin charging immediately when they arrive home and park, the increased demand on the electric system is less problematic than prior analyses have suggested" (p. 1171).

Erdem et al. (2010) carried out an online survey in different regions in Turkey about willingness to pay for fuel-efficient vehicles. They found that consumers who have high income, high educational level, and are concerned about global warming are more likely to be willing to pay for hybrids.

In addition to surveying the owners of EVs, Transport for London (2010) examined the interest in purchase of an EV among all drivers. Nearly three of four drivers would consider an EV, and 21 percent would consider buying an EV in *the next two years*. Those most interested had high car dependency, were frequent drivers in city centre zones, multiple car owners, new car owners, had higher income, were early adopters of the technology, fairly environmentally conscious, willing to pay a premium, and had a passion for cars. Drivers of interest were: saving money, appreciated convenience over public transport, and valued environmental benefits as a bonus, but not a sole driver.

Axsen and Kurani (2012b) examined the share of households where a plug-in electric vehicle could be recharged at home in the United States as a whole and in San Diego, California. About half of households in which a new car was bought in the United States had the potential to recharge their vehicle at home with at least Level 1 service (the possibility to park their vehicle within 25 ft of a 110/120V outlet at their home at some point during their diary day). About one-third of new vehicle buyers in San Diego have access to Level 2 (220/240 V), and about 20 percent are willing to pay the cost of installing Level 2 recharging at home.

Bandhold et al. (2009) carried out an online survey in the age group 25–65 years to examine the potential for EVs in Sweden. This group had access to a car or had planned to purchase one within the next five years. The results showed that 78 percent considered changing the car within 3–4 years, and 14 percent of those considered an EV (type not defined). About 37 percent know what EV and hybrid vehicles are, but only 16 percent know what a plug-in hybrid is. Men have more knowledge than women. Interest in buying an EV increases with level of knowledge about this vehicle and favourable conditions for its use. Those interested in buying an EV or PHEV are men who work in the private sector, have a high income and education and live in urban areas. Lack of interest in buying an EV is usually because of uncertainty about costs and scepticism of unknown technology.

Hanappi et al. (2012) did an online survey in the area of Vienna to examine determinants in the decision to purchase alternative fuelled vehicles. The total sample was 714 respondents aged between 17 and 85 years. The study shows that with increasing age the probability of car buyers choosing an alternative powered vehicle drops. Older people are most sceptical of CNG vehicles, followed by ethanol and EVs. Young males with high income, children, high education and a need to use the car on a daily basis were the group most likely to purchase alternatively fuelled vehicles. Furthermore, the income effect is highest for PHEVs. External variables such as high fuel prices, higher ranges of EVs and increases in coverage of the charging infrastructure will have major impacts on the market share of EVs. High fuel prices have the greatest effect on the market share of EVs in rural areas, whereas in regions with medium density it is the increase in the range of EVs that has the greatest effect.

Sentio Research Norway (2012) carried out an online survey with a random sample of 1000 Norwegians 18 years and older about whether they think an EV could satisfy their transport needs. The characteristics of those who answered "to a large degree" were 30 years and younger, did not live in families with children, were single without children, lived in cities with more than 50 000 inhabitants, not in sparsely populated areas, and students. Those who considered an EV as car number one were 30 years and younger, living in Oslo/Akershus (the metropolitan area), singles with or without children, had low household income, were students. People in the age group 31–39 years and families with children considered EV as car number two.

The results of an online survey by Halsø et al. (2010) among 1400 members of Tekna (Norwegian Society of Graduate Technical and Scientific Professionals) show that 37 percent would consider an EV as their next car – the following groups in the majority: women, 30–49 years, households with two or more cars, families with children (and more than one car), high income, living in Rogaland (county including the fourth largest city of Norway) and Akershus (the county surrounding Oslo). In total, 67 percent would consider a plug-in hybrid in the future. The majority lived in the larger cities and among people younger than 50 years. Important factors

regarding purchase of car number one were traffic safety (women, children in the household), price and size (children in the household). For car number two, the important factors were price, traffic safety and environmental impact (women).

Musti and Kockelman (2001) used data from the national household travel survey (NHTS) in the United States when developing a vehicle usage model for anticipating fleet composition, PHEV adaptation and GHG emission in Austin, Texas. They developed four scenarios, finding that 63 percent support a feebate[1] policy to favour more fuel-efficient vehicles. Under a feebate scenario, HEV, PHEV and (Mercedes) Smartcar are estimated will represent 25 percent of the fleet's VMT by the simulation year 2025. Two and three-vehicle households are simulated to be the highest adopters of HEVs and PHEVs across all scenarios.

Windish (2011), too, used data from a National Transport Survey when studying the potential for privately owned electric cars in the Paris region. In addition, she used a model of total cost of ownership (TCO) for the selected region. A combination of these two data sources combined with constraints regarding EV ownership (e.g. recharging at home) indicated that 10 percent of households in the region comply with the criteria; 0.03 percent in Paris (due to the parking criteria), 2.7 percent in Petite Couronne and 20.2 in Grande Couronne. Two scenarios were developed showing the increase in potential EV ownership by changing policies.

Based on data from the Danish National Travel Survey (Transportvaneundersøkelsen) and data from GPS loggers installed in 350 cars, Jensen (2011) analysed the potential travel behaviour of EVs and the need for a charging infrastructure. Her summary is: "Of the cars with a 150 km travel range belonging to families with two or more drivers, only a little less than 10% of the cars driven on the actual day will need to charge outside the home. If the travel range in practice .... is only 120 km, around 15% of the cars driven on the actual day will need to charge outside the home. For singles this is only 11%" (Jensen 2011: 3).

In Portugal, Baptista et al. (2012) did an online survey that included information to respondents about HEVs, EVs and PHEVs, i.e. vehicle range, battery recharging time, etc. The results showed that 80 percent of the respondents drive less than 50 km daily; 53 percent make weekly or monthly long round trips of 100–500 km, and 38 percent roundtrips of 500–1000 km; 90 percent were aware of HEVs and EVs, but only 56 percent of PHEVs. Disregarding price information – 40 percent are willing to buy a HEV, 13 percent an EV, 25 percent a PHEV. With information about fuel being 2–3 times cheaper, the consideration of buying an EV was 57 percent and of a PHEV 67 percent. As many as 70 percent would want to recharge at home. Car owners who drive less than the EV range (100 km) show a much higher probability of purchasing these cars than those driving longer. Potential buyers of EVs and PHEVs are sensitive to fuel prices/electricity prices – if running these cars is two to three times cheaper, the probability of buying more than doubles.

Accenture (2011) carried out an online survey in 13 countries (Australia, Canada, China, France, Germany, Italy, Japan, Netherlands, South Korea, Spain, Sweden, UK, US; N=7003) about the opinions and preferences of consumers toward PEVs

[1] **Feebate** is a portmanteau of "fee" and "rebate". A feebate program is a self-financing system of fees and rebates that are used to shift the costs of externalities produced by the private expropriation, fraudulent abstraction, or outright destruction of public goods onto those market actors responsible. Originally coined in the 1990s, feebate programs have typically been used to shift buying habits in the transportation and energy sectors (Wikiperida).

(plug-in electric vehicles). The results show that 30 percent understand enough about EVs to buy one, in China 44 percent (highest) and in Japan 20 percent (lowest). Fifty-eight percent are in favour of electric vehicles (PHEVs or EVs) replacing conventional cars over time, China 86 percent, Netherlands 41 percent, Sweden 64 percent. Sixty percent would consider an EV or a PHEV as an option for their next car purchase, China 95 percent, Netherlands 41 percent. The following factors are important in the motivation to buy an EV:

| | |
|---|---|
| Charging point available at home<br>65 percent prefer to charge the battery at home. | 63 percent |
| Battery range equal to a full tank of petrol in a conventional car | 53 percent |
| Total cost of buying and running the car that are lower that for conventional petrol/diesel cars | 51 percent |
| Option for fast charge | 50 percent |

The top three incentives were: no tax on car, 86 percent; free parking, 65 percent; toll discount, 44 percent. Seventy-one percent prefer a plug-in hybrid EV, 29 percent a full EV (the reasons for not choosing an EV are related to insufficient battery range, lacking availability of charging points and too long charging time). Reasons for preferring full EVs were lower running costs, greater impact on reducing carbon emission.

A Danish study about potential purchasers of EV found that price, range and ready availability of charging stations were the most important factors (Jensen et al. 2011).

- The methods and data used to calculate or evaluate the potential of ownership and use are very different, and so the results cannot be compared directly, although in Paris and Birmingham a potential of about 10 percent has been estimated. In the USA (California), the share of owners who could recharge at home has been estimated at about one-third.
- Reduced taxes, other benefits (parking), appreciated convenience over public transport and environmental benefits were areas of interest.
- Knowledge of the technology and practical experience of driving an EV are likely to raise one's interest in buying.

# 4 Positive and negative attitudes

Attitudes to and perceptions of EVs, both positive and negative, vary with experience, knowledge and the everyday context. In many surveys and studies about people's opinions of different aspects of EVs, there is little or no information about the respondent's level of knowledge and experience. The answers given can therefore be difficult to compare. The questions also vary, as can be seen in the review in this section. However, two aspects of the EV are mentioned time and time again, namely range and charging of batteries. "Range anxiety" – the fear of being stranded due to a depleted battery is not uncommon (Boulanger et al. 2011). Knowledge about the technology and practical experience of the vehicle increase the interest in purchasing an EV (Hagman and Assum 2012).

In a Norwegian study carried out for Volvo Norway (2012), the answers to the question: "How important are the following arguments for not purchasing an electric vehicle or a hybrid car next time?" were (percentage answering very important):

| | |
|---|---|
| I cannot charge the battery where I live | 63 percent |
| I cannot reach my weekend cottage or other out-of-the-way places with an electric vehicle | 58 percent |
| The car is too small | 57 percent |
| The car is too expensive | 49 percent |
| The car is not safe enough | 40 percent |
| I don't trust the technology | 21 percent |

In another Norwegian study , Sentio Research Norway (2012) found that the most important issues behind not buying an EV were the range (46 percent), the small size (22 percent), and uncertainty as to whether the benefits related to EVs (policy, which in Norway is very favourable) would last the test of time (16 percent). Range was also mentioned by 70 percent of a sample of members of Tekna (Norwegian Society of Graduate Technical and Scientific Professionals) (Halsø et al. 2010).

In a study of expectations and satisfaction relating to the use of EVs, Mathisen et al. (2010) found that satisfying aspects of the EV were that it was environmentally friendly, easy to park, low on noise, had a good reputation, and was economical. Dissatisfaction with EVs was related to battery charging, service, traffic safety, heating and functionality in the winter season.

In a study of the three largest cities in Norway (with a sample of EV owners and a random sample), Rødseth (2009) found that the three most important factors behind buying an EV given by EV owners were: the possibility of using the bus lanes, it was environmentally friendly and operating costs were lower. For the random sample, access to charging stations, the range of the battery and lower operating costs were the most important features taken into account when considering buying an EV.

The three most frequently mentioned *benefits* of an EV stated by the owners were that: it was environmentally friendly, driving in the bus lanes was permissible, and it was cheap to run. For the random sample, the corresponding factors were: it was environmentally friendly, cheap to run and parking was free. *Disadvantages* of the EV according to the owners were: the range of the car, time-use for charging the battery and security, and, for the random sample, the range of the car, the small size and problems when charging the battery.

Nearly 70 percent of EV owners say that it is likely they will buy an EV next time too. They also say that the possibility to drive in the bus lanes was important in buying an EV (63 percent). For non-EV owners, better range of the battery is the most important factor when considering an EV. About 40 percent of the non-owners agreed that driving in bus lanes would be an important motive behind buying an EV.

In the study carried out for Transport for London (2010), a large majority of the EV owners (80 percent) intended to replace their EV with another electric vehicle. Barriers to uptake of EVs related to battery issues, infrastructure and parking/charging. The current users were concerned about whether the financial incentives would be taken away in the future, and about differences in parking policies across London boroughs.

Part of the study from London concentrated on small and medium-sized enterprises and their attitudes to EVs. It was found that enterprises could roughly be divided into two groups depending on their main perception of the EV, i.e. Brand Focus and Cost Efficiency Focus. The first was characterized by: Early adopter status, image of the company, in a prominent position along main roads, and green credentials. Company personality was entrepreneurial and innovative, more flat structure, open to new ideas. The industries were: creative technology, high profile, media, and located in inner London. The Cost Efficiency Focus of the EV was about cost savings and image of cost saving. Company personality: Single industry focused, industries with services, manufacturing, supply chain, and location in both inner and outer London.

Special studies about range have been carried out. Franke et al. (2012) studied psychological barriers related to the experience of range among 40 EV users. Control beliefs, ambiguity tolerance and coping skills played a substantial role in the experience of "comfortable range". The result indicates that perceived range barriers can be overcome with the assistance of psychological interventions such as information, training and interface design.

The in-depth study from France of 30 EV owners in 2006 and 10 in 2008 (Pierre et al. 2011) showed that among owners of EVs there is both the exclusive motorist (only the electric or petrol car) and the multimodal user, who combines use of the car with use of other modes. "... the use of an electric car encourages a more rational use of the car and sometimes multimodal behaviour" (p. 514). "Users are multi-modal rather than convinced ecologists". EV owners also show an interest in cutting-edge technologies.

Owners who use the car on a daily basis appreciate its comfort and silence – low running costs are also mentioned. Driving range is mentioned less often and mainly because the distance between home and work is a prerequisite for purchasing an electric car. The car can usually be recharged at the end of the cycle.

Two important features of drivers of EVs are:

- Anticipating the journey ahead due to recharging, which most do at home or at work (planning – which is often not necessary when having access to a car) – not so much used for leisure activities caused by the uncertainty regarding recharging of the battery
- Adopting smooth driving in order to preserve battery power

EV owners say they use public charging terminals very infrequently because they are difficult to locate, sometimes reserved for professional fleets and poorly maintained. The reliability of public charging terminals is fundamental if their use is to be properly established.

Lieven et al. (2011) did a stated preference study in Germany, finding that price and range were most important features of all types of cars. Range was more important if the vehicle was the first car. They also found a potential of EV buyers of 6 percent for the second car as opposed to 4.2 percent for first.

Interviews of 40 users of battery electric cars (BEV) (20 participants) and a plug-in hybrid car (PHEV) (20 participants), 20 males, 20 females 24–70 years from Berkshire, Hampshire and Surrey, UK were carried out by Graham-Rowe et al. (2012). Their aim was to explore beliefs about, and attitudes towards, plug-in EVs as expressed after psychological distance was reduced by their experiencing the use of a BEV or PHEV over a seven-day period. The results identified six categories of attitudes: 1) cost minimisation, some drivers frustrated that they did not get feedback (savings) on their driving style; 2) vehicle confidence – some drivers not convinced of the range; 3) vehicle adaptation demand; 4) environmental beliefs – some drivers sceptical of the net environmental benefits of EVs; 5) impression management – dull design – 'soulless'; 6) perception that EVs were currently a 'work in progress' – some drivers waiting for new developments.

- Praiseworthy aspects of the EV found in several studies are that it is environmentally friendly, easy to park, low on noise, is well regarded and economically advantageous.
- Two negative aspects of the EV mentioned in many studies are: range and battery charging. "Range anxiety", i.e. the fear of being stranded due to a depleted battery, is not uncommon. Size, price, security and distrust of the technology are also mentioned as negative factors.

# 5 Concluding remarks

This review of the literature has indicated both a great variety of methods and topics related to ownership, use and attitudes to EVs and at the same time a lack of comparable studies across countries and years. This last point is primarily due to the technology being in transition and also to great differences in policy incentives between countries. The review shows that there is a need for follow-up studies examining the development in ownership and use and investigating the impact of different policy measurements. This review clearly shows that lack of information on the different types of EV is a significant factor in their potential ownership and use.

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# Appendix 1: Summary of references

Accenture (2011) Plug-in electric vehicles. Changing perceptions, hedging bets. Accenture end-consumer survey on the electrification of private transport. Accenture.

Method: On-line survey of consumer's opinions and preferences toward PEV. 7000 respondents from 13 countries (Australia, Canada, China, France, Germany, Italy, Japan, Netherlands, South Korea, Spain, Sweden, UK, US).

30 % understand enough about EV to buy one. China 44%, Japan 20%

58 % are in favor of electric vehicles (PHEV and EV) replacing conventional cars over time. China 86%, Netherlands 41%. Sweden 64%

60% would consider EV PHEV as an option for next car purchase. China 95 %, Netherlands 41 %

The following factors are very important for motivation you to buy an EV:

Charging point available at home 63%
Battery range equal to a full tank of a conventional car 53 %
Total cost of buying and running the car that are lower that for conventional gasoline/diesel cars 51%
Option for fast charge 50%

Top three incentives: No tax on car, 86 %, free parking 65 %, toll discount 44%

71 % prefer a Plug-in hybrid EV, 29 % full EV (the reasons are related to insufficient battery range, availability of charging points and too long charging time).

Reasons to prefer full EV, lower running costs, greater impact on reducing carbon emission. 65% prefer to charge the battery at home.

Axsen, J., Kurani, K. S. (2012) Who can recharge a plug-in electric vehicle at home? Transportation Research Part D, 17, 349-353.

Method: Study 1 – survey of 2373 new car-buying households 2007– matches the US population. Proximity to outlet leve 1 (119/129 V) Study 2 - 548 new vehicle buyers in San Diego, California. Access to level 1 and 2(220/240 V).

Study 1 – About half of the new buying car household in the US have the potential to recharge a vehicle at home with at least Level 1 service.

About one third of new vehicle buyers in San Diego have access to the Level 2 – about 20 % are willing to pay the cost required to install Level 2 recharging at home.

Axsen, J., Kurani, K. S. (2012) Interpersonal influence within car buyer's social networks: applying five perspectives to plug-in hybrid vehicle drivers. Environment and Planning A, 44,5, 1047-1065

Method: Review of literature (for development of theoretical/conceptual framework). 11 social networks participating in a PHEV demonstration project conducted at the University of California, Davis. Multimethod approach – structured interviews, diaries, online questionnaire

The paper explores processes of interpersonal influence within the question of how and why consumers buy new vehicles that offer societal benefits.

Conceptualization of the benefits of plug-in hybrid electric vehicle (illustrative examples)

| | **Functional** | **Symbolic** |
|---|---|---|
| **Private** | Save money<br>Reliable<br>Fun to drive | Expression of self-identity<br>Convey personal status to others<br>Attain group membership |
| **Societal** | Reduce air pollution<br>Reduce global warming<br>Reduce oil use | Inspire other consumers<br>Send message to automakers, government, oil companies |

Five perspectives on interpersonal influence:

6) **Contagion**: point –to point flow of information, e..g. a) Diffusion of innovations (DOI) (the process in which an innovation is communicated through certain channels over time among the members of a social system), - an unidirectional communication from 'innovators' and 'early adopters' to other consumers. Has been criticized for unsuitability for prediction, lack of focus on symbolic attributes, underlying motivation. b) Social network analysis – same limitations as DOI
7) **Conformity**: individuals perception of others' thoughts and actions – may best be applied to symbolic benefits. Includes threshold models – threshold may vary according to the strength of ties with other individuals (Granovetter 1978), physical proximity, structural equivalence
8) **Dissemination**: diffusion that is directed and managed by an organized group – the provision of societal benefits. Collective action approaches look for the appearance of a critical mass
9) **Translation**: treats innovations as dynamic, socially constructed artifacts and can address all benefits in the Table (over). A newly introduced artifact has a high degree of interpretive flexibility; different social groups may have differing interpretation of its meaning and content which influences further technological development.
10) **Reflexivity** : In modernity (Giddens) individuals must create their self identity, taking on 'a reflexive project'. Reflexivity is the dynamic, continuous, self-aware process of defining and expressing oneself. As a part of this project individual seek a lifestyle as a package of practices that are associated with their particular lifestyle, fashion, eating and other 'means of symbolic display.

Used on the empirical material the results are:

**Contagion, conformity and dissemination** provide useful concepts regarding interpersonal process that involve functional, symbolic and societal PHEV benefits. Contagion assumes unidirectional flow of information between groups, conformity describes only the current pressures and norms of a given social system, dissemination focused on a core group of prosocietal lifestyle practitioners.

**Translation and reflexivity** provide language and theoretical depth to describe observed perception and motives and also addressing dynamics in these perceptions and in consumer values. Acknowledge the ongoing negotiations and development of interpretations, values and lifestyle practices associated with evaluating an innovation.

There are three factors that support the development of new societal interpretation of vehicle technology:

(iv) If they already have or easily come to a basic understanding of functional aspects of PHEV technology
(v) Are in a transitional state of their lifestyle practices
(vi) Find supportive prosocietal values within their social network

To capture value change, behavior models should account for perceptions of functional and symbolic benefits, as well as identity and lifestyle practices.

Bandhold, H., Wallner, J. C., Lindgren, M., Bergman, S. (2009) Plug in road 2020. Elforsk rapport 09:40. Kairos future: Stockholm

Method: Online survey, N=1292, Sweden, respondents 25-65 years with access to a car or had planned to purchase on within the next five years.

78 % consider changing the car within 3-4 years – 14 % of those consider an El-car (not defined).

About 37% know what an EV and a hybrid is – only 16 % know what a Plug in hybrid is. Men know more than women.

The interest in buying el-car increases with increased information and with favorable conditions for El-cars.

Disadvantages EV: Short range, immature technique, inconvenient in use.

Those who are interested in buying EV or PHEV are men, work in private sector, have high income and education and live in urban areas.

Lack of interest in buying El-cars is based on uncertainty related to costs and skepticism towards unknown technique.

Baptista, P., Rolim, C., Silva, C. (2012) Plug-In Vehicle Acceptance and Probable Utilization Behaviour. Journal of Transportation Technologies, 2, 67-74.

Method: Web based survey 2009, over 3 month Valid N=809. Portuguese. No description of sampling process. Sample urban, high educated, 25-50 years of age, 85 % own a car, small or family vehicle.

Questionnaire with information about HEV, EV and PHEV, vehicle range, battery recharging time etc:
1) Age, gender, education residence location, driving licence, car
2) Private car users driving pattern
3) Car owners/future owners' attitudes toward a variety of attributes to be considered before purchasing a car
4) The awareness towards HEV, PHEV and EV technologies, opinion regarding environmentally friendly options, and willingness to under different conditions
5) To potential EV or PHEV drivers about charging

80 % of the respondents drive less than 50 km daily. %3 % make weekly or monthly long roundtrip 100-500 km, and 38 % 500-1000 km.

90 % were aware of HEV and EV, only 56 % of PHEV.

Disregarding price information – 40 % are willing to buy a HEV, 13 % a EV, 25 % a PHEV, with information about fuel being 2-3 times cheaper, EV 57%, PHEV 67%

66% find EV most environmentally friendly

70 % want to recharge at home

Car owners that drive less than electric range (100 km) show much higher probability of purchasing such cars than those driving longer.

Also some more results related to price. Potential buyers of EV and PHEV are very sensitive to fuel prices/electricity prices – if running such technologies is 2 to 3 times cheaper, the probability of buying more than doubles.

Boulanger, A. G., Chu, A. C., Maxx, S., Waltz, D. L. (2011) Vehichle Eltrification: Status and Issues. *Proceedings of the IEEE*, vol 99, 6, 1116-1138.

A review of the development of electric vehicles – challenges and opportunities. In the discussion of range – the fear of being stranded due to a depleted battery has been termed "range anxiety".

Campell, A.R., Ryley, T., Thring, R. (2012) Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom. Transportation Research Part A, 46, 1318-1327.

Method: Use of Census data from 2001 in Birmingham. Hierarchical cluster analysis to identify geo-demographic clusters who most closely fit the profile of an anticipated alternative fuel vehicle driver (input variables to the cluster analysis are based on review of literature).

Results of the cluster analysis shows that the 'early adopter' cluster constitutes 8 % of the (geographical) output areas. Within the areas of this cluster there are 32 000 households and 85 000 residents which equates to 9 % of the total population. They are concentrated in four areas. Early adopters have a large proportion owning two or more cars and showed high car use.

Caperello, N. D., Kurani, K. S. (2012) Households' stories of their encounters with a plug-in hybrid electric vehicle. Environment and behavior , 44, 4, 493-508.

Method: 36 household participated in a PHEV demonstration project 4-6 weeks. (In depth) Interviews four times in the period.

Themes from the narratives:

**Confusion about PHEVs** – the relation between electricity and gas, could not see the state of the battery on the display – did not know when it should be recharged, did not understand the information being displayed

**Recharging habits and etiquette** – the extension cord a hassle, few found an appropriate outlet away from home, many did not know how often and when they should recharge, several did not ask to recharge at the houses of friends or family because they were unsure whether it would be appropriate. Those who understood that the greatest benefits are achieved by maximizing the use of the battery were recharging almost every night.

**Changing driving behavior –** seeing the miles per gallon (MPG) on the energy display made some of the participants change their driving behavior - but most of the women drove as before

**Pay back** – the participants had problems finding out the cost and benefits of the car

Secondary themes – saving money? Prior expectations and the future – PHEV – a car for the future – not for today?

Cherry, C., Cervero, R. (2007) Use characteristics and mode choice behavior of electric bike users in China.

Method: Surveys in Kunming (2.5 mill inhabitants) and Shanghai (14 mill.). Respondents were recruited at several traffic points in the city. They answered questions about the previous day's travel and demographic and attitudinal questions. In shanghai 696 responses, in Kunming 502.

Compared to conventional bicycle owners: There was about 50 % gender split for both modes and users were in their mid30s on average. Education and income levels were all significantly higher for electric bike users. Relatively few respondents were from household with cars or motorcycle.

Travel distance (vehicle kilometres travelled is 95 and 22% higher than bicycles in Shanghai and Kunming., respectively. In Kunming people with electric bike more often had a car in the household than people with bikes.

Work trips constituted the overwhelming majority of reported trips for all two-wheel modes in both cities. In Shanghai one fifth of all electric bike trips were for shopping. Bus was the most likely alternative mode (50-60 %) for electric bike. A large group shifted from ordinary bike to electric bike. Very few shifted from car to an electric bike.

Cocron, P., Bühler, F., Neumann, I., Franke, T., Krems, J.F., Schwalm, M., Keinath, A. (2011) Methods of evaluation electric vehicles from a user's perspective – the MINI E field trial in Berlin. IET Intell. Transport. Syst., vol 5, 2, 127-133.

Methods: A field study with 40 users with an EV in the household. A 6 month period – Before the participants receive the car , after 3 month of usage and upon return of the car. The participants: residence in metropolitan area of Berlin, willingness to take part in metropolitan Berlin, willingness to take part in scientific surveys, willingness to pay the monthly leasing rate, available garage space, sustainable power supply and other technical conditions.

The study examines whether electric mobility systems are useable and satisfying in daily life in their present form. Four pillars for the evaluation:

1) Mobility 2) human – machine interaction (HMI) 3) traffic and safety implication and 4) acceptance.

1) *Mobility:* Can users rely on EV to fulfill their daily needs? What are the characteristics of trips that exceed an EV's capacities? Are the barriers that have hindered overall acceptance in the past psychological in nature?

Travel diary was used (3 times). The participants reported <100 km as insufficient, >200 as sufficient and 250 km as optimal as for range. About 80 % of daily trips could be done with EV.

2) *HMI* What relevant parameters (of the electricity) should be displayed in an EV? Feedback about energy efficient driving. Questions related to battery charging etc.

In-depth interview were implemented three times during this study + questionnaires three times about test driving the EV, battery charging, identification of problems driving the EV etc. ++

3) *Traffic and safety implications* Low-noise implications (mainly at low speeds., deceleration, stopping, entering or leaving a parking space were especially critical.

In-depth interviews and measuring eco-driving style using a Driving Style Questionnaire.

4) *Acceptance* different variables are examined as indicators for acceptance, e.g attitudes and purchase intentions. "In sum, a wide range of methods is necessary to gain an overall picture of how people evaluate today's EVs and to explore different influential factors." The environmental aspects of EV are important for some users – they see the EV as a symbol of environmental protection.

A six-point Likert scale + van der Laans acceptance scale were used. After 3 month: 97 % wanted to drive an EV in the future, 75 % indicated that future car purchases would include more eco-related issues. 95 % believed that renewable energy should be used for charging EVs. 33% approved of nuclear energy to charge EVs and 8 % would accept charging with energy from coal-fired power plants.

Davis, J., Kurani, K. S. (2010) Recharging Behavior of Household' Plug-In Hybrid Electric Vehicles. Transportation research Record: Journal of the Transportation Research board, No 2191, 75-83

Method: 40 household participated in PHEV demonstration project over 4 weeks to observe the recharging behaviour.

There is a large variation in recharging behaviour. On average the households plugging in their PHEV conversions about once per weekday and less frequently on weekend days. Those who lacked both a home and a workplace base for recharging rarely recharged. The household who could recharge both at home and at the workplace recharged more often than others.

Deland, C. O., Cheng, W-T. (2012) Consumers' attitudes towards electric cars: A case study of Hong Kong. Transportation Research Part D, 17, 492-494.

Method: Survey of 200 car drivers (82 % male, 18 % female) interviewed at the exits of five shopping centre car parks.

The results indicate that information about the environmental benefits of EV is low and that might be a reason of a slow adoption of electric vehicles in Hong Kong.

Econ analyse (2006) Elbileiernes reisevaner (Travel behaviour of EV owners) Rapport 2006-040. Oslo

Method: Survey – combination of postal questionnaire and online survey 1) private owners – 703 sample drawn from the total population of EV owners, respondent rate 71% 2) companies 103 – response rate 51%. Norway.

*Owner*: the typical owner is a man (65%), between 30 and 60 years, married or cohabiting, high education and income, live in or in the vicinity of a large city. 9 percent has EV as the only car.

89 % of owners EVs are located in Akershus, Oslo, Hordaland, Rogaland, Sør-Trøndelag and Buskerud.

Short range and long time for charging of the battery are the most mentioned disadvantages.

*Use:* Commuting is the most often purpose of the EV use. 90 % has one recurrent trip per day (95 % commuting). The travel time with EV is a bit shorter than with ordinary car due to the permission to drive in bus lanes. Time use is much shorter than with public transport.

The special conditions for EV (no VAT, free parking etc) have great impact on the decision of buying an EV.

Erdem, C., Sentürk, I., Simsek, T. (2010) Identifying the factors affecting the willingness to pay for fuel-efficient vehicle in Turkey: A case of Hybrids. Energy Policy, 38, 3038-3943.

Method: On-line survey in different regions in Turkey 2009. N=1983.

Consumers who have high income, higher educational level, concerns about global warming are more likely to be willing to pay for hybrids.

Franke, T., Neumann, I., Bühler, F., Cocron, P., Krems, J. F. (2012) Experiencing range in an electric vehicle: Understanding psychological barriers. Applied Psychology: An International Review, 2012, 61,3, 368-391.

Method: 40 EV were leased to sample of users for a 6 month field study. Qualitative and quantitative analyses of range experiences, including regression analyses of stress-buffering personality traits and coping skills in "comfortable" range.

Control beliefs, ambiguity tolerance and coping skills played a substantial role in the experience of "comfortable range". The result indicates that perceived range barriers can be overcome by the assistance of psychological interventions such as information, training and interface design.

Gjøen, H., Hård, M. (2002) Cultural Politics in Action: Developing User Scrips in relation to Electric Vehicle. Science Technology Human Values, 27, 262-281

Method: Qualitative. Studying "user scrips" (how the user perceive and experience the EV).

Two specific changes 1) More planning of the daily travels and 2 more eco-firendly driving (less accelerations/braking and calmer/slower).

Graham-Rowe, E., Gardner, B., Abraham, C., Skippon, S., Dittmar, H., Hutchins, R., Stannard, J. (2012) Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. Transportation Research Part A , 46, 140-153.

Method: Interview with 40 respondents at the end of a 7-days period of using of a battery electric car (BEV) (20 participants) and a plug-in hybrid car (PHEV) (20 participant) – 20 males 20 females 24-70 years from Birkshire, Hampshire and Surrey, UK.

The aim of the study was to explore beliefs about and attitudes towards plug-in EVs as expressed after psychological distance was reduced by experiencing the use if BEV of PHEV for a seven-day period.

The analysis of the data identified six categories: 1) cost minimisation - some drivers were frustrated that they did not get feedback (savings) on their driving style 2) vehicle confidence - not convinced of the range 3) vehicle adaption demand 4) environmental beliefs – sceptical about the net environmental benefits of EVs 5) Impression management - dull design – 'soulless'6) the perception that EVs are currently a 'work in progress' – waiting for new developments.

Hagman, R. Assum, T., Amundsen, A. H. (2011) Strøm til biler (Electricity for cars).TØI report 1160/2011, Institute of Transport Economics, Oslo.

Method: Postal questionnaire among owners of Hybrid Electric Vehicles (HEV) in Norway. Number of respondents 991, response rate 60 per cent.

The survey shows that the owners of HEVs are men (70 percent), 54 per cent are over 60 years, they have at least six years of higher education and live in the eastern parts of Norway (where the capital is located). The annual distance of the HEV is a little longer than the average for cars in general. The HEV is mostly used for leisure activities and commuting. Environmental reason is most important to buy a HEV, then low use of fuel. These attributes are also said to be the most important advantages of the HEV. Next time they buy a car 60 percent want a HEV (35 percent a plug-in HEV). The respondents were also asked about buying a EV and the distance they could accept between each battery charge – 40 percent answered 120 km.

Halsø, T. S., Myklebust, B., Andreassen, G. L. (2010) Norges satsing på el-biler, hydrogenbuker og ladbare hybrider. Oslo, Zero, Tekna

Method: Survey on Internet – 1400 respondents - members of Tekna (The Norwegian Society of Graduate Technical and Scientific Professionals). No information about the respondents

*Consider EV as next car*: total 37 %, majority: women, 30-49 years, households with two or more cars, families with children (and more than one car), increasing income, Rogaland and Akershus.

*Consider plug-in-hybrid in the future:* Total 65 %, majority in the larger cities and people under 50 years.

*Consider hydrogen car in the future:* total 53 %, men (in household with children), people living in Hordaland.

*Purchase of car no 1 - important factors* : Traffic safety (women, children in the household), price, size (children in the household

*Purchase of car no 2 - important factors* : Price, traffic safety, environmental impact (women)

*The three most important advantages of EV* (those who consider buying and EV): Environmental impact (women), a handy car no 2 for shorter trips (families with children), low costs (men)

*The three most important disadvantages:* Range (70 %, men) size (women, families with children). Traffic safety (women, families with children).

Lieven, T., Mühlmeier, S., Henkel, S., Waller, J. F. (2011) Who will buy electric cars? An empirical study in Germany. Transport Research Par D 16, 236-243.

Method: Stated preference, correspondence analysis. N = 1152

Price and range most important for all types of cars. Range more important if the vehicle is the first car than the second. A potential of EV buyers is 6 % for the second car as opposed to 4.2 % for first car.

Mathisen, T.A., Solvoll, G., Smith, K. H. (2010) Bruk av elbiler. Forventninger og tilfredshet (The use of EV. Expectations and satisfaction). SIB rapport 6/2010. Centre for Innovation and Economics. Bodø.

Method: Interview with companies and survey in the same companies.

Expectations: EV will be good for the environment and the use will support the environmental image of the company. Use of EV is a part of the environmental strategy of the company. It is important for the management that the use of EV is highlighted thru the media and that the company is profiled directly on the vehicle.

Satisfaction with EV: Environmentally friendly, easy to park, low on noise, good reputation, economic advantageous

Dissatisfaction with EV: Charging of battery, service, traffic safety, heating, functionality in winter season.

Musti, S., Kockelman, K. M. (2011) Evolution of the household vehicle fleet: Anticipationg fleet composition, PHEV adoption and GHG emission in Austin, Texas. *Transportation Research Part A,* 45, 707-720.

Method: NHTS 2001 to estimate a vehicle usage model, web-based survey of Austin-area household about vehicles preferences and 4 scenario a) type of car (12) b) gasoline price 5 dollar/gallon 3) gasoline price 7 dollar/gallon 4) environmental consequences of vehicles.

63 % support a feebate policy to favour more fuel efficient vehicles. 56 % indicate they would consider purchasing a PHEV if it were to cost 6000 dollar more than a conventional car.

Under a feebare scenario HEV, PHEV and Smartcars are estimated to represent 25 % of the fleet's VMT by simulation year 25.

Two- and three-vehicle household are simulated to be the highest adopters of HEVs and PHEVs across all scenarios.

Ozaki, R., Sevastyanova, K. (2011) Going hybrid: An analysis of consumer purchase motivations. Energy Policy, 39, 2217-2227.

What makes consumers adopt energy-sustainable innovation?

Method: Survey in cooperation with Toyota– 4000 people who had bought a Pius in the previous 24 month got a questionnaire 1) Demographic 2) openended questions about motives for buying Prius 3) Likert scale motivational questions. Response rate 37 %.

Factor analysis indicates various dimensions of motives: Value of comfort, technological interest, Identity, Brand and reputation, Style and fashion, Benefits from the transport policy, fuel economy, environmental awareness, general financial consideration – smart consumption, perceived compatibility with current practices and needs.

Pearre, N. S., Kemton, W., Guensler, R. L., Elago, V. V. (2011) Electric vehicles: How much range is required for a day's driving? Transportation Research Part C, 19, 1171-1184.

Method: 484 vehicles (liquid fuel) were monitored with GPS up to three years, 470 more than 50 days. The selection of vehicles (households) was random (Atlanta, Georgia greater metropolitan area). Whenever the ignition of the instrumented vehicles was turned on, a GPS data logger in that vehicle would record the position, time and several operation variables once per second until the vehicle again was switched off.

The paper discuss the limitations of NHTS since they do not follow the car, but the driver.

*Daily driving distance*: During a year a vast majority of daily range is in the 0-50 miles range, excluding days of zero driving, the mean daily driving range is 44.7 miles and the median 29.9 miles – with days without driving is included – mean 32.6 miles, median 18. 100 miles or more occurs on average 23 days in the year. 150 miles occurs in average less than nine times a year. This information can be used for addressing the questions about how many days per year would the average driver have to adapt his behaviour by, for instance 1) switching to a gasoline car 2) charging during the day 3) planning the day's trip to cover less total distance?

*Days of vehicle use and mileage:* Low correlation between number of days in use and travel distance, 0.18

*Maximum daily travel distance:* 50% of the fleet have one day of 313 miles.

*Days requiring adaption:* Meaning 1) use another car in the household or rent a gasoline car 2)recharging during the day or on the route 3) delaying part of the travel until the next day 4) choosing a different mode of transport. If the drivers were willing to adapt two days a year, those 100-mile EVs would meet the needs of 17 % of drivers, or if drivers were willing to adapt six days a year, the same 100-mile EV would meet the need of 32% of drivers.

*Segmenting by average daily driving distance*: Four groups – To satisfy 95 % of the lowest quarter of the days of driving requires only a 56-mile range, a 86 mile range for the second quarter, a 116 mile range for the third group and a 171-mile range for the highest quarter. For the lowest group an EV with 100-mile range would be sufficient for 32 % of drivers, without requiring any adaption. If two days per year of adaptations are tolerable this vehicle could satisfy 56 % of these drivers – with six days adaptations 83 % of those lower mileage vehicles could be replaced with 100-mile range EVs.

*Time-of –day driving patterns*: On an average weekday at 5 pm, only 15 % of the vehicles in the sample are on the road. 85 % of cars are parked at any given hour of the average day, and never in a year less than 75 % is parked. "Also, because the return trip home is widely spread in time, even if all cars plug in and begin charging immediately when they arrive home and park, the increased demand on the electric system is less problematic than prior analyses have suggested" (p 1171).

Peters, A., Agnosti, R., Popp, M., Ryf, B. (2011) Electric mobility – a survey of different consumer groups in Germany with regard to adoption. ECEEE Summer study, Energy efficiency first: the foundation of a low-carbon society.

Method: Online survey of four groups: 1) Users og EVs 2) consumers intending to adopt EVs in the future 3) consumers interested, but no concrete purchase intentions 4) consumers not well informed about/not interested in EVs. N=969 (80 % men).

1) Average age 45 years, low female rate 5.4 %, household with children, 2.2 cars
2) Age= 43 years, females 9.4%, less children, 1.4 cars
3) Age= 39 years, 18 % women, less children, live in a major city (50 %), 1.3 cars
4) Age 39.5 years, less children, female 32%, 1.4 cars.

Questions about : the *perceived relative advantages* of EVs, *compatibility* with own values, experiences and needs, complexity and ease of use, trialability.

The regression analysis of the total sample show that compatibility with own values, experiences and needs is the most important variables predicting intention to purchase and use an EV. In addition significant effects are observed for relative advantages with regard to operational cost of EV and driving characteristics.

In the analysis of the four consumer groups compatibility also was an important variable. But the more interested the respondents are in EV and the more experience they have, the more they evaluate the various dimensions in favor of EVs.

Pierre, M., Jemelin, C., Louvet, N. (2011) Driving an electric vehicle. A sociological analysis on pioneer users. Energy Efficiency, 4, 511-522.

Method: Interviews with 30 EV owners/users in 2006 and 10 EV owners/users in 2008 to trace different stages of use of an electric car (awareness, purchase, first steps, daily practice, breakdowns, maintenance etc.)

The users lived in near to large cities or in medium sized towns, middle class, with children, all had a conventional car which they drove most of the time. The EV was primarily used for commuting.

EV is complementary to other modes of transport, and many of the owners worked in places where they had been sensitised to such innovations – even as electricians or in municipality using a fleet of EV – and where they could learn how to drive it.

Among the owners of EV one finds both exclusive motorist (only the electric or petrol car) and multimodal users who combine their car with other modes. ..."the use of an electric car encourages a more rational use of the car and sometimes multimodal behaviour" (p 514). "Users are multi-modal rather than convinced ecologists". And show also an interest in cutting-edge technologies.

Owners who use the car on daily basis appreciate its comfort and silence – low running costs are also mentioned. Driving range is not that often mentioned – mainly because the distance between home and work was a prerequisite to purchasing an electric car. The car can usually be recharged at the end of the cycle. People with car(s – including EV) divides up the vehicles depending on the journeys to be made.

Two important features of the drivers of EV:

- Anticipating the journeys to be made – due to recharging, which most do at home or at work (planning – which is often not necessary when having access to a car) – not so much used for leisure activities caused by the uncertainty regarding recharging of the battery
- Adopting smooth driving in order to save the battery

EV owners say they use public charging terminals very infrequently – find them not reliable – difficult to locate, sometimes reserved for professional fleets, poorly maintained. The reliability of public charging terminals is fundamental to make their use possible.

Potoglou, D., Kanaroglou, P. S. (2007) Household demand and willingness to pay for clean vehicles. Transportation Research Part D, 12, 264-274.

Method: Online survey – respondents in the Hamilton area (CA). Using the snowball method to recruit respondents. N=902/602. Stated choice.

Reduced monetary costs, purchase tax relieves and low emission rate would encourage household to adopt a cleaner vehicle. Incentives such as free parking and permission to drive on high occupancy vehicle lanes with one person in the car were not significant.

Roche, M. Y., Mourato, S., Fishedick, M., Viebahn, P. (2010) Public attitudes towards and demand for hydrogen and fuel cell vehicles: A review of the evidence and methodological implications. Energy policy, 38, 5301-5310.

Method: A review of literature primarily of the attitudes towards hydrogen and fuel cell vehicles, but also towards EV and other alternative fuel vehicles.

General findings are a relative positive attitude, but low awareness and knowledge about the technology. No clear correlation with awareness, environmental attitudes or demographic variables.

Ranking of attributes on purchase decisions: 1) Vehicle and operation costs 2) Range between refuelling 3) Availability of fuel 4) Multiple fuel capacity 5) Reduced emissions.

Rødseth, J. (2009) Spørreundersøkelse om bruk av og holdninger til elbiler i norske storbyer (survey of use and attitudes toward EV in larger cities in Norway). Notat. Asplan Viak AS. Trondheim

Method: Telephone interview (Nordfakta AS); two groups of respondents: 600 owners of EV and 600 random sampled licence holders in Oslo, Bergen and Trondheim (the three largest cities in Norway).

The survey shows that the owners of EV differs from the random sample in the following ways: More men than women (68 % vs 32 %), the age groups between 30 and 50 represent 60 percent in the EV sample compared with 38 percent in the random sample, 84 percent of the EV sample have education on university level compared with 65 percent in the random sample, in the EV sample 72 percent live in household with more than two persons compared with 43 per cent in the random sample. 93 percent of EV owners also own a car with combustion engine. 23 percent of the random sample have two cars (10 percent have no car). More of the EV sample is working full time (73 percent vs 62 percent).

*Use*: Commuting – EV owners use car, 83 percent (16 % ordinary car 67 % EV) vs 47 percent in the random sample, public transport 6 % vs 22 %. EV owners increase their car use after they got the EV. There has been a change from public transport to the use of EV. 41 percent of the EV owners pass the toll ring daily compared to 14 percent of the random sample. (In Norway EV don't pay the fee for passing the toll ring).

The three most important factors for buying EV stated by the EV owners were use of bus lanes, that it is environmentally friendly and lower operating costs. For the random sample access to charging stations, the range of the battery and lower operating cost were most important when consider an EV.

The three most mentioned *benefits* of EV stated by the owners: Environmentally friendly, can use the bus lanes, cheap in use. For the random sample the corresponding three factors are environmentally friendly, cheap in use and free parking.

*Disadvantages* are for the EV owners: The range of the car, time for charging of the battery and security. For the random sample: The range of the car, the car is small and access to charging of the battery.

For the EV owners nearly 70 percent say that there is likely that they will buy an EV also the next time. They also said that the possibility to drive in the bus lanes was important for buying the EV (63%).

For non EV owners better range of the battery is the most important factor considering an EV. About 40 percent agreed that driving in bus lanes would be important consider buying an EV.

Sentio Research Norge AS (2012) Online survey for Profero AS.

Method: Survey, internet, random sample for Norway, 1000 respondents older than 18 years.

To what degree people think EV can satisfy their transport needs. To a large degree: 30 yrs and younger, not in families with children, single without children, cities with more than 50 000 inhabitants, not in sparsely populated areas, students.

If buying a new car or a car no 2, would you consider EV as an alternative?

As car no 1: 30 yrs and younger, living in Oslo/Akershus (the metropolitan area), singles with or without children, low household income, Student.

As ca no 2: 31-39 years, families with children.

The most important factors for not buying EV: The range (46%), too small (22%), uncertain whether the benefits (policy) will last (16 %).

Transport for London (2010) Electric vehicle market development. Mayor of London.

Method: Combination of qualitative and quantitative methods of both EV owners/considers, drivers and in-depth interviews with SME

Consumer objectives: To understand the consumer landscape for EVs, profile the target audience, including attitudes, barriers, tipping points and the purchase decition cycle

Business objectives: To understand motivations and barriers to installation of EV charge points and opportunities for Transport for London to provide appropriate and engaging incentives/support for businesses in London

*Current users*:

- Are affluent, car dependent who use the EV in addition to another car to make driving in central London cheap and easy
- Enjoy the benefits of being early adopters and worry about their benefits being eroded as others come to the market
- Want increased benefits
- Charging infrastructure is less important – they already have systems in place for charging

*Potential owners:*

- Motivated by the cost savings, but worry about battery life/range and infrastructure
- The charging schemes is therefore reassuring and motivation for the potential owner market

73 % of London drivers would consider an EV

21 % would consider an electric car in the next 2 years

Those most interested high car dependency, frequent driving in city centre zones, multiple car owners, new car owner, higher income, early adopters of technology, fairly environmentally conscious, willing to pay a premium - a passion for cars

Drivers of interest:

1. Saving money
2. Convenience over public transport
3. Environmental benefits a bonus – not a sole driver

Current and potential use:

1. Currents owners' electric cars are additional cars in household (91% multiple car owners)– potential wish for them to become the sole household vehicle (47 % multiple car owners)
2. High levels of confidence that electric car ownership reduces conventional car usage
3. Usage is broad across journey types (commuting most) but restricted to short distances.

Barriers to uptake of electric cars:

1. Battery issues
2. Infrastructure
3. Parking/charging

The current users are concerned about whether the financial incentives will be taken away in the future – and about differences in parking policies across boroughs

Purchasing electric cars

1. 80 % of electric car owners intend to replace their EV with another EV
2. EV marked is set to increase
3. Aside from the increase in infrastructure the market is looking for financial incentives, parking and bus lane privileges

EV in SME – primary benefits – Convenience (not having to pay parking, tax, free parking, easier to park, flexible in traffic)

| Brand focus | Cost efficiency focus |
|---|---|
| Early adopter status – image for the company | Cost savings |
| Standing out in roads | Image of cost saving |
| Green credentials | |
| Company personality: Entrepreneurial and innovative, more flat structure, open to new ideas | Company personality: Single industry focussed |
| Industry: creative technology, high profile, media | Industry: Services, manufacturing, supply chain |
| Location: inner London | Location. Inner and outer London |

Barriers owners: Limited market range/lack of vehicles, Unreliable engineering, Lack of Pr – market information

Barriers non owners. Limited manufacturer advertising

Low knowledge of EV functionality/capabilities

Turrentine, T., Garas, D. , Lentz, A., Woodjack, J. (2011) The UC Davis MINI E Consumer Study. Institute of Transportation Studies. University of California. Davis, California.

Method: 50 users of MINI E users (BMW converted MINI Coopers into high performance battery electric vehicles with about 100 miles of range.) Interviews, focus groups, surveys, driving diaries.

The MINI E learning process:

| | Discovery → | Translation → | Application |
|---|---|---|---|
| Definition | Drivers learn about the vehicles unique attributes | Drivers form opinions about discoveries | Drivers apply translated discoveries into their routine |
| Adaptation route example | Driving fast reduces vehicles range | "Driving slower to get more range is worthwhile to me" | Driver now routinely drives slower |
| Exploration route example | Regenerative braking allows for one-pedal driving | "I like driving with one-pedal because I feel more in control | Driver now drives with one pedal and rarely uses the mechanical brake |

Three significant lifestyle values emerge among drivers' response to the field of new attributes of BEV:

- The intersection of Clean and Fun – The MINI E meets drivers' desire for a vehicle that is both environmentally friendly and fun to drive
- Expanding Mastery of Energy Use: Drivers find value in using electricity as a fuel and mastering their energy use through driving behaviours, regenerative braking, and charging
- Developing their Electric Vehicle Territory: Drivers *adapt* to and *explore* limited range through better understanding of their activity space, and seek to expand their clean driving territory through the use of available tools.

Volvo personbiler Norge (2012) Miljørapport 2012.

Method: Interview (no information about number of respondents and interview method – survey carried out by Norstat).

How important is CO2 emission purchasing a car?

| | |
|---|---|
| Not important | 23% |
| Neither/not | 24% |
| Important | 50% |
| Don't know | 3% |

The probability of buying an el vehicle or hybrid vehicle next time?

| | |
|---|---|
| Unlikely | 56% |
| Neither/nor | 21% |
| Likely | 15% |

Would you have chosen an electric vehicle or a hybrid car if this had the same price, range and size as a conventional car?

| | |
|---|---|
| Yes | 79% |
| No | 21% |

How important are the following arguments for not purchase an electric vehicle or a hybrid car next time? (% very important)

| | |
|---|---|
| I cannot charge the battery were I am/stay | 63% |
| I cannot reach my cottage or other difficult accessible places with such a vehicle | 58% |
| The car is too small | 57% |
| The car is too expensive | 49% |

| | |
|---|---|
| The car is not safe enough | 40% |
| I don't trust the technology | 21% |

Williams, B., Martin, E., Lipman, T., Kammen, D. (2011) Plug-in Hybrid Vehicle Use, Energy Consumption, and Greenhouse Emissions: An Analysis of Household Vehicle Placements in Northern California. Energies, 4, 435-457.

Methods: 12 households in northern California used a (nickel-metal) Toyota Plug-In HV (one of the first manufacturer-provided plug-in hybrids available for study and is at the low end on the spectrum of battery size and CD (charge-depleting) rang) during one year. All had the ability to charge at home and work.

The objectives were how the car was used, adaption, recharging behaviour, energy and GHG emission.

The average trip was 14 min., 7 miles, trips ranged up to 2.4 hours and 133 miles long. Total distance 35 miles/day weekdays and 21 miles/day weekends.

Compared to the NHTS (RVU) study participants had a higher percentage of travel days exceeding key distances(10-50 miles)

Charging events lasted in average 2.5 hours peaking between 7pm to 11pm and 8am and 10 am.

Also information about energy use and emission, but no information about the participants experience with the trial and their attitudes.

Windish, Elisabeth (2011) The potential for privately owned electric cars in the Paris region: A disaggregate approach. EEVC Electric Vehicle Congress, Brussels, Belgium, October 26-28, 2011, 1-10.

Method: Use of a model of total cost of ownership (TCO) for the selected region (Ile-de-France) divided into three areas (Paris, Petite Couronne, Grande Couronne). Use of data from the National Transport Survey 2007/2008 for IDF region.

A combination of these two data sources combined with constraint to EV ownership; Home-work-home tours < 120 km per day, Home-secondary residence < 120 km/1-way trip, availability of EV (electric veichle) enabling infrastructure (details p 7), private parking at home, electricity close to home-parking, installation possible at own authority. The results indicate that 10 percent of the household in the region comply to the criteria; 0,03 % in Paris (due to the parking criteria), 2.7 percent in Petite Couronne and 20.2 in Grande Couronne. Two scenarios are developed showing the increase in potential EV ownership by changing policies.

## Institute of Transport Economics (TØI)
**Norwegian Centre for Transport Research**

Established in 1964, the Institute of Transport Economics is an interdisciplinary, applied research centre with approximately 70 professionals. Its mission is to develop and disseminate transportation knowledge that has scientific quality and practical application.

A private, non-profit foundation, TØI receives basic funding from the Research Council of Norway. However, the greater part of its revenue is generated through contract research. An important part of its activity is international research cooperation, mostly in the form of projects under the Framework Programmes of the European Commission.

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