# 11

# HOW WILL CAR USERS SHAPE ELECTROMOBILITY AND HOW WILL ELECTROMOBILITY SHAPE USERS?

**Pontus Wallgren**
**Helena Strömberg**
**Department of Product and Production Development, Chalmers University of Technology***

* Division Design & Human Factors
Chapter reviewers: Mats Williander, Viktoria Swedish ICT, and Beng-Erik Mellander, Solid State Physics, Applied Physics, Chalmers

Systems Perspectives on Electromobility 2013, ISBN 978-91-980973-1-3

## INTRODUCTION

In the early beginnings of the car, there were three propulsion systems that competed on more or less equal terms: the steam car, the electric car, and the petrol car. In 1900, 40% of all cars in the US were steam powered, 38% electric powered, and only 22% IC engine powered. Electric cars were perfect for city use as they were silent, clean and easy to manage, while their short range and low top speed made them less suitable for intra urban use. For example, a Detroit Electric had a range of approximately 130 km and a top speed of 30 km/h. Nevertheless, it was an electric car that was the first to break the 100 km/h speed barrier in 1899. Steam cars, on the other hand, offered reliable known technology, and high performance in terms of power. Steam was the propulsion of choice for many lorry manufacturers.

Early petrol cars were by comparison difficult to operate, and quite unreliable. They were, of course, mostly toys for very rich people and as such not expected to be of much real use. A major drawback to the petrol car was the lack of fuel infrastructure. While coal and electricity were readily available, at least in the cities, it was quite difficult to buy petrol.

The ultimate win for the internal combustion engine car was caused by many factors, e.g. the invention of the electric starter in 1912 (the year electric car sales peaked), gearboxes that were easier to operate and more reliable, and the discovery of large petroleum reserves in Texas, drastically lowering the price of petrol. Nevertheless, the most important factor was probably that the IC engine became engine of choice for Henry Ford. Thanks to mass production, the Ford Model T was sold at a much lower price than comparable electric cars ($650 compared to $1750 in 1912). Additionally, while electric cars got more expensive for each year, the Ford Model T got cheaper for each year (A model T roadster had a list price of $360 in 1916).

As cars became increasingly reliable and less expensive, new demands were put on them. To be of good use for travel, the car needed to be more practical. It needed, for example, boot space, sides and roof. With every improvement of the car, new uses were found and with them came new demands for further improvements to better suit the new uses. At the same time, the motorcar made demands on the world around it. Roads that worked fine for horse drawn carriages were not up to the challenges posed by cars capable of ever increasing top speeds. New roads, paved with asphalt or concrete, had to be built; networks of fuel stations had to be set up; guide books such as Guide Michelin had to be written so that the new motorist knew where to fix their car and where to eat while waiting.

When cars spread to larger groups of people it had consequences for the way people lived their lives. City planning changed as people started living in suburbs; the car allowed them to travel to work with ease and comfort. Shopping centres sprung up outside of the cities with new roads and great parking lots that offered all amenities in one place. This is a clear example of how technology shaped society and the way of life. And as the habits of people changed, the infrastructure and cars were developed to better meet these new demands.

Today, we live in a society shaped by the opportunities provided by the car as well as the demands this has placed on infrastructure. In many cases, we live far from our workplace, we drive our children to school and activities and we go by car on holidays. This is of course affects the reintroduction of the electric car and electromobility. New electric cars are compared to the concept of the car formed by our experiences of ICE cars, and it is found lacking (see also Chapter 12).

However, it is usually not acknowledged that electromobility might not be necessarily worse, but just different. This chapter elaborates on both the benefits and the drawbacks of electric vehicles from a user perspective and highlights some important areas for development in order to get users to adopt electromobility. Further, building upon the historical review of the ICE vehicle, it discusses how electromobility and its users may co-develop in the future.

This chapter is focused on full electric cars, i.e. battery electric vehicles, BEVs, except where specifically mentioned. Quite often, plug-in electric hybrid vehicles are included when one discusses electric cars. However, the plug-in hybrid electric vehicles, PHEVs, are quite different in terms of mobility and how the driver can use and interact with the vehicle. Plug-in hybrids are in a way much easier to adopt since they essentially can perform the role of an ICE car (Chapter 10). On the other hand, they are immensely more complex in terms of how they function (Chapter 3) and how their user interface has to be designed in order for the user to understand how to drive them in an eco-efficient way.

## PERCEIVED BENEFITS OF ELECTROMOBILITY

A good starting point for understanding electric cars and how these may shape future mobility is to study what people who already own one has to say about them. In studies of electric vehicles where people have actually spent their own money to buy or to lease an electric car, the involved drivers have stated many reasons for doing so. Among the reasons stated are: economic reasons, technology interest, environmental concerns, political reasons, as well as the excitement of friends and family.

While electric cars in general are quite much more expensive to buy, the running costs are low, at least when you don't consider depreciation and cost for replacing worn out batteries (Chapter 12 and 13). However, in France for example, where the government made substantial investments in electric vehicles during the 1990s, there exist a relatively large amount of used electric cars. These cars can be acquired at low cost, which makes them economically attractive.

Many participants in the different electric car tests that have been made state a high interest in the technology. There are people who are interested in cars in general and therefore want to test what is viewed as the upcoming technology for cars, as well as people with a general interest in technology such as electronics and electric power and want to test what these technologies can do for the car. Participants also state that the excitement of colleagues, friends, and their children was an important reason for acquiring an electric vehicle since electric vehicles are being seen as novel and cool.

Another often-claimed reason for choosing an electric vehicle is environmental concern. This could involve local issues such as reducing the pollution in the city you live, or concerns about global warming. A final reason for acquiring an electric vehicle is related to resources and international politics. There seems to be a growing concern, not least in the USA, that the dependency of foreign oil leads to political instability and to war.

One can assume that the people belonging to either of the latter two categories will be more inclined to give up some of the ICE car convenience than people in the former categories. Indeed our research indicates that this is the case. For example, in one of our studies on electric vehicles there was a participant with a strong interest in environmental issues. He worked with measuring mobile phone base station signals from a car. He stated that the standard procedure was that two people did this from a van since there was so much equipment involved. He, on the other hand, for environmental reasons used an ordinary estate car. During the test he forced his co-workers to join him in a small two seat electric car with much of the measuring equipment in the lap, and he claimed that he intended to continue with this even after the test period.

Whatever the reason for adopting the electric vehicle, all studies seem to indicate that the ownership of an electric car drives interest in environmental and energy issues. There are many examples of users of electric cars, previously not very engaged in energy or environmental issues, e.g. installing solar panels.

Electric cars also offer some unique benefits that become apparent when you try them out. All electric cars on the market use re-generative braking in order to reduce energy use. Typically, they offer different settings with the standard setting allowing coasting much like with an ICE car and one or two settings with harder braking force, intended for driving down hills or at high speed. Users, however, reports that this hard re-generative braking is very useful and relaxing in city traffic as it allows the car to be driven with one foot on the accelerator at all times. For the drivers, this then becomes a feature that increases their comfort, rather than a feature that offers a means to increase range.

Another benefit of the electric car is the performance in everyday driving. Although electric cars in general have quite low top speed, the torque characteristics of electric motors gives electric cars high acceleration at slow speeds, leading drivers of even such low powered cars as the "Think" to describe its performance in city traffic as quite nippy. The Mini-E that was used as test car in a couple of studies has some real performance advantages in terms of acceleration and handling, outperforming most cars in the segment.

## PERCEIVED PROBLEMS OF ELECTROMOBILITY

Even if the electric car can be viewed as an eco-friendly, fun, technological marvel, it also has some drawbacks. One very real problem is people's *perception of electric power, electronics, and batteries as being complex* and out of reach for common people. Research has shown that drivers have problems understanding how electricity can power a vehicle.[1,2] Electricity is a concept hard to grasp to start with and batteries offer further problems.

In addition, people are inexperienced with electric energy measurements and ways of displaying that information. This causes problems in understanding important aspects of driving an electric vehicle. Studies have shown that drivers new to electric vehicles do not know how to relate to information displayed and wonder such things as "Why is the amount of electricity in the battery constantly changing?"

The uncertainty this causes is manifested in both concerns about the feasibility of the technology, concerns about how to treat the battery in the best way, but mostly in what is popularly described as "*range anxiety*". When asked about electric vehicles, many people express concerns regarding range anxiety, i.e. they are

1 Strömberg et al., (2011), Drivers, Electric Cars, and HMI: A Human Factors Approach, EEVC Brussels, Belgium, October 26-28, 2011

2 Cocron, P. et al. (2011), Methods of evaluating electric vehicles from a user's perspective – the MINI E field trial in Berlin, ET Intell. Transp. Syst., 2011, Vol. 5, Iss. 2, pp. 127–133 doi: 10.1049/iet-its.2010.0126

worried about getting stuck in the middle of the road with no power left. Taking into account that most car trips are local and not very long at all, this appears somewhat surprising. Possibly, motor journalists fuel this anxiety when they cannot refrain from putting any electric vehicle they test through some trial that involves long distance driving.

In a test where we let people have access to an electric car for free during three months this aspect was typically expressed as: "I was constantly worried that the electricity would run out, even though I never saw less than half power left on the meter". Similar results can be found in all short-term tests of electric cars.

On the other hand, in studies that report on long-term use of electric cars, such as the Mini-E studies[2,3,4] and Magali et al.[5], this anxiety seems to diminish with use. The participants in those studies still desired longer range, but they did not express any anxiety. Instead they learned how the car behaved in different conditions and what types of journeys are possible in different circumstances. Cocron et al. described it as users appraised range as a resource to which they could successfully adapt and that satisfied most of their daily mobility needs.[2] On average the participants in that study used 82% of the available range.

The importance of the user interfaceIt is a known fact that people use their experience of similar things when they assess new technology. Most people's experience of battery-powered devices is probably that they are unpredictable and never reach the performance stated in the advertisements. If you are used to computers advertised as having seven hours of work time on battery and are never able to reach more than three, you are bound to be anxious about the performance of car batteries. There is, however, lots of evidence that when they are offered control and adequate feedback, drivers change their behaviour and therefore are able to exceed the stated technical potential of electric cars.

In the Mini-E study in Germany there was a trend that people who had tried to reach the range limit were more confident in driving closer to the range limit.[6] The authors concluded that user interfaces that helped the drivers to test the limitations would be beneficial to reduce concerns about range.

These findings lead us to two important areas of improvement, the infrastructure has to be developed to better suit the characteristics of the electric car and the driver-vehicle interface has to be developed to support the driver to utilize the electric car in the most efficient way.

Careful design of the driver-vehicle interface can facilitate the dissemination of electric vehicles by helping the user gain a better understanding of the vehicle, and thereby reduce range anxiety and recharging issues. Even though the driver

3 Franke, T. et al. (2012). Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior. In Sullman, M., Dorn. L. (Eds.). Advances in Traffic Psychology. Farnham, UK: Ashgate.

4 E.g. Turrentine, T., et al. (2011), The UC Davis MINI E Consumer Study

5 Magali Pierre, Christophe Jemelin, & Nicolas Louvet, (2011), Driving an electric vehicle. A sociological analysis on pioneer users, Energy Efficiency , DOI 10.1007/s12053-011-9123-9

6 Franke, T. et al. (2012). Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior. In Sullman, M., Dorn. L. (Eds.). Advances in Traffic Psychology. Farnham, UK: Ashgate.

interacts with the whole car, the instrument cluster is the most natural place to communicate the specifics of driving electric vehicles to the driver.

According to Biscarri[7] the instrumentation should reflect the vehicle's significant variables (e.g. battery state-of-charge, necessary to see if the car will work) and intended use (e.g. speedometer, necessary to keep within legal limits). As drivers today are familiar with ICE instrumentation and their interpretation, this familiarity can be used to speed up adoption where communality exists (such as with the speedometer).

However, it may also lead to confusion when similar meters and symbols are used for measures that work differently in an electric vehicle (e.g. having state-of-charge meters that look like fuel meters). The relationship between state-of-charge and range is more complicated than the relationship between fuel level and range. As range is limited in EVs, this becomes an important aspect to communicate. A common solution is to include instrumentation for both range and state-of-charge (SOC). However, it is hard to accurately present estimated range as it fluctuates with the driving conditions and driving style. Studies have shown that this may in turn lead to confusion and uncertainty when the driver is given several different ranges for the same state-of-charge on different occasions, or levels that vary greatly within the same trip. Nevertheless, with time, drivers learn the range of their car, as well as gain an understanding of how it varies with the driving conditions.[8]

The EV interface will also need to communicate some unique points that are more naturally understood in ICEVs because of additional sensory cues missing in EVs. One example is that an ICEV will give off some noise and vibrations when the vehicle is started. In EVs this is not the case, and therefore an indication of "vehicle ready to drive" is necessary. A second important example is that some form of feedback is necessary when the vehicle is plugged-in and charging. Again, with ICEVs it is possible to hear that there is fuel going into the tank without a special indicator.

Novel instruments related to battery and the electric drivetrain can also be added. One such instrument is the powermeter, which shows how much power is drawn from, or is regenerated to, the battery. The power drawn from the battery not only affects the range, but also the longevity of the battery through the strain put on it. Therefore, this instrument can help explain the relationship between state-of-charge and range, while also encouraging the use of regenerative braking by showing its positive effects.

As previously noted, electricity is perceived as a difficult concept and people in general are unaccustomed with electricity as a means of propulsion. Therefore, instruments with an educational approach, such as power flow displays, have been suggested. However these have not proven successful, as they have been perceived as unnecessary at a first glance causing drivers to lose interest after a while. In some cases they lead to more confusion than understanding, and they

7 Biscarri, E.L., (2001), Instrument Clusters for Electric Vehicles, SAE Technical papers series E, 2001-01-3959

8 Wellings, T. et al. (2011). Human Machine Interfaces in Low Carbon Vehicles - Market Trends and User Issues, HMI 2.1 Report Low Carbon Vehicle Technology Project: Workstream 13

can even interfere with the driving performance.[9,10] Hence, we argue for simple, or minimalistic, design of the interface, where the instrument cluster should be designed in such a way that the vehicle can be operated with ease and without any safety concerns or inconvenience to the driver. Studies have shown that drivers learn the relationship between state-of-charge, driving conditions, driving style, and range quite quickly without complicated instrumentation. The focus should be on information that is easy to understand, reliable and not distracting.

## COEVOLUTION OF TECHNOLOGY AND PRACTICE

The shift from horses to motorcars to electromobility can be compared to other technology shifts. When new technology is introduced, it is often inferior to the existing technology in some aspects, but with time the drawbacks can be dealt with while the benefits stay. Latour criticises the idea that innovations appear suddenly and are adopted by people if they are perceived to offer benefits greater than their costs.[11] Instead, he argues that when technology is introduced, people discover new uses for it which leads to technology development to better serve the new applications, which in turn generate new demand and further development and so on and so forth. There is a coevolution of technology and practice.

To give an example, Latour describes the development of roll film. Before Kodak invented roll film, all photography was done by professionals or by advanced hobbyists. These people prepared their own glass plates and developed the photographs themselves. Kodak started selling pre-prepared glass plates, and then roll film that offered simplicity at the cost of image quality. Professionals did not like this, but it opened a market for amateurs who could now take their own photos. These amateurs, however, did not want go through the trouble of processing film and making paper copies so Kodak had to develop these services as well. One outcome of this was pre-processed photo paper, which the professionals *did* like. Over time, roll film was developed to the point that glass plates became obsolete, not because roll film was inherently better, but because the great demand afforded the development costs. In the last ten years we have seen a similar change of technology where roll film has been phased out in favour of digital photography. At the start, it offered simplicity and speed at the cost of image quality but today it has almost totally superseded roll film for all applications.

When the car was introduced it was an expensive plaything for very rich people, but within a quite short period of time it was faster, more convenient and perceived as more environmentally friendly than a horse, and within economic reach for middle class people. One could imagine that electric vehicles can go the same way, if the industry chooses to focus their development activities on electric vehicles (see Chapter 2 and 15). So far, the traditional car manufacturers have chosen to move quite carefully, adapting existing car platforms for electric propulsion. The benefit of electric propulsion that is communicated is that of lower emissions (a "common good"). With use, people seem to find other benefits that have the character

9 Kurani et al. (2009), Plug-In Hybrid Electric Vehicle (PHEV) Demonstration and Consumer Education, Outread, and Market Research Program, UCD-ITS-RR-09-21

10 Wellings et al. (2011). Human Machine Interfaces in Low Carbon Vehicles - Market Trends and User Issues, HMI 2.1 Report Low Carbon Vehicle Technology Project: Workstream 13

11 e.g. Latour Bruno, (1998) Artefaktens återkomst: Ett möte mellan organisationsteori och tingens sociologi, Nerenius & Santérus Förlag, Stockholm

of “private goods”, such as driver experience and comfort. We argue that these benefits have to be picked up, developed, and marketed, if the electric vehicle shall have a chance to replace the ICE vehicle (see also Chapter 12).

If we are to change from a liquid fuel transport system to a system that to a large degree is based on electromobility, we have to adapt the infrastructure so that it fits the electric car in much the same way that we adapted the infrastructure from a horse-driven transport system to a motorcar based system (see also Chapter 9 and 10 on issues related to charging infrastructure). Electric cars need electric power outlets placed close to parking spaces. This fact will put some demands on the infrastructure. Today, most discussion surrounds public charging stations, and while convenient in some situations, this is clearly a thought coming from an old system where fuel is tanked on special petrol stations away from home. Electric cars, on the other hand, are pre-dominantly charged at home, just as your smartphone is charged at home during the night. As long as the charge is enough for a day’s use, you do not have to bother with how much electricity is still in the battery. Looking at long-term studies of electric car use this has proven to be a big advantage of electric cars: “You never have to fill the tank”. This is of cause only true if you live in your own house, or if you have a rented parking space with a power outlet. For most people living in apartments, the lack of power outlets is a major hurdle to electromobility (if based on car ownership, see Chapter 12 for alternatives).

Several studies on long term effects of electric car use shows that the electric car triggers the interest in environmental issues, regardless of the initial reason for acquiring an electric car. Electromobility therefore has the potential for a positive impact on the environment that is greater than just the direct effects of changing propulsion system. On the other hand, there are also indications that electric car users transfer their trips from other modes of transport to the electric car. In a test where 40 people leased a Mini E for 6 months, 70% of all trips were made with the Mini E. ICE car use was lowered from 71% of all trips to 21%. Biking, walking, and public transport use was almost non-existing when the participants had access to an electric car.[12] This can to some extent be explained with the electric car being trendy and something that you want to be seen in. This effect will probably disappear as electric cars get more common. On the other hand, if it is an effect of people believing that they have done their contribution to improving the environment and therefore don’t have to take the bus, or bike, it might constitute a problem.

The marketing of electric cars as a “secondary car” is questionable. Instead, we would argue that the electric car would make an excellent “first car” for everyday commuting, shopping etc. Hence, it should be comfortable, good looking, have a premium feeling, and therefore also possible to sell at a premium price. The petrol car could then be relegated to second car. There are several signs indicating that such a strategy could viable. One is that there is a clear trend for premium car manufacturers, at least in Europe, to introduce small premium cars. The BMW 1-series, Audi A1 and the new Mercedes A show that customers accept the idea

12 Franke, T. et al. (2012). Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior. In Sullman, M., Dorn. L. (Eds.). Advances in Traffic Psychology. Farnham, UK: Ashgate.

of an expensive car that isn't very big. Another fact supporting our argument is that the US Mini E study showed that the participants shifted the application areas of their cars, preferring to do as much driving as possible in the electric car. This way, they found the Mini E (a strict two-seater car with limited boot space) practical for 90% of their trips, and it was space as much as range that was the limiting factor.[13] Similar figures were noted for a long-term test of the same vehicle in the Berlin area. It was also noted in these studies that the participants adapted to the smaller car by e.g. changing cars with their neighbours in those few occasions they actually needed a bigger car.

To conclude, manufacturers of electric cars market their cars as "technical wonders who are good for the environment" with big displays that show how complex and novel they are, but looking at what people who actually has bought or leased an electric car say about them, what they should focus on is "fun and easy to drive, and very comfortable".

13 Turrentine, T., et al. (2011), The UC Davis MINI E Consumer Study