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Lessons Learned from the Danish EV Living Lab

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Abstract

The success of EVs in the marketplace will highly depend on the end-user acceptance. Insero E-Mobility has examined the user acceptance of EVs through a living lab study, where 80 Danish families used EVs for a period of 8-10 weeks as their only car. The study included a general test and identification of problems faced during usage as well as positive features of the EVs. Fleet potentials were additionally investigated with two trials in departments in Danish municipalities for 14 days. The living lab approach was used to reveal actual and latent needs as well as to facilitate innovation processes with the purpose of rendering input for product and business model development that will increase chance of end-user acceptance of EVs in the future. Long term public user trials has also in the case of the Danish EV Living Lab proven to provide comprehensive and rich amount of information on end customer needs and perceptions that can be used to define value across a range of attributes considered in vehicle purchasing decisions. Key conclusions are that 90% of families found that an EV could fulfil their demands but that range is an important issue even though it is mostly a psychological barrier. For fleets the EVs make sense to an extent depending on the predictability of driving behaviour and available infrastructure.

Keywords: Living Lab, anthropological study approach, electric vehicles

1 Introduction

Denmark is an obvious EV country for a number of reasons. Already today there is a high degree of renewable energy in the country's energy generation and ambitious goals have been politically decided for the future: 50% of electricity should by 2020 come from wind turbines alone and by 2050 the country should be independent of fossil fuels. Already by 2020 it is a politically set goal to reduce CO2 from transportation by 30% [1]. EVs are part of the solution for obtaining the goals and therefore the EVs are exempt from tax whereas traditional gasoline cars are taxed heavily. Adding to this, the country is small and flat and travelled distances are short. Moreover; private operators, Clever and former Better Place, have heavily invested in charging infrastructure which makes it possible to travel country-wide in EVs. But one thing is what makes sense for politicians and environmentalists. Another thing is the end users who will ultimately decide whether to adopt EVs or not. In order to test the attractiveness of EVs for end-users an EV Living Lab was established in 2009, including 80 test families and two fleet studies. And what has been the experience of the first 80 families who tested the first commercially available EVs? The 3 year project Try1EV has now finished its trials with two different vehicles and the results have given inspiration for new solutions and valuable knowledge and information on user needs and behaviour for both private users and fleets. The Living Lab approach has proven

effective and valuable for not only testing products but also to drive product and business model innovation for the future in order to find ways to make EVs attractive to end customers.

1.1 Study approach

Through a period of 3 years, 80 households were provided with an EV for their usage for a period of 8-10 weeks with full mounted trackers to monitor how they used the vehicles. The households were chosen based on an application process, where they volunteered to test the vehicle and report about this. The families were chosen to reflect different ages, family typology and driving pattern. The first 50 households were equipped with a rebuilt Citroen C1 EV, whereas the last 30 households were given a Citroen C-Zero with a better service contract.

Further to the overall study, a number of minor analyses were done based on identified interests or needs.

Early in the test period a need for safety sound on the vehicle was identified. One of the vehicles was therefore, for a smaller part of the test, equipped with exterior safety sound to test the effect of such a system on pedestrian safety and driving comfort.

Adding to the tests with private users, the Try1EV project was also extended to include fleet tests with 8 Citroen C-Zero in two municipalities. The tests were performed by two departments (Home care and Business council) for a period of two weeks with an anthropologist following their behavioural pattern and ending with focus group interviews. The period of 14 days were chosen since previous conclusions in the project had shown this to be the adequate learning period in order for users to get accustomed to the vehicle.

The main focus of the project was to examine how private households/users would utilize the EV in a daily life situation and how it would fit their actual needs for range as well as in general. On a secondary level, the test with the two selected municipalities also generated some basic knowledge on fleet implementation.

The Try1EV project was methodologically run as a living lab project including the following:

- Anthropological field studies to gain user insight through participant observation of everyday routines
- Semi-structured interviews with participants both as preparation to and follow-up on living lab experiments
- Combined field-studies and interviews (mash-up method). The combination is valuable because participant observation uncovers what the users actually do, and not just what they claim they do. The qualitative interviews can explain the dissonance between the wanted behavior and life as it is experienced in reality.
- Going-along interviewing for ongoing updates targeting ‘on the fly’ insights
- Cultural probes designed to investigate user’s emotions, social relations, tacit knowledge, tacit needs and other qualitative aspects that are difficult to uncover through traditional methods such as focus groups, surveys and even interviews.
- Workshops and- games to challenge the users’ mindsets and see new possibilities
- Written questionnaires to explore the explicit thing the user say about the product as a starting point/basis for in-depth interviews or to draw statistic on certain areas
- Micro-blogging where users get a digital channel of expression and at the same time are connected to other users and the public. It thus turns into combined blogging and community building with a highly relevant dialogue between EV users and their ICE counterparts. The EV Living Lab project group monitored both monologue and dialogue and through analysis subtracted valuable lessons from it. The blog is in Danish but can be viewed on the project website: http://www.energihorsens.dk/ElbilForum/Blog/

1.1.1 The concept of Living Labs

In today’s business world companies often work with highly accelerated tests to secure reliability of their products, but the most important test is when the product encounters actual daily use in a real environment.

A living lab is essentially a research concept which is user-centered and which integrates research and innovation processes within a public-private-people partnership [2].

The concept is based on a systematic user co-creation approach that integrates research and innovation processes to reveal input for product and business model development. Tests in living labs are thus integrated through the exploration, experimentation and evaluation of innovative ideas in real life use cases. The approach allows all involved stakeholders to evaluate both the overall performance of a product or service and its potential adoption by users.

The living lab approach offers access to valuable information on all aspects of product usage as well as reveals unmet demands. It is therefore a powerful driver of innovation.

2 EV Living Lab findings

The EV living lab tested whether EVs can meet the demands of todays' family. When the EV Living Lab was launched in 2009 it was not possible to get access to EVs from OEMs and it was therefore necessary to rebuilt C1s for the project. Due to EV development it was possible to change the vehicles to C-Zeros half way through the project. This change provides comparable data on two different vehicles. Looking at the distance driven in the different vehicles, see figure 1 and 2, it shows that the more comfortable and reliable C-Zero drove almost double the distance in average than the rebuilt C1 EV. The rebuilt C1s drove in total 96.481 km corresponding to approx. 113 km per week with a significant spread between the cars driving max and min. The tests performed in the C-Zeros drove in total 159.586 kilometers corresponding to 236 kilometers per week and also with large differences between the cars driving max and min.
By the end of the project the cars had in total driven 256.000 kilometers.

The explanation behind this result is partly due to the fact that many of the C1 EVs were troubled with technical instability and many faults. Consequently they spent substantial time in the auto repair garage, which affected the range travelled in the project; however not enough to explain the large difference in driven distance. The results show that users will, logically, tend to use a car they can rely on much more than an unstable car with unreliable system feedback.

2.1 Private Users

After finalising the project all test persons believe that EVs will become part of the future but only 33% claim to be interested in buying one, if the price is right, range is acceptable and the economic risk is pacified (for instance by leasing). The reason for this is partly to be found in the different types of users, who participated in the tests (see 2.2 Expected EV buyers).

One of the more profound findings of the EV Living Lab was that range turned out not to be a big problem in everyday use, especially not for households with two cars. It was found that it takes a household about 14 days to get used to the range of the EV as well as the charging routines. Once they are beyond that point, they know how far they can go and feel secure at using the full range of the vehicle. The families describe the range limit mostly as a "*mental blocking*" that they need to get over, and it was often commented that "*it's just a matter of planning*" how to use the infrastructure, especially the fast chargers. For families with two vehicles the EV quickly gets established as car number 1, which is used for most trips since it is comfortable, regarded as "quick and clean" and cheaper to use. The number 1 car was then used for longer trips but used for fewer kilometres and in effect ends up as the "back-up car". One of the conclusions of the study is that it would be very beneficial for market penetration to let potential customers borrow an EV for 2 weeks with support. That way the households would learn by own experience and thereby be much more motivated and engaged in the possibilities the EV provides. After the first two weeks range anxiety diminishes drastically and users are more rational on the issue of range. Nonetheless, users still required a longer range for EVs in order for them to be interested in buying them themselves. Even though 80% of the users had their normal need for range covered by the EV they want a range of 150-200 km when purchasing car number 2 and single car families want a range around 300 km. End users conclusively want their car(s) to be able to cover their marginal needs even though it seldom occurs.

Another interesting finding in the project is that charging routines are not a problem. It was even commented that charging is easier and more convenient than fuelling as gas stations since it is predominantly done at home during the night. Test

persons found it positive to save the time normally spend fuelling as gas stations. But concern was expressed with the fact that cables were not protected against theft or vandalism, which must be ensured in order for EVs to become a mainstream product.

Test families found the cars to be easy to drive and liked the fact that cars have automatic transmission and are noiseless. Families with kids even noted that children tend to be quieter when driving the EVs as there is less back-ground noise.

A few tests regarding charging were done during the project in order to investigate the possibilities for smart charging during the night. Dynamic electricity prices and different incentives were introduced in order to find out what it takes to change end-user charging habits into charging outside peak periods and preferably during the night when wind turbines are still producing but consumption is low. The general conclusion was that end-users strongly prefer to start charging right after returning to their home in the afternoon. If charging is automatically controlled it generates some nervousness as to whether the car will be fully charged the next morning. Economic incentives can have an effect but they need to be higher than what can be allowed by dynamic electricity prices in Denmark. A way forward for intelligent charging is therefore to introduce reliable, automatic charging and to ensure end-users have a possibility of instant charging.

Regarding perceived value of products and pricing this was studied in a number of ways during the project and with varying results. In questionnaires the EVs were by the end-users compared with same size ICE even though the EV is transmission free. The limited range was for a majority of the test families not made up for by the positive attributes of the car being "green", low noise, no transmission. But in interviews families were found to be willing to pay an initially higher purchase price for EVs to make up for the cheaper running costs. Many were not aware that EVs have smaller running costs and their attitude towards initial cost changes when the concept of total cost of ownership is explained.

Pricing is, naturally, an important issue for customer acceptance and the lower range in EVs are by many end-users expected to be reflected in the expected price. This will of course vary from customer segment to segment also depending on transportation pattern. It is in this connection important to note that the EV Living Lab only included families living outside a big city.

2.2 Expected EV buyers

To drive an EV is seen as a statement and test persons perceived the EVs as a car but something more. Many families found positive nicknames for their EV and were proud of driving it (or taking part in the EV Living Lab). The project "E-trans" [3] has previously divided EV drives into the following categories:
1. The Technology enthusiast – where the car is a hobby project
2. The Environmentalist – where the car is an ethic consideration
3. City boheme – where the car is a way of being a trend setter and set a new agenda
4. The Design passionate – where the car is an icon and an aesthetic statement
5. The Rationalist – where the car is a tool
6. The Pragmatic – where the car is chosen based on what makes sense
7. The status hunter – where the car is a symbol of status

The results from the Danish EV Living Lab partly support this segmentation, however there has not been found basis for distinguishing between the Status hunter and the Design passionate. Cars like Tesla and Fisker Karma target this segment. In order to win wider customer uptake there has to be several EVs to fit different segments and they can be sold on different attributes to be attractive to one or more the mentioned segments.

The following parameters were found to be most important reasons for not buying an EV for private customers:

- Too high initial price – Becomes less important when informed about lower running costs but requires active selling of the point of total cost of ownership
- Range – There is a demand for higher range and quick chargers alongside high ways.
- Uncertainty of residual value, especially concerning the battery – Therefore leasing would be preferred.

- Design – The design and size should fit the segment and there is a demand for more variety.

2.3 Fleet Users

The two fleet tests showed that EVs have their strength in usage within a defined range and that user acceptance can be established within only two weeks if driving patterns do not vary strongly from day to day. The home care service had no problems with range or usage of the vehicles and the ergonomic benefits, the fact that they are noiseless, have automatic transmission and are easy to access, made the employees rate the vehicles higher than their regular cars. The employees expressed that they "*would be ready to switch completely to electric vehicles tomorrow."*

For the business council the driving patterns change from day to day and employees are individually responsible for planning meetings out of the office as well as transportation to and from meetings. The 8 EVs were made available to use during the two weeks but it was not mandatory to use them. Therefore employees in a number of cases prioritized to use their own car instead of the available EVs in order to be confident that range would not be a problem. It was thus not possible to overcome the issue of range anxiety during the period of 2 weeks. End-user acceptance would require a planned implementation phase and it was in that connection found that access to a quick charger near the office would be relevant in order to allow charging during the lunch break. This would solve the psychological range anxiety. Another way of integrating EVs successfully into the fleet would be to allow employees to use their own cars for trips more than a certain number of kilometres and accept that the available EVs should not solve 100% of driving needs. A fleet with 60-80% of EVs would be possible in both cases.

The two fleet tests also show that results are very much affected by how the EVs are introduced to the employees by management and whether or not they are made mandatory to use. Fleet owners should work with both "push" and "pull" strategies in order for employees to embrace the EVs. A proper introduction to the new technology is essential in making implementation work.

3 Main conclusions

The Danish EV Living Lab was establish in order to investigate the end-user acceptance of EVs and give input for future development of products and business models in order to make EVs successful in the marketplace. According to the living lab concept, anthropological study approaches were used to gain user insights and drive innovation. A concrete example of product innovation from the project is the development of an exterior safety sound system for EVs, due to the identification of end-users feeling insecure when driving the noiseless EVs in urban areas [4].

A general conclusion from the EV Living Lab was that 90% of private families found that they could use an EV, but they want longer range than offered by EVs today. The users found the EVs to be very easy and comfortable to drive and more than 90% offered to do another test period (if this was during the summer where heating of the car would not be an issue).

A more general conclusion from the project is that the EVs sold in the marketplace today are suitable as car no 2. This market corresponds to approx. 400.000 cars in Denmark alone. It was found that when EVs are taking into the household as the number 2 car, range anxiety is smaller but the EV will end up driving the most kilometers as it is preferred for shorter trips. As range was found to be the overall problem with EVs in relation to end-user acceptance a need for heating comfort in the cars without diminishing range is an important issue. This has been improved in later EV models, but is still an issue as end-users will not accept less climate comfort without switching for other value for instance price.

For more than 80% of the users the EV covered their normal range requirement but still range was perceived too low by nearly all users. Car no 2 users were found to want 150 to 200 km actual range, whereas single car families want 300 km range.

The EVs are perceived too expensive by all test families as very few look at total cost of ownership. All families agree after the trial that EVs have lower fuel costs and almost all agree that service costs will be lower. In terms of value perception of EVs many forget to take into account the comfort of automatic transmission and low noise when comparing first cost with very basic

small cars. The general conclusion is that end-users value range high and positive attributes of EVs less important to make up for the lower range. Consequently prices of EVs are expected by many customers to be lower than ICEs, also to make up for the insecurity of buying new technology and uncertainty of residual value. The findings on pricing and perceived value in the project were not consistent as it was found in interviews that families were willing to accept a higher initial purchase price to reflect the lower running costs.

In conclusion it is important to sell the EVs with strong focus on other attributes than price and to argue that price of car should be seen as total cost of ownership.

Regarding charging it was found in the project that quick chargers were seldom used. The vast majority of charging was done at home and users quickly, within 14 days, adjusted to the charging routines which were found to be easier than fuelling at gas stations by many users. In order to shift to night time only charging at home, it will require some automatic help or very strong incentives. Users strongly preferred to start charging as soon as cars were plugged in. It will require some adjustment for users to rely on intelligent charging and it must be possible to choose instant charging. It was found in the project that even non-intelligent charging was not an immediate threat to the electric grid in the tested area, but it will depend on local grid circumstances.

In case of the fleet test it was found that EVs are well suited for local community employees with static driving patterns but that the use of EVs will depend on how they are introduced and whether the use of them are mandatory or employees can choose to use their own cars.

The EV Living Lab has shown that demonstration and test driving is still needed. The positive qualities of driving an EV must be experienced in person to balance the often negative media focus on an EV as an expensive substitute for a car with limited range.

A more general conclusion has been that living lab tests do indeed generate valuable user insights that can also drive new business opportunities. The Danish EV Living Lab resulted in the following business initiatives:

- New commercial product: Intelligent attention sound for electric vehicles (the company EC Tunes)
- Living Lab setup offering product test, demonstration and innovation [5]
- Test-en-elbil – the largest EV demonstration and test in Denmark

4 Figures, Tables and Equations

4.1 Figures

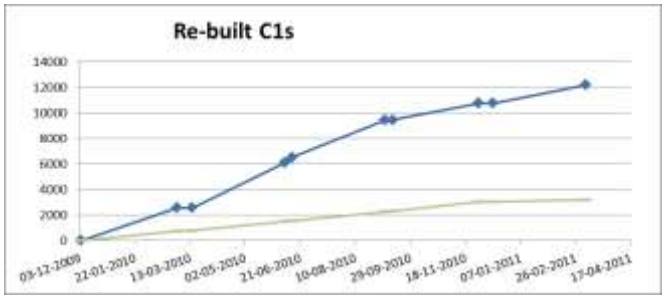

Figure 1 – Max and min kilometres driven by re-built C1s during test period.

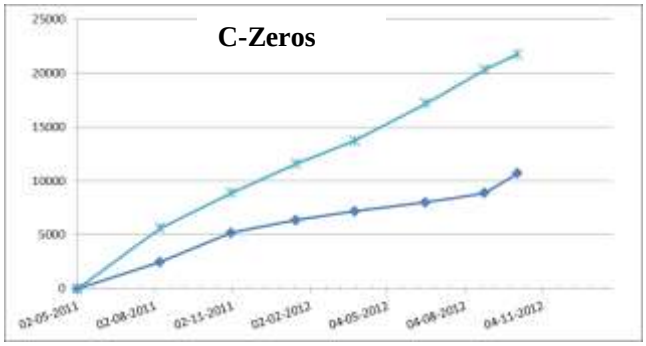

Figure 2 – Max and min kilometres driven by C-Zeros during test period.

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