

## **New vehicle buyers that are Battery Electric Vehicle Compatible (BEV-C)**

Jens Hagman<sup>1</sup>, Sofia Ritzén<sup>2</sup>, Jenny Janhager Stier<sup>3</sup>

<sup>1</sup>*The Royal Institute of Technology  
jenshagm@kth.se*

<sup>2</sup>*The Royal Institute of Technology  
ritzen@kth.se*

<sup>3</sup>*The Royal Institute of Technology  
jennyj@md.kth.se*

---

### **Abstract**

This paper aim to identify and investigate a group of potential adopters that are compatible with Battery Electric Vehicles (BEV) in terms of range and charging, a group labeled as BEV Compatible (BEV-C). The results reveal that the BEV-C group constitutes 14 % of new vehicle buyers and that their intention to adopt BEVs are stronger compared to the non BEV-C group. The BEV-C group can be characterized as individuals that are less likely to conduct occasional longer drives (over 150 km), perceive BEVs more positively, have higher environmental awareness and have been exposed to more BEV information compared to the non BEV-C group.

*Keywords: Battery Electric Vehicle, Range, Charging, Marketing, Sales*

---

### **1. Introduction**

Eco-innovations such as Electric Vehicles (EV) are of high potential to decrease CO<sub>2</sub> emission, noise pollution and local emission from transport as they now emerge to the mainstream markets. Battery Electric Vehicles (BEV) differ from other vehicles with partial electric propulsion systems such as Plug In Hybrid Vehicles (PHEV) and Hybrid Electric Vehicles (HEV) in the sense that they lack a secondary propulsion system and hence rely solely on the capabilities of the battery and access to charging for sustaining the users driving needs. Most BEVs on the market today have significantly lower range compared to conventional vehicles and thus require more extensive charging to fulfill the same driving distance. BEVs therefore require a change of behavior from its users. BEVs have been slow to diffuse on the market, as represented by in the 0.86 % share of new car sales in Sweden during 2015 [1]. New BEVs released on the market and efforts from the government in the form of purchase subsidies and construction of charging infrastructure have clearly not been enough to propel them into mass-market consumer acceptance. Small share of new vehicle sales also means that consumers experience with BEVs is still limited. BEV specific limitations such as limited range and performance, lack of charging infrastructure challenges and high price has been found to be significant consumer barriers [2], [3], [4]. Understanding these barriers is important since they can be assumed to limit a large proportion of new vehicle buyers from adopting BEVs. Equipped with the realization that BEVs are facing specific barriers and demand a change of behavior from its users the authors acknowledge the need to identify potential early adopters that can be more susceptible to adopting BEVs.

Previous studies have found that early adopters of EVs are likely to live in larger cities [5], to be young or middle aged and have higher education [6], have a desire to decrease environmental impacts [3] and motivated to be less dependent on petrol [7]. Anable et al [7] argue that potential consumer segments for EVs are to a large degree defined by the consumers' perception of EVs related to identity, anxiety, parking difficulty, willingness to pay and symbolic motives. This paper builds on previous research by conducting a segmentation of new vehicle buyers that are compatible with BEVs as measured by their perceived compatibility with range and charging possibilities. It is hypothesized that sufficient range and access to charging are critical preconditions needed for an individual to be able to adopt a BEV, i.e. being able to

complete desired travel needs. Range and charging are mutually interdependent for these needs to be met. The same argumentation can be used for other products such as mobile phone technology; without access to electricity (charging) and network access (calling, surfing and texting) no consumer utility can be extracted, no matter how positive consumers are of the benefits of adopting mobile phone technology.

The theoretical context of this argumentation is based on the concept of *Perceived Behavioral Control* introduced by Ajzen [8] as a part of his seminal theory of planned behavior as well as the role of *Compatibility* in the diffusion process as described by Rogers [9]. The individuals that perceive the BEV to provide sufficient range and perceive that they have access to charging infrastructure can thus be argued to constitute the current gross market potential for BEVs and the growth of this group of consumers, here labeled *Battery Electric Vehicle Compatible (BEV-C)*, is vital for the diffusion process of BEVs.

Nevertheless the authors recognize that other barriers can exist that is hindering this BEV-C group from adoption, even though BEV-C is necessary for adoption it is likely not sufficient for adoption to occur. The BEV-C group is of particular interest in the short-run since they, all else equal, should be closer to adoption compared to the other group and in the long-run since its size will presumably increase as barriers related to range and charging are likely to be mitigated by continuous improvement in battery technology and build up of charging infrastructure, hence making widespread diffusion of BEV theoretically more possible for a larger group of individuals. Early signs of this can already be seen in the market with long-range BEVs such as the Tesla Model S and charging infrastructure investments made by both private and public actors. In this paper the BEV-C group is identified through a survey with respondents of Swedish new vehicle buyers that have not yet adopted a BEV. Non-adopters are of particular interest since current BEV users are assumed to already belong to the BEV-C group.

The point of departure for this paper is that understanding potential adopters of BEVs can increase diffusion. By studying a group with the highest potential for adopting BEVs today critical knowledge for contributing to an increased diffusion can be gained. BEV-C, which perceives to be compatible with BEV range and charging, is assessed to represent the group with the highest potential. Therefore the purpose of this paper is to identify the characteristics of BEV-C, compare this group to other new vehicle buyers and analyze the implications these characteristics can have on BEV diffusion. Thus the paper may give valuable insight for guiding policy makers and producers in designing both policies and deliverables to the market that can have a critical impact for BEV diffusion.

## **2. Background**

The BEV-C group is investigated in order to increase knowledge on how to enhance the diffusion of BEV. Research in innovation diffusion provides a valuable theoretical background to the factors that influence the aggregate adoption of innovations. It is the foundation, which constitutes the backbone in this article, although this paper investigates a specific aspect of diffusion, namely consumers that perceive to be compatible with BEVs on the most basic level. The background section will therefore funnel existing knowledge in the innovation diffusion literature toward the more specific area of sufficient range and charging as motivated by previous presented literature in perceived behavior control and compatibility.

### **2.1 Innovation diffusion**

Innovation diffusion describes the aggregate of individual adoption decisions, often as a process based on economic frameworks and information sharing of the innovation in the market place. In Rogers' [9] book innovation diffusion is explained as a process largely depending on five factors: *Relative advantage*, *Compatibility*, *Complexity*, *Trialability* and *Observability*. Rogers argue that an innovation will successfully diffuse on the market place when it is believed to be sufficiently superior to current solutions by the potential consumers. Other diffusion models, such as the epidemic model and the probit model [10] have followed. The epidemic model builds on the premise that all potential adopters share similar characteristics and what limits the speed of usage is the lack of information available about the new technology, such as how to use it and what it does [10]. The probit model follows from the premise that different actors with different goals and abilities, are likely to want to adopt the new technology at different time depending on their individual knowledge, supplier offerings, technological expectations, learning and search cost, switching costs and opportunity cost [10]. Literature in innovation diffusion describes a rich variety of factors that determine the speed and magnitude of the diffusion process. Compatibility in isolation from the others is hence not sufficient for diffusion to occur.

## **2.2 Diffusion of electric vehicles**

BEVs have a set of unique characteristics and barriers that affect its diffusion. Previous research has found that some of the biggest concerns among car buyers in regards to BEVs are: battery range limitation, lack of charging infrastructure and high cost [2], [3], [4]. In extension to these barriers, consumer characteristics, knowledge of BEVs and attitudes towards BEV related attributes also play a role in determining uptake [11]. Hidrue et al [6] identified that levels of education, income, and environmentalism are positively correlated to the likelihood of purchasing a BEV. Public visibility has been found to be of importance for adoption uptake of cleaner vehicles [12], [13]. Anable et al [7] argue that potential early consumer segments for EVs are to a large degree defined by the differences in consumer perception regarding identity (association with EV ownership), anxiety (range), parking difficulty (charging), willingness to pay (price and environmental benefits) and symbolic motives (status, social acceptability). In extension, early user to a higher degree identified through attitudes rather than demographic differences. Lifestyle and attitude factors have strong influence on vehicle purchasing decisions [14].

## **2.3 Sufficient range and charging infrastructure**

Determining sufficient range has been the focus of numerous studies examining data on travel behavior [15]. Findings based on representative data of everyday automobile usage in Germany show that on a typical day, 95 % of the cars on the road travel less than 100 km [16], which is below the operating range of most BEV currently on the market. Despite less than 100 km of range needed daily Bunzeck et al [17] found that German consumers stated an average required driving range of 328 km. Egbue and Long [3] also found an apparent discrepancy of desired electric vehicle range and average miles driven per day. 71 % of the respondents in their study averaged driving distances less than 21 miles per day, but 86 % stated a desired BEV range of greater than 50 miles.

Franke and Krems [15] found that range preference tend to decrease with experience of BEV, in their study over a period of three months. Other scholars have suggested that high range preferences can also be influenced by inaccurate conceptions of usual mobility needs [18], high anchors for estimating required range stemming from experience with combustion vehicles [18] and range anxiety [19]. Range anxiety in BEVs is defined as the continual concern and fear of becoming stranded with a discharged battery in a limited range vehicle [20]. Range and charging is therefore closely related since more access to charging infrastructure makes users less dependent on the range of the vehicle. The battery capacity (range) of a BEV is determined by the trade-off between cost, weight and desired range. Strategies to cope with the battery capacity trade-off varies among different producers, incumbent firms such as Nissan, Renault, BMW and VW have battery packs with an approximate range of between 150 – 200 km, whereas Tesla have chosen a different route with a larger and more expensive battery pack with a range of between 390 – 500 km. As a comparison some modern conventional vehicles can have a range of more than 1 000 km and re-fueled within minutes. The short range of most BEVs on the market reflects the current high price of batteries, despite the short range BEVs can fetch price premium of 50 % or more compared to conventional vehicles in the same market segment.

Charging infrastructure refers to locations where charging a plug-in vehicle such as a BEV is possible. Some of the most common forms are residential, work and public slow and fast chargers. Previous research suggests that a large majority of charging among existing BEV users is done at home [21], [3], [14]. Sufficient charging infrastructure is needed for consumer acceptance of BEVs [4]. A study conducted by Sierzchula et al [22] found that out of several factors examined in multiple countries, charging infrastructure (corrected for population) proved to be the most strongly related to electric vehicle adoption.

To fit a BEV into the transportation lifestyle of consumers it seems not only to depend on range needs (objectively sufficient range), but also on consumer range preferences and access to charging infrastructure.

## **2.5 Perceived behavioral control and Compatibility**

In the seminal work regarding theory of planned behavior, Ajzen [23] describes the factors that influence consumer behavior. The factors that influence intentions to perform a behavior are attitudes toward the behavior, subjective norms and perceived behavior control. The factor of most interest for the scope of this paper is perceived behavioral control that plays an instrumental role in the model and is described by Ajzen [23] as people's perception of the ease or difficulty of performing the behavior of interest. In order for a person to perform a particular behavior it is reasonable to assume that certain opportunities and resources

are needed such as time, money and skills. Ajzen [23] discusses the close relationship between perceived behavioral control and intention to perform a certain behavior, to the extent that a person has the required opportunities and resources and intends to perform the behavior, the person, all else equal, should perform that behavior.

Compatibility is defined by Rogers [9] (p. 224) as “*the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters*”. Innovations that have a higher perceived compatibility have a more rapid rate of adoption since it requires less of a change in behavior from potential adopters. In the context of this paper the authors have segmented new vehicle buyers partly inspired of the third dimension of compatibility; the innovation’s compatibility with potential adopters’ needs.

Rogers [9] discuss the compatibility needs of potential adopters in general terms. This paper expands this by attempting to identify and empirically apply the key compatibility factors needed for the diffusion of BEVs, namely sufficient range and access to charging. Perceived behavioral control provides a theoretical foundation for understanding the impact of possessing opportunities and resources needed to perform a certain behavior, provided that a person intend to perform that behavior. In the case of BEV several other factors such as price and size could potentially also be classed as important in order for consumers to be compatible with BEVs. However, the authors argue that sufficient range and adequate access to charging facilities are essential basic attributes that potential adopters need to perceive as sufficient in order to adopt.

## 2.6 Research questions

BEV-C is argued to be a prerequisite for diffusion of BEVs to occur, hence motivating the segmentation of new vehicle buyers based on BEV-C in order to identify potential adopters. However, this is more strongly motivated if the group is of a sizeable share of potential new vehicle buyers and if they have a higher propensity to adopt BEVs compared to the non BEV-C group. Therefore the first and second research questions are defined as:

1. How large is the BEV-C group among new vehicle buyers?
2. What differences can be seen between the BEV-C group and the non BEV-C group in their intention to adopt a BEV?

Being BEV-C is likely not sufficient for adoption a BEV, as revealed in the literature of innovation diffusion and consumer behavior. Therefore, the authors will investigate the characteristics of the BEV-C group in terms of their perceptions of BEV attributes, exposure to BEV information and environmental values, factors that have proved important for adoption of BEVs in previous research. The possible linkage of BEV-C and intention to adopt BEVs will be explored and the impact of the results will be elaborated in the context of BEV diffusion. Consequently the third research question is defined as:

3. What are the characteristics of the BEV-C group and how do the individuals in the BEV-C group differ from the non BEV-C group?

Through the identification of BEV-C characteristics the implications of these characteristics can be analyzed and an increased knowledge on how to increase BEV diffusion can be gained.

## 3. Method

An internet-based survey was constructed and used in this study in order to collect data from new vehicle buyers in Sweden during the autumn of 2014. The survey was distributed by a Swedish survey collection company with many years of experience within the automobile sector. In similarity to [24], the authors define “new vehicle buyers” as consumers who either have bought a new or at the most two-year-old vehicle within the last 12 months or consumers planning to buy a new or at the most two-year-old vehicle within the next 12 months (Both groups include leases and company vehicles chosen by individuals). In 2015, a total of 345 108 new vehicles were sold on the Swedish market [1]. An initial pilot survey with 100 respondents was conducted and slight changes were made in the survey design to increase clarity. For the final survey a total of 12 570 potential respondents were contacted through e-mail with a response rate of 40%; of those 4 990 respondents 23% belonged to the target group “new vehicle buyers”, composing the total number of 1148 respondents that has been used in this study. 54% of these planned to buy a new or a less than two-year-old vehicle and 46% had already bought one.

Table 1: Characteristics of the respondents

| Variables                                | Number of responses | (%) |
|------------------------------------------|---------------------|-----|
| <b>Gender</b>                            |                     |     |
| Female respondents                       | 445                 | 39  |
| Male respondents                         | 703                 | 61  |
| <b>Education</b>                         |                     |     |
| Elementary school education              | 76                  | 7   |
| High school education                    | 426                 | 37  |
| University degree                        | 646                 | 56  |
| <b>Household members</b>                 |                     |     |
| Single household                         | 167                 | 15  |
| Couple/Married                           | 651                 | 57  |
| Single parent                            | 36                  | 3   |
| Couple/Married with children             | 256                 | 22  |
| Other                                    | 38                  | 3   |
| <b>Place of residence</b>                |                     |     |
| Large city                               | 348                 | 30  |
| Medium-sized city                        | 218                 | 19  |
| Small city                               | 407                 | 35  |
| Rural area                               | 175                 | 15  |
| <b>Age</b>                               |                     |     |
| 18 – 24 years old                        | 61                  | 5   |
| 25 – 34 years old                        | 142                 | 12  |
| 35 – 44 years old                        | 221                 | 19  |
| 45 – 54 years old                        | 223                 | 19  |
| 55 – 64 years old                        | 233                 | 20  |
| 65 – 74 years old                        | 232                 | 20  |
| Older 75 years old                       | 36                  | 3   |
| <b>Household monthly income</b>          |                     |     |
| Less than 15 000 SEK                     | 28                  | 2   |
| 15 001 – 25 000 SEK                      | 87                  | 8   |
| 25 001 – 35 000 SEK                      | 170                 | 15  |
| 35 001 – 45 000 SEK                      | 158                 | 14  |
| 45 001 – 55 000 SEK                      | 144                 | 13  |
| 55 001 – 65 000 SEK                      | 161                 | 14  |
| 65 002 – 85 000 SEK                      | 136                 | 12  |
| 85 001 – 105 00 SEK                      | 61                  | 5   |
| More than 105 000 SEK                    | 51                  | 4   |
| Do not wish to disclose                  | 152                 | 13  |
| <b>Vehicle ownership</b>                 |                     |     |
| Owner of a vehicle                       | 980                 | 86  |
| Do not own, but have access to a vehicle | 141                 | 12  |
| Do not own or have access to a vehicle   | 27                  | 2   |

The composition of the population for new vehicle buyers in Sweden is unfortunately not defined by existing market data. For that reason, the authors used stratified random sampling in order to capture a degree of heterogeneity in terms of income, age, geographic location and household composition from the new vehicle buyer population. The sample population's characteristics are illustrated in table 1. The survey questions were inspired by previous studies testing for attitudes among buyers of green vehicles, such as [3] and [24]. The 7-point Likert type statements explore diffusion-related attributes, inspired by Moore and Benbasat's [25] framework, but adopted to the specific topics of interest. The 1-7 point Likert type statements were ordered to either a positive or a negative statement towards BEVs compared to conventional vehicles (CV). The respondents were divided into groups based on constructed dichotomized variables extracted from the Likert type statements related to sufficient BEV charging and BEV range. Modifying continuous variables to dichotomized variables is a common practice in previous research such as in psychology [26]. Classing the respondents in the dichotomized variables is conducted in a conservative fashion by the authors, responses of five and above (on a one to seven scale) were classed as acceptable, thereby removing neutral or undecided respondents. The respondents perception to charge a

BEV and/or have range needs that is covered by a BEV is divided as illustrated by the authors suggested framework in Figure 1:

|              |                |                                |                               |
|--------------|----------------|--------------------------------|-------------------------------|
| BEV charging | Sufficient     | <b>Non<br/>BEV-C<br/>(I)</b>   | <b>BEV-C<br/>(II)</b>         |
|              | Not sufficient | <b>Non<br/>BEV-C<br/>(III)</b> | <b>Non<br/>BEV-C<br/>(IV)</b> |
|              |                | Not sufficient                 | Sufficient                    |
|              |                | BEV range                      |                               |

Figure 1: The segmentation into BEV-C and Non BEV-C Groups

- I) Consumers perceiving to have range needs greater than the range of a BEV but sufficient access to charging (Non BEV-C).
- II) Consumers perceiving to have range needs within the range of a BEV and sufficient access to charging (BEV-C).
- III) Consumers perceiving to have range needs greater than the range of a BEV and with not sufficient access to charging (Non BEV-C).
- IV) Consumers perceiving to have range needs within the range of a BEV but without sufficient access to charging (Non BEV-C).

Case I, III and IV the BEV will yield little or no consumer utility; one without the other will yield the BEV insufficient to fulfill desired transportation needs. Only in case II desired transportation needs are fulfilled.

In line with the purpose of this study the authors will cluster these four groups into two groups, first, new vehicle buyers that are BEV Compatible (BEV-C) and second, new vehicle buyers that are non BEV Compatible (Non BEV-C). Statistical analysis of differences between the groups will be conducted through Independent T-test, Mann-Whitney U and Chi-Square tests depending on the classification (nominal, ordinal or interval) of the independent variables. A possible limitation of this study relates to the terminology surrounding BEV that could be confused with other vehicle technologies such as Hybrid Electric Vehicles (HEV) and Plug-in Hybrid Electric Vehicle (PHEV). The authors used the Swedish term that refers to BEV in the survey, and the survey answers indicate that the vast majority of the respondents probably refer to BEV when answering rather than HEV and PHEV. However, it is possible that some respondents have confused the meanings of the different technologies.

## 4. Results

### 4.1 The BEV-C group

The identification of the respondents belonging to the BEV-C is made in three steps: first, respondents that have indicated that they find the range of BEVs sufficient for their household needs, second, respondents that have indicated that they have sufficient access to charging to cover their household needs and third, adding the individuals that have indicated that they find both range and charging as acceptable will be computed in the BEV-C group. 14 % of all new vehicle buyers are BEV-C (Table 2).

Table 2 – Range, charging and BEV-C

| Variables                                           | Number of responses | (%) |
|-----------------------------------------------------|---------------------|-----|
| Sufficient range <sup>a</sup>                       | 355                 | 31  |
| Sufficient charging <sup>b</sup>                    | 241                 | 21  |
| Sufficient range and charging (BEV-RC) <sup>c</sup> | 158                 | 14  |

<sup>a</sup> Answers above 5 (1-7 scale) was ranked as acceptable. 129 respondents did not know.

<sup>b</sup> Answers above 5 (1-7 scale) was ranked as acceptable. 138 respondents did not know.

<sup>c</sup> Answers above 5 (1-7 scale) for both range and charging was ranked as acceptable. An average of 133,5 respondents did not know.

### 4.2 Socio-demographics

None of the socio-demographic variables proved to be statistically different between the BEV-C group and the non BEV-C group. The Chi-Square test for gender (Table 3) indicates no statistical difference between the two groups. The Mann-Whitney U test for age, education, income and population size of residence (Table 4) also showed no statistical difference between the groups.

Table 3: Gender

| Pearson Chi-Square |       |    |                        |
|--------------------|-------|----|------------------------|
| Variable           | Value | DF | Asymp. Sig. (2 –sided) |
| Gender             | 1.425 | 1  | 0.233                  |

\*Significant at the 0.05 level.

Table 4: Age, Education, Income and Population size of place residence

| Mann-Whitney U     |                |                        |                            |
|--------------------|----------------|------------------------|----------------------------|
| Variables          | Mann-Whitney U | Asymp. Sig. (2 –sided) | Measure of effect size (r) |
| Age                | 62220          | .716                   | - .012                     |
| Education          | 62770          | .833                   | - .007                     |
| Income             | 45047          | .115                   | - .054                     |
| Pop size residence | 61431.5        | .527                   | - .020                     |

\*Significant at the 0.05 level.

### 4.3 Driving patterns

Driving patterns refers to the estimated driving patterns of the respondents in this survey and should in the mind of a rational consumer correspond closely to the perception of the sufficient range of the BEV. Driving distance is tested in three ways; *Yearly distance driven*, *Daily distance driven* and *Nr of yearly drives over 150 km*. The theoretical range of current BEVs constitutes approximately 150 km, hence the relevance of the two latter variables. The variables were tested against the BEV-C group and the non BEV-C group through independent T-test statistics and Mann-Whitney U tests (Table 5 and 6). In the driving pattern comparison one variable *Number of yearly drives above 150 km* proved significantly different between the groups. The BEV-C group travel significantly fewer times above 150 km on a yearly basis. There was no significant difference between the groups in terms of *Yearly distance travelled* and *Daily distance*.

Table 5: Comparison of the yearly driving distance driven

| Independent T-test     |                 | BEV-C |       |                | Non BEV-C |      |                |
|------------------------|-----------------|-------|-------|----------------|-----------|------|----------------|
| Variables              | Sig. (2-tailed) | N     | Mean  | Std. Deviation | N         | Mean | Std. Deviation |
| Yearly distance driven | .082            | 151   | 3.695 | 1.637          | 766       | 3.97 | 1.817          |

\*Significant at 0.05 level.

Table 6: Comparison of daily driving distance driven and the number of yearly drives over 150 km

| Mann-Whitney U                      |                |                        |                            |
|-------------------------------------|----------------|------------------------|----------------------------|
| Variables                           | Mann-Whitney U | Asymp. Sig. (2 –sided) | Measure of effect size (r) |
| Daily distance driven               | 57286,5        | .680                   | - .014                     |
| Number of yearly drives over 150 km | 51409          | .002*                  | - .102                     |

\*Significant at the 0.05 level.

#### 4.4 Environmental awareness

The variables that were designed to measure environmental attitudes; *CO<sub>2</sub> emissions will cause problems in the future*, *Concerned about the consequences of using a car* and *BEV better for the environment* proved all to have statistically significant differences between the two groups. The BEV-C group are significantly more concerned about the environment and the consequences of driving as well as being more positively inclined to the environmental benefits of BEVs (Table 7).

Table 7: Environmental awareness

| Independent T-test                                          |                 | BEV-C |       |                | Non BEV-C |       |                |
|-------------------------------------------------------------|-----------------|-------|-------|----------------|-----------|-------|----------------|
| Variables                                                   | Sig. (2-tailed) | N     | Mean  | Std. Deviation | N         | Mean  | Std. Deviation |
| CO <sub>2</sub> emissions will cause problems in the future | .000*           | 157   | 5.726 | 1.422          | 782       | 5.033 | 1.737          |
| BEV better for the environment                              | .000*           | 153   | 6.220 | 1.259          | 762       | 5.682 | 1.660          |
| Concerned about the consequences of using a car             | .000*           | 158   | 4.532 | 1.661          | 801       | 3.664 | 1.749          |

\*Significant at 0.05 level.

#### 4.5 Perception of BEV attributes

Thirteen different variables related to the performance of BEVs compared to conventional vehicles were tested. A majority of the variables showed significant differences between the BEV-C group and the non BEV-C group. The survey shows that the respondents in BEV-C group were significantly more positive towards the BEV in the following aspects compared to the non BEV-C group: *quality, safety, purchasing price, comfort, design, purchasing price in the future, status, fun to drive, ease of charging, fuel economy and working wintertime*.

For several of the factors e.g. purchasing price and status, both the groups found the BEV inferior to conventional vehicles. The BEV-C group found the BEV to be superior in quality compared to conventional vehicles, whereas the non BEV-C group found the opposite, i.e. the BEV to be inferior in quality to conventional vehicles. For all other factors, the groups agreed in if BEVs are superior or inferior to conventional vehicles. Table 8 illustrates the results.

Table 8: The respondents' perceptions of BEV attributes

| Independent T-test             |                 | BEV-C |       |                | Non BEV-C |       |                |
|--------------------------------|-----------------|-------|-------|----------------|-----------|-------|----------------|
| Variables                      | Sig. (2-tailed) | N     | Mean  | Std. Deviation | N         | Mean  | Std. Deviation |
| BEV higher TCO <sup>a</sup>    | .271            | 127   | 4.756 | 1.617          | 608       | 4.571 | 1.746          |
| BEV lower quality              | .002*           | 117   | 3.573 | 1.657          | 593       | 4.115 | 1.738          |
| BEV higher safety              | .001*           | 114   | 3.342 | 1.504          | 554       | 2.863 | 1.401          |
| BEV has lower purchasing price | .026*           | 137   | 2.219 | 1.684          | 662       | 1.876 | 1.279          |
| BEV has worse comfort          | .126            | 132   | 3.023 | 1.585          | 615       | 3.273 | 1.729          |
| BEV better design              | .000*           | 136   | 3.559 | 1.543          | 678       | 2.932 | 1.445          |
| BEV expensive in the future    | .011*           | 132   | 2.720 | 1.550          | 633       | 3.131 | 1.711          |
| BEV lower status               | .003*           | 142   | 2.655 | 1.705          | 685       | 3.143 | 1.755          |
| BEV fun to drive               | .000*           | 117   | 3.940 | 1.610          | 549       | 3.182 | 1.498          |
| BEV harder to drive            | .410            | 126   | 2.317 | 1.451          | 581       | 2.442 | 1.561          |
| BEV better fuel economy        | .001*           | 146   | 6.082 | 1.300          | 622       | 5.678 | 1.579          |
| BEV works in winter            | .000*           | 120   | 4.367 | 1.749          | 511       | 3.282 | 1.822          |
| BEV easier to charge           | .000*           | 130   | 3.700 | 1.829          | 646       | 2.675 | 1.802          |

\*Significant at the 0.05 level. <sup>a</sup>Total Cost of Ownership

#### 4.6 Information and experience

Since information are important for diffusion [9], [10], four variables related to information and experience of BEVs were tested to investigate differences between the BEV-C group and the non BEV-C group. These variables are; *Friends, family and acquaintances talk about BEV*, *BEV in the media*, *Where to test-drive BEV* and *Driven a BEV*. The results indicate that the BEV-C group has a higher degree of BEV awareness in the sense of exposure from various information sources (friends and family and media coverage) as well as a better understanding of where to go to test-drive a BEV. Previous experience in the form of driving experience to BEV did however prove insignificant.

Table 9: Information and experience of BEV

| Independent T-test                             |                 | BEV-C |       |                | Non BEV-C |       |                |
|------------------------------------------------|-----------------|-------|-------|----------------|-----------|-------|----------------|
| Variables                                      | Sig. (2-tailed) | N     | Mean  | Std. Deviation | N         | Mean  | Std. Deviation |
| Friends, family & acquaintances talk about BEV | .000*           | 154   | 3.084 | 1.789          | 784       | 2.219 | 1.547          |
| BEV in the media                               | .024*           | 146   | 3.548 | 1.563          | 749       | 3.204 | 1.708          |
| Where to test-drive BEV                        | .005*           | 148   | 3.865 | 2.27           | 712       | 3.299 | 2.202          |

\*Significant at the 0.05 level

Table 10: Experience of BEV

| Mann-Whitney U |                |                        |                            |
|----------------|----------------|------------------------|----------------------------|
| Variables      | Mann-Whitney U | Asymp. Sig. (2 –sided) | Measure of effect size (r) |
| Driven a BEV   | 60180          | .138                   | - .048                     |

\*Significant at the 0.05 level.

#### 4.7 Intent to adopt a BEV

The BEV-C group is hypothesized to be closer to adoption of BEVs. Intention to adopt is often used as a proxy for adoption [23]. It is therefore interesting to investigate if there is a difference in intention to adopt a BEV between the groups. Intention to adopt a BEV was tested in both the short and the medium term. The variable *As next vehicle* can proximate the consumers intention to adopt a BEV in the short term. The

variable *Within 5 years* can proximate consumers intention to adopt a BEV in the medium term. The results indicate that the BEV-C group has significantly higher intentions to purchase a BEV both in the short to the medium term compared to the non BEV-C group. A mean score of 3.493 (a score of 4 would be neutral) indicates that the BEV-C group on average does not intend to purchase a BEV as their next car although they are more likely to do so within the next 5 years seen by a mean of 4.213. Table 11 presents the results.

Table 11: Intent to buy a BEV

| Independent T-test |                 | BEV-C |       |                | Non BEV-C |       |                |
|--------------------|-----------------|-------|-------|----------------|-----------|-------|----------------|
| Variables          | Sig. (2-tailed) | N     | Mean  | Std. Deviation | N         | Mean  | Std. Deviation |
| As next vehicle    | ,000*           | 150   | 3,493 | 1,853          | 757       | 2,148 | 1,499          |
| Within 5 years     | ,000*           | 150   | 4,213 | 1,759          | 737       | 2,786 | 1,749          |

\*Significant at the 0,05 level.

## 5. Discussion

As argued earlier in this paper, both sufficient range and charging are necessary conditions that need to be fulfilled in order for an individual to have possibilities to adopt a BEV. The results indicate that the BEV-C group makes up 14 % of new car buyers, a sizable share in relation to the current small market size of BEV, thus in terms of range and charging 14 % of new vehicle buyers are already compatible with BEVs. It can nevertheless be concluded that a vast majority (86 %) of new vehicle buyers are not BEV-C, still blocking widespread diffusion of BEVs. The authors found that BEV-C group have a higher inclination to intent to buy an BEV both as their next car and within five years. This finding is closely in line with the argumentation proposed by Ajzen [23]; individuals that have a higher *Perceived behavioral control* to perform a behavior are more likely to intend to perform that behavior. In extension to *Perceived behavior control* the authors also based the approach of this paper on Rogers' [9] factor of *Compatibility* which is argued by Rogers to influence the diffusion process. Once again the findings of this paper confirm this argumentation and the value of conducting a segmentation of consumers based on their compatibility.

The statistical analysis of the characteristics of the BEV-C group compared to the non BEV-C group revealed some interesting findings. Socio-demographics showed no statistical difference between the BEV-C and the non BEV-C groups, similar weak links between socio-demographics and EV adopter groups have been found in previous studies [7]. If consumers were perfectly rational, the main determining factors for individuals belonging in the BEV-C group ought to be their actual driving patterns that require a certain driving range and access to charging, a hypothesis that proved significant for the number of times annually that individuals drove over 150 km. Annual and daily distance on the other hand had no explanatory power to why an individual belongs to the BEV-C group or not, implying that new vehicle buyers perceive BEVs to be largely compatible in their daily driving patterns. Occasional incompatibility with the BEV due to longer drives are thus a more important aspect for consumers to deem themselves incompatible to BEV, independent from daily and yearly driving distance. This finding supplies knowledge to the literature regarding the discrepancy between average daily driving distance and desired BEV range [3], [17] by suggesting that occasional longer drives can be of greater significance. The BEV-C group has a statistically significantly greater concern about the environment compared to the non BEV-C group. An interesting finding since environmental awareness at first glance should not be related to BEV-C, although it has been found to be a common trait among early adopters of EVs [6]. A similar pattern can be seen when testing for perceptions of BEV attributes compared to conventional vehicles. An overwhelming majority of the variables show significant differences between the BEV-C group and the non BEV-C group and are indicating a more positive perception of BEVs for the BEV-C group. This combined demonstrates that BEV-C is a condition where consumers generally have a more positive perception of BEVs as well as higher level of environmental awareness.

The spread of information about a technology has been found to be of great importance in the diffusion literature [9], [10]. The respondents' intake of information was tested through exposure to BEV information from different channels and experience of driving a BEV. The results show that the BEV-C group is statistically significantly different from the non BEV-C group in terms of perceived higher exposure to information about BEVs through word of mouth (friends, family and acquaintances), media coverage and awareness on where BEVs are available to test-drive (presumably indicating knowledge of

what vehicle manufactures that sell BEVs). Previous BEV driving experience did however prove insignificant, a finding that somewhat contrasts previous research that found that range preferences decreased with driving experience [15].

These results compel the authors to suggest a couple of claims and suggestions related to the diffusion of BEVs. It can be concluded that in extension to being compatible with BEVs does the BEV-C group also possess a generally more positive perception of BEVs as well as a higher intention to adopt compared to the non BEV-C group. Accordingly it can be presumed that the next wave of BEV adoption is likely to come from the BEV-C group and that policy makers and marketers can more efficiently nudge these consumers to adopt BEVs compared to targeting all new vehicle buyers. The findings presented in this paper also suggest that increasing the size of BEV-C group might not only be function of performance and cost improvements in battery technology and expanded charging infrastructure, other activities show promise to influence the movement from non BEV-C to BEV-C. One such activity is further exploration and experimentation to mitigating the perceived inability/inconvenience of the BEV to perform the occasional longer drives. A factor that already appears to be known to market stakeholders as seen in recent experimentations from vehicle manufactures to package access to conventional vehicles for a certain number of days annually with the purchase/lease of a BEV. The authors believe that investigating the impact of such offers is a promising area of future research and continued market activities. Another key take away from this paper is the clear difference in general perceptions of BEVs between the BEV-C and the non BEV-C group. The origin of which would be of great value to investigate further, the significant difference between the two groups in information exposure points to an interesting area to start further investigations. The spread of information is a key concept in the diffusion literature [9], [10], it can be hypothesized that increased information of the abilities of the BEV could expand the BEV-C group and improve general perceptions of BEVs and hence foster the diffusion of BEV.

## 6.Conclusion

The purpose of this paper is to investigate potential adopters that perceive BEVs to have the ability to perform their travelling needs, i.e. consumers that are compatible with BEVs (BEV-C). The results indicate that a sizeable share of new vehicle buyers are BEV-C, especially when comparing the share in relation to BEVs share of new vehicle sales in Sweden, 14 % versus 0.86 %. However, being BEV-C is not sufficient for adoption to occur. The BEV-C group cannot be identified through socio-demographics, annual driving distance or daily driving distance. The main difference in characteristics of the BEV-C group and the non BEV-C group can be seen in a lower frequency of longer drives (over 150 km), a more positive general perception of BEV attributes, higher environmental awareness, more exposure to BEV information and consequently a higher intention to buy a BEV. These results validate the attractiveness of the BEV-C group for both policy makers and BEV producers; individuals in the BEV-C group are more likely to be adopters of BEVs in the future compared to consumers that are not compatible.

## Acknowledgements

This research was funded by the Swedish Energy Agency.

## References

- [1] Bil Sweden (website). Retrieved on the 11<sup>th</sup> of March 2016.  
<http://www.bilsweden.se/>
- [2] Carley, Sanya et al. "Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cities." *Transportation Research Part D: Transport and Environment* 18 (2013): 39-45.
- [3] Egbue, Ona and Suzanna Long. "Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions." *Energy Policy* 48 (2012): 717-729.
- [4] Struben, Jeroen and John Sterman. "Transition challenges for alternative fuel vehicle and transportation systems." *Environment and Planning B: Planning and Design* 35.6 (2008): 1070-1097.
- [5] Parrish, David D., et al. "Air quality progress in North American megacities: A review." *Atmospheric Environment* 45.39 (2011): 7015-7025.

- [6] Hidrue, Michael K., et al. "Willingness to pay for electric vehicles and their attributes." *Resource and Energy Economics* 33.3 (2011): 686-705.
- [7] Anable, Jillian, et al. "Who will adopt electric vehicles? A segmentation approach of UK consumers." *Proceedings to ECEEE summer study* (2011).
- [8] Ajzen, Icek. *From intentions to actions: A theory of planned behavior*. Springer Berlin Heidelberg, 1985.
- [9] Rogers Everett, M. "Diffusion of innovations." *New York* (1995).
- [10] Geroski, Paul A. "Models of technology diffusion." *Research Policy* 29.4 (2000): 603-625.
- [11] Krause, Rachel M., et al. "Perception and reality: Public knowledge of plug-in electric vehicles in 21 US cities." *Energy Policy* 63 (2013): 433-440.
- [12] Krupa, Joseph S., et al. "Analysis of a consumer survey on plug-in hybrid electric vehicles." *Transportation Research Part A: Policy and Practice* 64 (2014): 14-31.
- [13] Ozaki, Ritsuko, and Katerina Sevastyanova. "Going hybrid: An analysis of consumer purchase motivations." *Energy Policy* 39.5 (2011): 2217-2227.
- [14] Tran, Martino, et al. "Realizing the electric-vehicle revolution." *Nature climate change* 2.5 (2012): 328-333.
- [15] Franke, Thomas, and Josef F. Krems. "What drives range preferences in electric vehicle users?." *Transport Policy* 30 (2013): 56-62.
- [16] Friedl, Christa. "Autos unter Strom: Ergebnisbroschüre erstellt im Rahmen des Projektes optum" Umweltentlastungspotenziale von Elektrofahrzeugen Ñ Integrierte Betrachtung von Fahrzeugnutzung und Energiewirtschaft." (2011)
- [17] Bunzeck, I., C. F. J. Feenstra, and M. Paukovic. "Preferences of potential users of electric cars related to charging-A survey in eight EU countries." (2011).
- [18] Kurani, Kenneth S., Tom Turrentine, and Daniel Sperling. "Demand for electric vehicles in hybrid households: an exploratory analysis." *Transport Policy* 1.4 (1994): 244-256.
- [19] Nilsson, Maria. "Electric vehicles: The phenomenon of range anxiety." *ELVIRE, Gif-sur-Yvette Cedex, France, ELVIRE Consortium FP7CICT-2009C4-249105*(2011).
- [20] Tate, E. D., Michael O. Harpster, and Peter J. Savagian. *The electrification of the automobile: from conventional hybrid, to plug-in hybrids, to extended-range electric vehicles*. SAE International, 2008.
- [21] Smart, J. and Schey, S., "Battery Electric Vehicle Driving and Charging Behavior Observed Early in The BEV Project," *SAE Int. J. Alt. Power*. 1(1):27-33, 2012, doi:10.4271/2012-01-0199.
- [22] Sierzechula, William, et al. "The influence of financial incentives and other socio-economic factors on electric vehicle adoption." *Energy Policy* 68 (2014): 183-194.
- [23] Ajzen, Icek. "The theory of planned behavior." *Organizational behavior and human decision processes* 50.2 (1991): 179-211.
- [24] Lane, B., and N. Banks. "Low CVP Car Buyer Survey: Improved environmental information for consumers." *Low Carbon Vehicle Partnership* (2010).
- [25] Moore, Gary C. and Izak Benbasat. "Development of an instrument to measure the perceptions of adopting an information technology innovation." *Information Systems Research* 2.3 (1991): 192-222.
- [26] Frazier, Patricia A., Andrew P. Tix, and Kenneth E. Barron. "Testing moderator and mediator effects in counseling psychology research." *Journal of counseling psychology* 51.1 (2004): 115.

## **Authors**

Jens Hagman is a Ph.D. student at the department of Machine Design at the Royal Institute of Technology, Stockholm, Sweden. Focusing on consumer barriers for electric vehicles and its relationship with diffusion theory as well as the Eco-innovation literature. Jens earned his first M. Sc. in Economics from Jönköping International Business School in 2009 and a second M. Sc. in Entrepreneurship at Lund University in 2010.

Sofia Ritzén is an Associate Professor at the Royal Institute of Technology and her research is focused on product development and issue on change and on how to create organizational learning. Sofia earned her Ph.D. at the department in Machine Design, Royal Institute of Technology in 2000 and was assigned Associated Professor in Integrated Product Development, Royal Institute of Technology in 2005.

Jenny Janhager Stier is an Assistant Professor at the Royal Institute of Technology and her main research focus is user- and customer involvement in the product development process. Jenny earned her Ph.D. at the department of Machine Design, Royal Institute of Technology in 2005 and was assigned Assistant professor in Integrated Product Development, Royal Institute of Technology in 2006.