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# Investigating EV Driving as Meaningful Practice

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## ABSTRACT

Studies show that people find meanings such as freedom and independence in driving. However, the transition towards electric vehicles (EV's) challenges these meanings as they present different driving experiences such as shorter driving range and missing supportive infrastructures. This suggests that people find other meaning in EV driving. This paper presents a qualitative study with 11 Danish participants who reflect on their experiences of driving EV's in everyday life. As driving is embedded in many practices along with being a practice in itself, we draw on social practice theory as a framework to unfold how participants make use of technology to make EV driving a meaningful and desirable practice. We report on how participants facilitate their driving practices using interactive technology and charging infrastructure. We discuss these findings under three headings with ideas to inspire future HCI research and design for meaningful, sustainable EV driving practice.

## CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

## KEYWORDS

Electric vehicles, sustainability, mobility, practices


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## 1 INTRODUCTION

The car is massively important in today's society. Although many transport alternatives exist, the car remains the most widely adopted means of mobility across more than 947 million vehicles worldwide, accounting for approximately 70 per cent of all journeys [1]. The act of efficiently moving between places has become crucial to access our surroundings, such as going to work, on holidays, or simply getting the groceries. Further, owning and driving cars have been associated with shared expectations, e.g. a high degree of personal freedom, comfort, and independence [28, 53].

In recent years, the increasing adoption of electric vehicles (EVs) has challenged the traditional use and understanding of the car. Studies show adoption barriers such as shorter driving range and missing supportive infrastructures. Towards this end, HCI research has studied how to design interfaces to reduce drivers worrying about battery depletion (e.g. [26, 34, 36, 37]). However, few HCI studies have investigated actual use in peoples everyday lives and how people find meaning in electric driving. These studies have studied the EV as a mobile household appliance and how it is integrated into existing households [5, 58]. Despite this research, a limited amount of research exists, which investigates actual driving experiences with EV's in everyday life.

In this paper, we extend HCI research on EV's with an empirical understanding of how and why EV owners find meaning in driving practices and if charging with own-produced electricity influences desirable driving experiences. We report from a study of 11 EV drivers (five households with own-produced electricity) where we conducted informal conversational technology tours and semi-structured interviews. We use social practice theory as an analytic lens, guided by

questions such as what role digital technology plays in shaping EV driving, what kind of expectations people embed into their EV driving practices, and how people adjust driving an EV compared to the traditional fossil-fuelled car.

We present findings in four themes of Joyful Electric Driving, Transitioning into EV Driving, Planning through Interactive Technologies, and (Un)Sustainable Driving Expectations. Findings indicate that EV driving is an enjoyable and meaningful practice and that planning and technology support is essential aspects in shifting to EV driving. Finally, experiences of EV driving indicate increased driving activity. We discuss these findings under three headings with ideas that may inspire future HCI research and design for the EV.

## 2 RELATED WORK

Studying interactions with the car has been a subject of research in HCI for years. A body of literature exists on studies describing the driving situation and how to ensure the driver eyes on the road. This research predominantly focuses on using various technologies in the car and how this affects the driving situation. Several papers have presented results related to the above, for example on interacting with existing in-car car technology (e.g. [6, 20, 35]), novel interfaces (e.g. [10, 30, 38, 39]), and how drivers appropriate interactive technologies (e.g. [2, 26]).

In HCI research, we have seen a shift in how people use the car that is closely related to the development of technology. One of these shifts is the use of connected features of the car. Many cars today are shipped with an internet connection, which means that people can interact with the car both from the inside and the outside using other mobile devices (e.g. [7, 42, 62, 63]). Chiesa et al. ([7]) demonstrate ideas for collaborative parking utilising connectedness. Ostergren ([42]) suggest a system for social music experiences by tuning into music experiences of cars nearby.

HCI studies are also investigating different ways of using cars. Studies of traditional car ownership have found that usage of cars indicate that people find meaning in a high degree of freedom and independence that they provide instead of practical values such as saving time [28, 53]. However, today, there are many alternatives to traditional car usage, e.g. car and ride-sharing that allow for the car to be accessed as a service. Studies of such services indicate that people find meaning in other qualities. For example, in a study of car sharing, Shaheen et al. found that people found meaning in social and environmental aspects of car use [48].

### HCI Research on Electric Vehicles

Following HCI discourses on sustainability, we have seen an interest in electric vehicles (EV's) in later years. A significant number of HCI studies on EV's have focused on the challenges and opportunities in adopting and driving these, as they form a new kind of driving experience compared to a fossil-fuelled car [26, 34, 36]. To this end, several studies investigate range-related issues such as range anxiety where drivers worry about the depletion of the battery before they reach their destination [26]. As such, this work has resulted in more design-oriented research addressing challenges related to range anxiety and lack of feedback (e.g. [26, 36, 37, 57]). As examples, Jung et al. [26] explore the impact of displayed uncertainty in the car's instrumental estimates of range, while Landau [34] focuses on creating an interface that makes up for the lack of feedback in EVs, for example, the lack of sound or vibration, or knowing when the EV is ready to drive.

In contrast to design-oriented research, empirical studies that investigate how people find meaning in the use of EV's, have received less attention within HCI. Most HCI research in this area has addressed how and why owners use EV's and how they appropriate these in their daily lives. This work suggests that people own and drive EV's for reasons such as becoming more sustainable [5, 14, 58] and interests in novel technology [59]. Bourgeois et al. [5], for instance, investigated the feasibility of self-sustaining electrical mobility and provided an understanding of owning and integrating EV's into household routines. The authors found that utilising own-produced electricity, and the feeling of being sustainable was a reason for owning and driving an EV. Svangren et al. [59], investigated connected cars and the use of digital technology. They found that some challenges related to EV driving, like range anxiety, are mitigated through the use of digital ecologies. However, despite the above research, there is still a gap in exploring actual EV driving and how people find meaning in the experience through use of technology.

### Sustainable Change and Social Practice Theory

In later years, we have seen a growing interest in the HCI research community to engage in the design of digital technology and sustainable change. In this line of work, different theoretical frameworks have been applied to both understand and discover means to design interventions for sustainable change [9]. In particular, suggestions to use practice-oriented methods [32] have been advocated within sustainable HCI studies to better account for the social values and norms influencing how resources are consumed [11, 22, 31, 44]. As most resource consumption is interwoven in mundane routines people perform in everyday life (e.g. cleaning, cooking, heating, and driving), practice theory highlights that changes to such routines are shaped by what people find meaningful and desirable. Therefore, designing meaningful and desirable experiences of interactions with technology may shape practice [19], and thus influence resource consumption.

While social practice theories originate from social science, we also see a growing research interest in HCI that

focuses on understanding why early adopters desire to use and interact with new digital technology. Commonly, these studies aim to help uncover both the sustainable benefits and pitfalls of new digital technology use. Strengers [56], for example, use social practice theory to understand the influence of eco-feedback design in everyday life to help frame alternative design directions for HCI. Pink et al. [45] explore heating practices through sensory ethnography as an approach to inform future sustainable design for heating. Hasselqvist et al. [18] use social practice theory to study three families' experiences of car-free living, while Ganglbauer et al. [15] investigate food practices from a social practice theory perspective, to suggest design strategies of related practices to influence more sustainable food waste practices.

***Practice as a Framework***. To help frame practices and understand how they change, Shove and colleagues provide a concise framework of social practice change [50]. In this work, the authors argue that practices change when elements (competences, materials, and meanings) of practice is mixed in different ways. Importantly, Shove [49] also argues that desired social-shared expectations, which people associate with performing a practice, contribute to or undermine sustainability outcomes. This is exemplified by Jensen et al.'s [23] empirical investigation that draws on the concept of 'desiderata' and social practice theory to uncover the energy impacts of peoples' desires to use smart home technology. Kent et al. [28] also investigated traditional car practices and found that the shift to more sustainable transportation forms, is undermined by social expectations of driving, such as flexibility, freedom, autonomy, and comfort.

## 3 STUDY DESIGN

This paper aims to investigate peoples' use and experiences of driving an electric car. At the same time, the paper explores if and how own-produced electricity influence desirable driving experiences. In contrast to previous studies in this area [5, 14, 58], the purpose of this study is to unfold how early adopters of such perceived sustainable technologies adjust practices to make the EV a meaningful and desirable means of transportation when they can charge their car with own-produced electricity. Moreover, we aim to uncover the kinds of energy implications EV driving practice may have in everyday life. To this end, we use social practice theory as a lens [50], and are guided by questions such as what role technology and infrastructures play in shaping EV driving (materials), what kind of meanings and expectations people embed into their EV driving practices (meanings), and how people adjust driving an EV compared to a traditional fossil-fuelled car (competences). In the following, we describe in detail; the background of EVs in Denmark, an overview of participating households, data collection, and analysis.

### Electric Vehicles in Denmark

The reported research in this paper is part of a larger research project investigating future sustainable scenarios for energy and transportation systems in Denmark. Actors in the Danish energy sector envision householders to play a significant role in the transition into a more sustainable energy future. The scenario of electric vehicles that can be charged at home by electricity produced from small wind turbines and solar panels is often promoted as a step towards a more sustainable future in this vision. Using this argument, the Danish government has introduced economic incentives to promote households to invest in these technologies by, for instance, reducing registration tax on EVs compared to fossil-fuelled cars. These incentives have led to an increased Danish EV fleet, with sales increasing from 0.25 per cent of total car sales at the beginning of 2017 to 3 per cent at the beginning of 2019 [12]. Yet, while EVs can be charged at home, public available charging infrastructure is also starting to emerge from a range of private companies. Most commonly, these public charging stations require a subscription to the particular provider. However, there is no standard for EV charging spots. Sometimes, charging spots are marked for EVs with a symbol or a sign to signal that only they can park there. However, in many cases, they are just regular parking lots with a charger next to it.

### Participants

Five households (11 people) participated in this study. Each household also produced electricity from their own solar panels or wind turbines. Participants were between the age of 16 and 72. All participants were driving at least one of the household's EVs. All participants had a drivers licence except Adam (Household A) who were currently acquiring his. A demographic overview can be found in Table 1. The participants from each household are referred to in the table by anonymised pseudonyms (e.g., Kirsty) and household number (e.g., A). In the following, we will describe each of the five households in depth.

***Household A***. The household owns a Tesla, a Renault Fluence, and a Mahindra Reva. They mainly drive in the Tesla (50.000 km a year) and Renault (20.000 km a year). The Reva was bought for Adam, who plans to drive to school when he gets his driver licences. Today, Adam uses the bus or an Air Wheel (a small electric one-wheeled scooter). The household drives more after getting the Tesla, as driving sometimes replaces flying on holiday. Jim also started to drive the Tesla for business trips instead of flying. The household owns solar panels that produce 18.000 kWh of electricity a year. However, the household uses three times as much electricity yearly. Two-thirds of this is used to charge their three EVs. The family drives around 70.000 km a year.

| H | Name | Age | Adults (Children) | Occupation | Living area | EV Model |
|---|---|---|---|---|---|---|
| A | Kirsty, Jim, Adam | 46, 47, 16 | 3 (2) | Nurse, Assoc. Prof., Student | Rural | Tesla M. S, Renault Fluence, Mahindra Reva |
| B | Ina, Jeffery | 70, 72 | 2 | Both Retired | City (winter) and Rural (summer) | BMW I3 |
| C | Irene, Franky | 50, 48 | 2 (3) | Healthcare Helper, Early Retirement | City | Tesla M. S |
| D | Clara, Tony | 53, 52 | 2(3) | Retail Assistant, Military Consultant | Rural | VW E-Golf |
| E | Isabel, Jett | 34, 38 | 2(2) | Regional Clerk, Consultant | Rural | Tesla M. S |

**Table 1: Description of participant households.**

***Household B.*** The household bought the new hybrid car last year. Before this, they used to have an older EV model. The new car has an electric motor, and a backup petrol generator that can produce electricity to run the motor in the case it runs out of electricity. The electric car-range is about 150 km and 150 km for gasoline. The adults spend most of their summer in their rural summerhouse where they have solar panels as the only source of electricity. In the winter they live in their city flat, where they have a power charging set up. They drive around 17.000 km a year, and this has not changed with their new model. In the summer months, they use about half of their produced electricity for their car.

***Household C.*** The household owns a Tesla that drives 40.000 km a year and a fossil-fuelled Mustang that drives 20.000 km a year. The Tesla is the preferred car because they believe this is the most economical choice for driving. Before they got the Tesla, they would drive about 30.000 in their former cars. The children also use buses, mopeds and bikes for transport purposes as they do not have a driver licence. The household has solar panels. The family produce 7200 kWh of electricity a year, which is about the same amount they use yearly.

***Household D.*** The family owns two cars; an E-golf and a fossil-fuelled Audi. Tony also has a fossil-fuelled motorbike, while the children use bikes. They drive around 30.000 km a year in the E-Golf, about 10.000 km in the Audi and 8.000 km on the motorbike. The children bike every day to school or take the bus if the weather is terrible. As the only household, the family produce between 25.000 and 30.000 kWh a year from an 11 kW wind turbine. The electricity, they do not use themselves, is sold at a flat rate of 0.78 DKK (0.14 USD) per kWh. From 2021 they have to transfer to dynamic trading conditions, meaning they might have to pay money to sell electricity due to high amounts of wind energy in Denmark.

***Household E.*** This household owns two cars; a Tesla and a 20-year-old fossil-fuelled Golf. They drive around 30.000 km a year in the Tesla and 10.000 km in the Golf. Occasionally, they take a train or bike to work. The family owns solar panels that produce 4.000 kWh a year, which covers ordinary household energy-consuming activities. They use about an extra 6.000 kWh for charging their only EV.

### Data Collection

In order to get an understanding of why households desire to electrify car transportation, we conducted an in-depth qualitative study with early adopters that already embed electric cars in their everyday life and also produce micro-generated electricity. To this end, we designed our study to consist of four steps; an informal, conversational technology tours, individual interviews, group interviews and a debriefing session between two researchers.

***Informal Conversational Technology Tours.*** To get an understanding of the access to and use of different technologies, we conducted informal, conversational technology tours [3] with each of the households. Here, we asked participants to show us their EVs and what technology they used for charging it. We asked them to give examples of how they used technologies individually and in collaboration. The purpose of the technology tours was twofold. Firstly, we wanted

to get a richer and more concrete understanding of how the individual households used their cars. Secondly, we wanted the participants to be able to speak more openly about technology and reveal possible tacit knowledge. This approach resulted in many participants not only demonstrating but also sometimes wanting us to try out their technology so we could get first-hand experiences.

***Individual and Joint Interviews***. Following the technology tours, we conducted individual and joint semi-structured [33] interviews with all participating household members. The purpose of the individual interviews was to reveal individual opinions, such as competences and meanings for the technologies touched upon in the technology tours. For example, we asked them individually about motivation towards owning and driving the EV, individual routines involved in driving and charging it, along with individual driving patterns.

We conducted joint semi-structured interview sessions with all participating household members. The purpose of this session was to understand shared social values and practices and to reveal possible tensions between household members. Here we asked more general questions about the structure of the households, the driving patterns as a household, and common motives for driving an EV. These sessions would sometimes result in discussions between our participants about their reflections on the "most correct" way of doing things.

Two researchers participated in the data collection sessions. Right after each visit to the households, the researchers had a debriefing sessions [61]. The purpose of this session was to support *"the research team to discuss and work through the successes, issues, and challenges encountered"* [61]. These debriefing sessions facilitated the process of sharing thoughts and reflections on the researchers' observations and impressions that were not verbalised by the participants. The debriefing sessions were audio-recorded.

### Data Analysis

We took notes, pictures, and recorded audio with consent during the technology tours. All interviews were documented through researcher notes and audio recordings. A total of ten and a half hours of audio were transcribed for analysis by two of the authors.

We coded the transcriptions accordingly. We identified broad themes using inductive coding [46, 47]. Next, we used the three elements of social practice theory as a lens to guide the thematic analysis (materials, competencies, and meanings). The analysis resulted in four themes. As part of the analysis, participants were given a pseudonym (see Table 1).

## 4 FINDINGS

Our findings highlight different aspects of how EV driving is experienced as meaningful practice, focussing specifically on driving and adaptation of the EV into household routines. Drawing on our analysis, we structured the findings into four overall themes; *Joyful Electric Driving, Transitioning into EV Driving, Planning through Interactive Technologies, and (Un)Sustainable Driving.*

### Joyful Electric Driving

The first theme describes how participants find joy in driving their EV compared to the vehicle they owned before. Further, the theme describes how expectations of playfulness and new sensory experiences of coolness shape how the EV becomes infused in driving practices.

***Playful Technology***. The households were generally characterised by a high level of interest in technology. All the participants reflected that many of the technologies related to the EV gave them a feeling of driving a car of the future, which in turn added a layer of comfort. Because of this added comfort, most participants thought that driving non-electric cars felt like a step down technologically. They used words as *"feels like a step backwards"*, *"old fashioned"* and *"inconvenient"*. This, for example, was reflected by Jim in household A that owned three EVs;

> *"For the Tesla, one doesn't even have to control it [...] That completely convinced me that there was no reason why our car shouldn't be electric in the future because it seemed technically superior - I like that"* - **Jim (A)**

Playfulness was also associated with getting to know a technologically advanced car, which resulted in time being spent on exploring and playing around different features. We found that many of the participants were very interested in technology (at least one on every household), thus figuring out how the EVs worked or could be modified became a hobby for many of them. This meant time spent acquiring competencies to incorporate these technologies into everyday life was seen as enjoyable as the participants found these amusing and fun to play around with. Jeffery exemplifies this;

> *"I have to admit that I was a little tempted by all that technology and there is also a lot of it in this car. Yes, I think it's fun, and I like the principles. [..] Anyway, that's how it is with toys, so when I then got the car in my hands I played with it"* - **Jeffery (B)**.

The combination of playful EVs technology and using electricity from the solar panels or wind turbines each household owned, meant it became highly engaging to integrate the EV into overall household activities;

> *"So the technology I think is very interesting, that is, something that is as annoying as the f***ing wind can be turned in to something useful. It fascinates me, and then, of course, I am also very aware that it is environmentally correct that I do not have to burn off gasoline or oil. It fascinates me tremendously!"* - **Tony (D)**

Under the technology tours, we saw several homemade devices meant to support charging when the car was at home, which made us ask if this also applied while driving. We found that sharing knowledge through digital technology with other people owning an EV were quite important for these participants. One aspect of this was sharing experiences and useful advice through social media and forums on everything from charging infrastructure to how to hack software in the cars;

> *"The forums [Facebook], and the social aspects are quite important to us. We share experiences on everything from unavailable chargers to advice on how to polish our Tesla with people who also own an EV. Once every now and then we also arrange hackathons through them where we tinker with our cars. We share both our success and frustration"* - **Jett (E)**

***Sensory Experiences and Coolness***. Another aspect making EV driving a joyful experience was related to the creation of new sensory experiences through the new technologies found in these cars. The new sensory experiences added to expectations of comfort and pleasure of the time spent in the car. These expectations also further enhanced the feeling of being in a "cocoon of the car" because *"you just drive silently - no noise, no diesel noise, there is only noise from the road"* - **Jim (A)**. Because of this, driving the EV was popular in these households, which meant it became the preferred means of transport in their daily activities. As a result, who drove the EV would often be up for debate, as it was an attractive alternative to those who also had a fossil-fuelled car;

> *"It's my wife that drives the EV to work because she has to drive the furthest, then I will, sadly, have to suffice with the other one. However, I'm changing jobs soon, so I'll get the EV, that's how it is, it's the rule. But I'm certainly not going to complain about that"* - **Jett (E)**.

We further found that all households experienced substituting driving a fossil-fuelled car with an EV had made speed less relevant. A slower speed was foremost to save range, however enjoying the drive also became important;

> *"When I take the diesel, I find myself rushing to my goal constantly thinking about when to overtake the car in front of me. It's very stressful. However, when I drive the EV, I slow down, thinking about how I drive and I enjoy the trip. It's sort of this zen thing"* - **Tony (D)**

Another aspect the participants reflected upon was the experience of feeling cool owning and driving an EV. Part of this was related to the uniqueness of the technology. For instance, electric cars do not feature a gearbox as conventional cars. Many also offer different forms of autonomous driving, and interactive applications making it possible to interact with the cars through other devices. We also found that coolness was associated with having a special car that few people own, making the EV something cool and desirable to show to friends and family. Adam, the older son in household A, for example, thought that having his own electric car was;

> *"Iconic in some ways because it is a special, little car. I have some friends who have seen it, and they think it's cool"* - **Adam (A)**

Especially for the Tesla owners, the feeling of uniqueness, was partly due to how Tesla's ecology of technologies worked together. This uniqueness contributed to making the EV cool to own;

> *"There has been talk of a Jaguar and a BMW. And then we looked into these Teslas — you cannot say anything other than it's a brilliant car and it's just an even bigger idea"* - **Franky (C)**

### Transitioning into EV Driving

In this section, we describe how participants transitioned into EV driving from previously owned vehicles. Although there were many aspects related to this (e.g., getting used to driving with regenerative breaking), we found that planning for available driving range was the most important aspect of this transition.

***Planning Household Charging***. As participants reflected on questions about driving range, most of them described they had been through an adaption period to accommodate charging their EV. One aspect was experiencing a limited driving range and the consequences of forgetting to charge;

> *"Yes, we've tried sometimes that I, for example, forgot to charge. Yes, then there is nothing you can do. I can't just ride down to the petrol station and pick up a dunk of gas. You'll just have to wait it out"* - **Kirsty (A)**

In the beginning, some households experienced they had to compromise on comfort features. They would, for instance, turn heaters and wipers off during the winter months in their old EV to save range to make it home. Household B expressed their early experiences with EVs as; *"not suitable for Danish winter weather"* - **Ina (B)**. However, when asked about how to overcome the limited range, most households

agreed that many of the issues could be mitigated through planning and new routines. As such, it quickly became a new routine to plug in the car when arriving home and plan charging points while driving, to ensure they were ready for driving when needed;

> *"We are used to all the cars are parked and ready for charging during the night, and that they are ready to drive in the morning. When we come home, we just plug it in"* - **Adam (A)**

Because it had become routine to charge at home it also enhanced the expectation that the car was always fully charged when leaving home. This could sometimes lead to problems for households switching between EVs and fossil-fuelled cars: *"She ended up running of petrol because, whoops, it had not been refuelled like with the Fluence that is freshly charged every morning"* - **Jim (A)**. However, the participants saw this availability of electricity as flexibility and convenience when compared to fuelling at gas stations, which compensated the inflexible time aspect of charging the electric car;

> *"Finding time to charge is not a problem for me. I would say that I on average spend one minute a day with charging activities — and yes that's even a high estimate. I just have to plug it right in and out. How long do you think people spend on a gas station in a month?"* - **Jim (A)**

***Charging Away from the Household***. Available charging infrastructure outside the households, both public and private, was regarded as a useful means to reduce experiencing the EV's limited driving range. When away from home, many participants explained they would plan holidays by finding hotels where they could charge the car when arriving at the hotel. As electricity is available in many places, all the participants also spoke of the convenience of being able to charge their car in other peoples' homes.

> *"When I visit my son, the first thing I do, is to put the car in the socket. It's become quite expensive for him to have us come by for a coffee"* - **Jeffery (B)**

One challenge of having to charge in different households was the non-standardised charging infrastructure (e.g. different sockets and power availability). This meant not all cars were able to charge in all charging outlets with a standard plug. In household D, Tony was well prepared for the different situations. He had various cables and extension cords, so he was always able to charge when away from home.

> *"I've become more used to it. It is very much habitual that I have to think a bit about where I go and the electricity options. Therefore, I bring different adaptors. Most often, if we have to visit the family or the likes, we can just charge the car there. I don't think there's anyone who would say no if you bring an adaptor"* - **Tony (D)**

Having to wait to charge in the middle of a drive at available public charging stations was not regarded as an inconvenience by these participants. This was mainly because these stops had been planned beforehand, and often in combination with a bathroom or coffee break. Some participants even regarded the charging time as additional time to do desirable activities, not normally fitting into busy family life;

> *"I like to read a book, and I never have the time elsewhere because I always have so many projects. But now I have the time for it, and then I sit there for an hour, and I read a book. I really just use this time to disconnects, and I think of it as my relax or leisure time"* - **Irene (C)**

Some participants experienced that charging was free at their workplace; *"they have a free charge for the staff's electric car, so if they come in the morning they plug the EV in and then it is finished when they go home in the afternoon"* - **Ina (B)**. This option was often considered if the EV was discharged and no public charger was nearby; *"And I was thinking about a parking garage near where I work - there's an outlet with grounding outside."* - **Irene (C)**. Tony did not have the option to charge at work, and his EV's range was not sufficient to drive both ways. Therefore, he had an agreement with a friend to charge at his house, near his workplace. To compensate for the electricity he used, he kept track of the consumption using a measuring device;

> *"I have to charge while at work because otherwise, I can't make it back. I have an agreement with a friend that lives just by my workplace. It fits very well with my driving patterns"* - **Tony (D)**

### Planning through Interactive Technologies

We found that participants used various digital applications to help them plan their drives. Being able to plan a drive influenced how limited range and scattered charging infrastructure was disregarded as a major inconvenience. Therefore, participants expressed that planning through digital technologies had become a major part of their routines. The use of digital technology, however, depended on the kind of drive they needed planning for: mundane driving for everyday purposes or extraordinary, longer, and more uncertain drives. Tony, for example, differentiated between the two;

> *"For everyday mundane driving, I don't care. I just drive and charge when I get home and check the EV feedback when it's done. Almost like a regular car. I want to say that it's a habit. And if we are going to have that extraordinary trip, then I sit down with this [a smartphone app] and say, okay*

> *we should do that and that and then we have to adjust the drive a bit to charge"* - **Tony (D)**

***Mundane driving***. We found the most common use of participants EVs was for mundane purposes such as going to work, getting groceries, and driving kids to events. For these purposes, planning was minimal, and something that had become routine quite fast. Mainly two technologies were used to support charging for such drives; feedback displays providing information about charging status and remaining charging time, and charging timers that provided an opportunity to schedule charging;

> *"Usually, when we come home, we just plug it in. It has become a routine, I don't have to plan. However, I have an app that warns me if I forget, because you learn very fast how very annoying it is, if you have to go to work and it doesn't have the range"* - **Franky (C)**

Both feedback and timer functions were accessed through an app on their smartphone or the EV display. Clara described a typical scenario;

> *"I often use the charging feedback I get from the EV to see how much time it takes to charge just enough to make it to the grocery store. If I can see that it will just be 15 minutes I'll wait, and I won't have to take our secondary car"* - **Clara (D)**.

Timers were often used to ensure that the EV would be ready for the next day because charging was usually done a night when the EV was not being driven. Timing functionality could in most EVs be accessed through the EV display or an accompanying app. Isabel expressed how they used the timing function to ensure optimal conditions for their car;

> *"I use the timer in the car to make sure it stops charging just before I leave in the morning. In an EV you really want to stop charging right before you drive as the battery will be warm and the car brakes work much better"* - **Isabel (E)**

***Extraordinary driving***. Extraordinary driving, like going for longer drives or going to an unknown place, required more planning. For these purposes charging away from home on publicly available charging infrastructure was often required. However, the participant spoke of several challenges beside ensuring available range, emphasising the necessity for planning extraordinary trips. For example, in Denmark, most public charging stations require a subscription, and subscriptions do not work across providers, meaning planning also entails finding the right chargers. At the same time, a charger can be unavailable either because it is broken, it is being used by another EV, or because the parking space where the charger is located is blocked by other fossil-fuelled vehicles. Especially the latter scenario annoyed Tony;

> *"I saw that some people just park in dedicated parking spots meant for EVs. That really, really annoys me. If I come to a spot and a diesel car is parked there, I simply can't accept it. If I'm there and can't get to my destination because I need to charge, then I get upset. You don't see me park at their gas station"* - **Tony (D)**

Although it was possible to avoid the above challenges through ad-hoc use of technology while driving, the preferred way of overcoming these challenges was to plan ahead of a drive. Most often, participants adjusted a driving route according to where chargers were available by using various apps providing such information. Some households (Tesla owners) could plan a trip in their car or on the smartphone using the vendor app for dedicated Tesla chargers. However, all households were using a variety of applications to complement each other. Examples include; applications with different functionality developed by charging infrastructure providers (restricted to chargers of that particular provider), or open applications giving an overview of different providers;

> *"We have different apps for all sorts of situations — this one gives me an overview of public chargers available to me, this one gives me access to Tesla chargers, and this one gives me an overview of chargers that private persons borrow out"* - **Franky (C)**.

Going for longer drives to unfamiliar places was not for everyone. Although the majority of participants could explain in detail how they would plan a trip, not all members of the households felt comfortable going on long drives. This was primarily due to inexperience with the technologies used for planning, although they might feel comfortable driving the EV. For example, for everyday purposes Clara would often use their EV, but would take their other car (diesel) when going for a long trip alone;

> *"I don't feel comfortable driving for longer trips alone because what if I run out of range? Then I have to find a charging spot, and I'm not as experienced as Tony planning that. I would much rather just take the Diesel. At least I know how the gas station works"* - **Clara (D)**

### (Un)Sustainable Driving Expectations

For many participants, sustainability was considered an important aspect of buying an EV. This argumentation was strengthened as all households owned facilities capable of producing electricity (solar panels and wind turbines). However, we also found the EV driving experience resulted in unsustainable driving practices like increased driving because it was more pleasant than their former car.

***Driving on Sunshine***. As participants were in a unique situation of being suppliers of their own electricity, it also influenced how they thought about driving their EVs. Motivation to plan and drive on electricity households produced themselves was both rooted in sustainable and more rational concerns. To most participants, driving on their own produced electricity was an important alternative; *"I think that one should use it while it is being produced, but I also think it makes sense from a bigger perspective"* - **Jim (A)**. This further provided many householders with a unique experience of being sustainable and self-sufficient;

> *"That you drive on the sun - that feeling is fantastic!"* - **Ina (B)**

Rational reasons for driving on household produced electricity could also be observed. For households owning solar panels, saving money was also important. However, having to plan daily charging was seen as difficult because EVs were used during the day when electricity production was the highest. However, for household D that owned a wind turbine capable of delivering electricity both during the day and at night, charging was more effortless but still seen quite important as it was a cheap way to utilise the turbine's capacity for powering the car. As such, the incentives to charge the EV was also rooted in monetary reasoning; *"After we got the electric car, and started to drive more in it, and we have become better at using the EV, we have become more proficient and better at using electricity for ourselves"* - **Tony (D)**.

***Increasing Driving Activities***. As opposed to saving range and charging on self-produced electricity, most of the participant expressed that driving the EV had served more unsustainable routines by driving more. The families reflected that not only did they invest in sustainable technology, but for many of them, it was also an economic investment. However, one consequence of this investment meant that driving activities had increased. For example, in Household A, the decision to invest in a Tesla, an expensive car to buy compared to other makes, where partly reasoned by the possibility of free charging. These factors, combined with that they had started to take the EV on holidays to Norway and Germany instead of flying, meant an increase in driving activities;

> *"In fact, we use mostly cars, that is, our driving has increased. We don't have to go down and fill it up at the petrol station, so we think it is not so terribly harmful to the environment if we charge a little extra or if we drive a little more in the car. So we drive more in the car, there is no doubt about that. Also, we've started to take it on holiday instead of flying it's much more comfortable"* - **Kirsty (A)**

This notion of increased driving combined with the advances in the technology found in many of the EVs also influenced the participants' expectations of comfort. Indirectly, this led to an increase in electricity consumption. For example, because they could get access to the car's functions from devices such as a smartphone, some participants utilised electricity consuming features such as pre-heating on cold mornings to heat the car, so it was nice and comfortable when driving.

> *I set it to heat consistently at a certain time in weekdays, but that is probably also because we are running on flat rate so now we don't save money on limiting pre-heating. [...] pre-heating the cabin simply means that you do not come out to a cold car, which is terrible and wastes range if it has to be done while driving.* - **Jim (A)**

## 5 DISCUSSION

The findings in this study contribute to understandings of the kinds of aspirations and expectations people associate with everyday electrified driving activities. In the following, we discuss what implications these findings have for HCI researchers and designers attempting to understand and design for EV related driving activities and supporting services.

### Towards Sustainable Desirable Driving

As Shove and colleagues argue [49–51] social shared meaningful experiences shape how people embed (or reject) designed 'things' (including digitally supported sustainable technology such as EVs) in everyday practices. Shove [49] also argue that expectations, e.g. the 3Cs (comfort, convenience and cleanliness), play an essential role in how people use a designed technology and what they expect it to do, which also have significant energy consumption effects. Kent [28] has also highlighted that expectations of flexibility, freedom, autonomy, and comfort are desirable social shared expectations influencing how people make use of the car as a means for transport.

Our study shows that expectations continue to play an important role when people embed the EVs into driving practices, despite the many regarded concerns and uncertainties associated with driving EVs [26, 34, 36]. Our findings illustrate how participants adapted expectations they associated with driving in their EVs. At the same time, our findings highlight such expectations shape how people embed technologies regarded as sustainable (Evs and own-produced energy technologies) in electric driving practices, beyond the desire of "driving on sunshine". For instance, hedonic sensory experiences of joyfulness, enhanced comfort, and coolness might actually undermine the possible sustainable benefits of these technologies. These findings are in line with similar studies investigating sustainable smart home technologies [17, 23] illustrating that expectations of desirable

experiences of embedding advanced digital technologies into everyday practices, may undermine the sustainable benefits because they are actually used more. Based on the findings in this study, we argue a need to better account for such expectations in future designs of sustainable driving. One suggestion would be to look at other meaningful forms of sustainable mobility, e.g. car or ride-sharing [29, 60].

Another interesting direction could be to explore the feeling of slowing down when driving the electric car - an experience highlighted by several participants in our study. We believe such experiences relate to the notion of slow travel [8], which may be used as a means to envision other desirable experiences surrounding sustainable travel beyond "going green" visions. The qualities of slowness reflect related visions of slow technology [16], e.g. slowness with personal data [41], slow energy [27, 43], and slow living in the smart home [24] used to promote less energy-intensive activities. Thus, we believe slow mobility for sustainable driving to be a ripe area for HCI researchers and designers to engage in.

### Towards Playful Tinkering

Studies have shown that it is usually one person in the household that is the driving force for bringing new technologies into the household [21, 40], which generate new forms of household work and play [23, 54, 55, 58]. Our findings in this study also highlight this particular tendency. The participants in our study experienced the EV as a playful and cool technology, which resulted in time being spent on exploring and playing around its different features. Moreover, the time spent on these tinkering activities was not experienced as inconvenient. In particular, the participants experienced the interplay of the EV and energy-producing technologies playful and found tinkering with different technologies to make them fit household needs as amusing and fun. We believe the notion of playful tinkering and time spent acquiring competencies to incorporate new technologies into everyday life is an area often disregarded when exploring sustainable interaction designs. Therefore, in order to better understand how possible sustainable futures can be practised, we believe HCI designers can obtain inspiration from the way that these early adopters of such technology improvise and tinker with new technology.

### Supporting EV Driving through Digital Ecologies

Besides the car itself, using various technologies to plan a ride was considered important in the practice of meaningful EV driving. The participants described technologies such as feedback displays and timers to support charging the car, while various apps were used to gain an overview and access charging infrastructure in sequence when going on long drives. Combining different interactive technologies to support a particular practice is not new to HCI. The most common term for such systems of technologies is digital ecologies (e.g. [4, 13, 26, 52]). Towards cars in general, digital ecologies have proven useful to serve a range of novel types of mobility, for example, ride-sharing where digital platforms can support switching between different modes of transportation [60]. Further, it has been indicated that digital ecologies are important means for supporting people interacting with the EV itself as a digital device [59]. Along these lines, we especially see digital ecologies as a mean towards supporting adopters of EVs to navigate the many different available charging providers. We see an opportunity for both researchers and designers to draw inspiration in the way that people combine applications to access charging infrastructure as a meaningful whole instead of fragments. In this process, frameworks that identify interaction (e.g. [25, 52]) could be used to analyse existing digital ecologies.

## 6 CONCLUSIONS

In this paper, we have presented a study of practices surrounding driving electric vehicles. Through a qualitative study of interviews and informal conversational technology tours with five Danish households, we identified themes that describe how participants experience driving their EV. Our findings reveal EV driving as an enjoyable and meaningful practice and that planning- and technology support is important aspects in transitioning to EV driving. Finally, the experience of the EV also led to increased driving activity compared to their former car.

To inspire HCI future research and design on EVs, we discussed three headings with ideas to inspire future HCI research and design for meaningful EV driving practice. Firstly, we discussed which implications the EV as new technology have on peoples' experiences and use to become more sustainable. Secondly, we discussed how technology-interested people could provide further inspiration for research and design with EVs in HCI. Lastly, we discussed the importance of the role of a digital ecology, supporting EV driving.

Our study has some limitations. Firstly, the recruited households were early adopters of EVs, and many of them had a high degree of technology literacy. We realise this may influence how they understand and use their cars. Secondly, car use and opinions vary across geographical locations, and so, carrying out a similar study in a different location, such as another country, might yield different results.

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