Understanding consumer knowledge, perceptions, and preferences regarding pro-environmental technology: The cases of plug-in electric vehicles and utility controlled charging

by

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Abstract

Consumer demand is an important aspect of a successful transition to low-carbon technology. In this study I explore consumer knowledge, perceptions, and preference formation for two such technologies: purchasing a plug-in electric vehicle (PEV) and enrolling in a green electricity program (to power the PEV). I explore this through in-depth interviews with 22 households in Metro Vancouver, British Columbia. Results provide several key insights into how consumers perceive and may come to value such technologies. First, I find that participant awareness is very low for both technologies; the majority of participants were confused about plug-in hybrid technology and did not understand the sources of electricity they consume. Secondly, once the technologies were explained to participants, most perceived both technologies according to a wide range of attributes, including functional (e.g., cost and performance), symbolic (e.g., "strangeness" and loss of control), and societal (e.g., pollution reduction). Third, I find that most participants do not have pre-existing preferences for these technologies. Instead, they construct preferences as they learn about them and reflect on their various attributes. Interestingly, the initial lack of awareness is not necessarily a barrier to participants developing positive preferences for the case technologies once explained. These findings suggest that research and policy ought to carefully consider the roles of knowledge and different types of perceptions in consumer preferences for low-carbon technologies.

Keywords: Preferences; Consumer knowledge; Plug-in electric vehicles; Pro-environmental technology; Green electricity

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List of Acronyms

BEV	Battery Electric Vehicle
GE	Green Electricity
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
UCC	Utility Controlled Charging

Chapter 1.

Introduction and Background

1.1. Introduction

Both electrification of transportation and decarbonisation of electricity generation may be required to achieve deep reductions in greenhouse gas emissions (Williams et al., 2012). These transitions would involve increased adoption of plug-in electric vehicles and renewable electricity sources such as wind, solar, and hydro. With current driving habits in Canada, adoption of plug-in electric vehicles could reduce marginal emissions relative to conventional (gasoline) light duty vehicles by between 44 and 79% – depending primarily on the sources of electricity used for charging (Axsen et al., 2015). Renewable energy technologies could conceivably reduce marginal greenhouse gas emissions from electricity production to near zero in many jurisdictions, even when accounting for hourly variabilities throughout the year (Hohmeyer & Bohm, 2015). Further, integrating the adoption of plug-in electric vehicles with the deployment of renewable energy technologies would improve the environmental potential of each and may in fact be necessary to achieve emissions reductions at a large scale (Hart & Jacobson, 2012; Lund & Kempton, 2008; Williams et al., 2012).

A substantial shift to low-carbon electricity and transportation systems is inevitably associated with consumer or human behaviour. What individuals and households know and perceive about plug-in electric vehicles and renewable energy could have a significant influence on the extent to which these technologies are purchased or utilized. This is especially the case for pro-environmental technologies that need to be purchased directly by consumers (rather than citizens more broadly). Some approaches to renewable electricity deployment involve voluntary participation from electricity buyers. Research suggests that electricity consumers may be more likely to support increased solar- or wind-based electricity generation if they understand the technologies' environmental benefits (Salmela & Varho, 2006), and if they feel that supporting renewable electricity generation would reduce national dependence on foreign oil (Ozaki, 2011).

In this study I examine influences underlying consumer preferences for plug-in electric vehicles and willingness to support renewable (green) electricity generation. My focus is on consumer knowledge and perceptions of the case technologies. My analysis is exploratory and qualitative. As part of the larger Canadian Plug-in Electric Vehicles Study (CPEVS) described in Axsen et al. (2015), I draw from primary data collected through 22 in-depth interviews with new car buying households in British Columbia, Canada.

In the remainder of this chapter I outline the technological and analytical context for my analysis. In Sections 1.2 and 1.3 I describe the case technologies, and the related consumer adoption literature. In Section 1.4 I provide my conceptual framework and state my specific research objectives.

1.2. The case technologies

A plug-in electric vehicle (PEV) is any vehicle that has the ability to be propelled by electricity from an external power source. This includes electric-only vehicles (sometimes called battery electric vehicles or BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs, such as the Nissan Leaf or the Tesla Model S, do not have internal combustion engines and run exclusively on power stored in their batteries. PHEVs, such as the Chevrolet Volt, do have internal combustion (typically gasoline) engines but can supplement this with electricity stored in batteries that can be charged by plugging in to an external power source. BEVs must be recharged using an external source (i.e., an outlet or charging station) when their batteries are depleted, whereas PHEVs' range can be extended by engaging the internal combustion engine. Conventional hybrid-electric vehicles, such as the conventional Toyota Prius hybrid, are not considered to be PEVs. Conventional hybrid-electric vehicles cannot be plugged-in and do not use electricity from an external power source. This type of vehicle exclusively uses electricity that is generated within the vehicle itself (using the alternator and regenerative braking systems).

With regards to consumer support for renewable energy, I focus on wind turbines, solar (photovoltaic) panels, and small-scale hydro. I refer to these three technologies collectively as ‘green electricity’ (GE). Other studies use this term more broadly, often including geothermal, wave, or biomass energy (e.g. Clark, Kotchen, & Moore, 2003; Hansla, Gamble, Juliusson, & Gärling, 2008; Kotchen & Moore, 2007). Here I examine support for wind, solar, and small hydro as examples of renewable energy more generally, but my definition explicitly excludes fossil fuels, nuclear, and large-scale hydro. Further, I focus on support for GE by consumers as one potential means of GE deployment. In the literature, consumer support for GE is typically examined in the form of tariffs paid to electricity providers through voluntary programs (e.g. Kotchen & Moore, 2007; MacPherson & Lange, 2013; Ozaki, 2011).

In this study I examine consumer support for GE by linking it with PEVs through the concept of utility controlled charging (UCC). With UCC, PEV owners allow the electric utility to have some degree of control over the charging of their vehicle’s batteries. This control can involve the timing or direction of electricity flow to PEV batteries. UCC can facilitate the integration of GE sources into the grid because GE sources are often intermittent. Intermittency is challenging for utilities to manage since it means that supply does not reliably correspond with the timing of demand. However, GE intermittency could be managed by using PEV batteries as electricity storage, using a concept known at vehicle-to-grid (V2G) integration (Kempton & Tomić, 2005; Parsons, Hidrue, Kempton, & Gardner, 2014; Weis, Jaramillo, & Michalek, 2014). At a basic level, linking PEVs and GE can be imagined as a type of dispatchable demand, where the timing of when PEV batteries are charged is aligned with variable supply. A more complex scenario involves drawing charge from PEV batteries in ‘vehicle-to-grid’ (V2G) systems to help meet electricity supply shortfalls (Andersson et al., 2010). The term UCC is intended to encompass the broad idea of this type of PEV-GE linkage.

1.3. Consumer preferences and emerging pro-environmental technology

In considering the perspective of vehicle and electricity consumers, attributes of technologies such as PEVs and GE can be categorized as functional, symbolic, or societal (Axsen & Kurani, 2012). Functional attributes of a technology have tangible consequences for the individual consumer such as losing time or saving money. Symbolic attributes also affect individual consumers, but more abstractly. Specifically, symbolic attributes are those that carry social or emotional meaning. For example, a symbolic attribute of a PEV might be that this technology expresses some aspect of the owner's self-identity or that its use evokes feelings of independence or power (Heffner, Kurani, & Turrentine, 2007; Schuitema, Anable, Skippon, & Kinnear, 2013; Steg, Vlek, & Slotegraaf, 2001). Societal attributes of a technology have consequences for the wider society. These may include reducing air pollution or increasing energy security, for instance.

Functional attributes are undoubtedly important influences on consumer decision-making. These attributes tend to be the primary focus of many analyses, especially those which examine consumer adoption of PEVs. Studies commonly assess consumer perceptions and valuation of PEV operating cost, driving (battery) range, and recharge time (e.g. Carley, Krause, Lane, & Graham, 2013; Dimitropoulos, Rietveld, & van Ommeren, 2013; Hackbarth & Madlener, 2013; Hidrue, Parsons, Kempton, & Gardner, 2011). The importance of these functional attributes is often underscored with quantitative analysis such as calculating willingness to pay for a one unit improvement in a given attribute (e.g. fuel savings or electric range) derived from the specific context presented in a stated choice experiment or other valuation method (e.g. Axsen & Kurani, 2009; Axsen et al., 2015).

Recent studies indicate that symbolic attributes of both PEVs and GE can also have important influences on consumers' choices. For example, Schuitema et al. (2013) found that consumers' intentions to adopt PEVs can be positively influenced by an expectation of feeling proud to own one, or inversely, negatively influenced by an expectation of feeling embarrassed to drive one. In a related study, Heffner (2007) showed that a consumer's purchase of a hybrid electric vehicle could be about constructing and communicating a self-image of intelligence or caring about others. Similarly, Ozaki (2011) found that demonstrating the importance of environmental issues to peers was an important factor in the decisions of some consumers to adopt voluntary GE tariffs. Finally, Axsen et al. (2015) found that some consumers were concerned about privacy and loss of control when presented with the idea of supporting GE through UCC. These symbolic attributes are not as easily quantifiable as functional attributes such as PEV range, but in some cases may be as or more important for consumer adoption (Noppers, Keizer, Bolderdijk, & Steg, 2014).

Both PEVs and GE have societal (particularly environmental) attributes that can play an important role in consumer decision-making. For example, Clark et al. (2003) found that participants in a GE program indicated that reducing air pollution was a primary motivation for their support of this technology. Lieven et al. (2011) found that general consumers prioritized environmental attributes of PEVs over convenience. A number of studies have found that consumers are willing to pay for societal attributes of GE such as reduced wildlife impacts or reduced emissions (Bergmann, Hanley, & Wright, 2006; Hobman & Frederiks, 2014; Noppers et al., 2014; Roe, Teisl, Levy, & Russell, 2001). As well, researchers frequently look at the relationship between an indicator of support for a technology and consumers' pro-environmental attitudes or values. Implicitly, these studies are highlighting the influence of societal attributes on consumer decision-making, typically finding a positive relationship (e.g. Hansla et al., 2008; Kotchen & Moore, 2007; MacPherson & Lange, 2013).

Whether functional, symbolic, or societal, it is how attributes of technologies are perceived by consumers which determines how these attributes influence decision-making – and this is based on consumers' knowledge (including awareness that a technology exists and familiarity and understanding of how it operates). For emerging technologies such as PEVs and GE, this knowledge is likely to be imperfect. Consumers may not be aware that certain technologies exist. For example, Ozaki (2011) found that some study participants were not aware that their utility offered the option of paying voluntary tariffs to support GE (when indeed their utility did provide that option), and Axsen et al. (2015) found that many survey respondents were unclear as to what a plug-in hybrid vehicle was. Or consumers may not understand the implications of a technology. Krause et al. (2013) found that in a large scale survey of urban drivers the majority of respondents underestimated battery range and overestimated operating costs of PEVs. Consumers interviewed by Salmela and Varho (2006) expressed uncertainty about the sources used to generate their current electricity and how these would differ from GE; in other words, they did not understand the potential basic impacts of supporting GE. In sum, consumers' perceptions may be mistaken or uncertain, or consumers may not be aware that technologies and their attributes exist.

When consumers come into contact with a novel technology, they tend to construct their preferences as they learn about it and its attributes (Bettman, Luce, & Payne, 1998; Slovic, 1995). Especially for emerging technologies such as those examined here, consumer preferences are often constructed only when a choice is required. The results of studies examining ‘stated’ or ‘revealed’ preferences for PEVs and GE (e.g. Hackbarth & Madlener, 2013; Ziegler, 2012) should therefore be interpreted in the context of imperfect knowledge and potentially unformed or unstable preferences. As consumers learn about these novel technologies their preferences are likely to evolve.

1.4. Conceptual framework and research objectives

To explore consumer knowledge, perceptions and preferences for novel pro-environmental technologies, I utilize the conceptual framework outlined in Table 1 below. This framework is built around three principal constructs – perceptions, knowledge, and preferences. Perceptions are defined here as what a consumer thinks about a technology – including the attributes they perceive and how these are evaluated. Perceptions can be functional, symbolic, or societal as described above. Knowledge is defined here as what a consumer knows about the technology – including awareness (the extent to which they are conscious that a technology or an attribute exists), familiarity (how well acquainted they are with the details of a technology), and understanding (their comprehension of a technology’s implications and how it operates). Finally, preferences are defined here consumers’ general attitude towards choosing one technology ahead of alternative options.

These three constructs work together in my conceptual framework. Consumers’ perceptions shape their preferences because preferences for technologies are to some extent preferences for packages of attributes as they are perceived by individual consumers. Consumers’ perceptions of technologies are based on their knowledge because what they are aware of, familiar with, and understand about a technology determines both which attributes are used to construct preferences and how those attributes are perceived. Finally, knowledge is likely to be imperfect regarding emerging technologies, and preference construction can happen as consumers learn about and experience such technologies.

Table 1: Definitions and Conceptual Framework

Construct	Definition	Conceptual Framework	Potential Examples
Perceptions	What a consumer thinks about a technology. This includes: attributes (characteristics) they perceive how they evaluate perceived attributes Note that this construct is based on the consumer's perspective, and might not be objectively accurate.	Preference formation is shaped by a consumer's perceptions. A preference for a technology is in essence a preference for a package of attributes (characteristics) as they are perceived by the consumer. Influential perceptions can be: Functional (pertaining to functional attributes with impacts on the individual) Symbolic (pertaining to non-functional attributes with impacts for either the individual or society) Societal (pertaining to functional attributes with impacts shared with the wider public)	Functional: "PEVs save fuel expenses" "Supporting GE takes too much effort" Symbolic: "PEV ownership demonstrates the importance of environmental issues" "UCC involves loss of privacy" Societal: "PEVs have a large lifecycle footprint" "GE reduces air pollution"
Knowledge	What a consumer knows about a technology. This includes: Awareness (the extent to which they are conscious that a technology or an attribute exists) Familiarity (how well acquainted they are with the details of a technology) Understanding (their comprehension of a technology's implications and how it operates)	A consumer's perceptions of a technology are based on her or his knowledge. What they are aware of, familiar with, and understand about a technology determines both which attributes are used to construct preferences and how those attributes are perceived. With regards to the case technologies (which are both emerging), consumer knowledge is likely to be varied and imperfect.	Awareness: Consumer knows that PHEVs are a specific type of vehicle Familiarity: Consumer knows how a PHEV would be fuelled Understanding: Consumer knows that the intermittency of wind generated electricity is a challenge for utilities
Preferences	A consumer's general attitude towards choosing one technology ahead of alternative options. Preference is expressed as the consumer's interest in potentially purchasing and driving a PEV, or as their willingness to accept UCC in order to support GE.	Preferences are not always known or pre-determined; a preference may be constructed at the time it is elicited. This is particularly so for emerging technologies where the consumer may have no or very little familiarity or experience. Preference construction can go along with the development of knowledge and draws on perceptions.	High: High level of interest in purchasing a PEV High willingness to accept UCC in order to support GE Moderate: Moderate level of interest in purchasing a PEV Moderate willingness to accept UCC Opposition: Opposition to PEV adoption Opposition to accepting UCC

My overarching goal with this study is to characterize the formation of consumer preferences for the case technologies. I approach this by examining the constructs described above, in relation to the study participants and these technologies. My specific research objectives are to:

1. Assess participant knowledge of the case technologies (awareness, familiarity, and understanding),
2. Identify participants' key functional, symbolic, and societal perceptions of the case technologies (including evaluations); and
3. Explore how preferences for PEVs and UCC are shaped by participants' knowledge and perceptions.

To address these research objectives I collected qualitative data through household interviews. Study participants were general consumers and not topic specialists. The interviews involved in-depth discussions regarding the case technologies in which I interactively explored participants' knowledge, perceptions, and preferences.

In the next section I describe my methodology, including data collection and analysis, as well as provide details of the study participants and study location. In Sections 3 and 4 I present my findings for PEVs and UCC, respectively and according to the research objectives stated above. In Section 5 I provide a summary discussion and conclusion.

Chapter 2.

Methods

2.1. The study context and larger project

Before describing my specific study, I first provide further context for plug-in electric vehicles (PEVs) and utility controlled charging (UCC) in the region of British Columbia, Canada. Various brands and types of PEVs (including plug-in hybrid and battery-only vehicles) are available to consumers in British Columbia; however, in Canada as a whole, PEV sales in 2014 were estimated to account for less than half of a percent of total market share of new vehicle sales (Klippenstein, 2014). To my knowledge utility controlled charging has not been employed in any form in British Columbia and remains essentially a hypothetical technology. The green electricity (GE) sources I focus on (wind turbines, solar panels, and small-scale hydro) exist in British Columbia but account for very little of the total electricity generated or consumed in the province. Almost all electricity produced in British Columbia comes from large-scale hydro-electric dams (BC Hydro, 2014). British Columbia's *Clean Energy Act* requires that at least 93% of total generation be met by clean or renewable resources, which are defined as including large-scale hydro, the GE sources examined here, and others (*Clean Energy Act*, 2010). However, the province is part of a larger electricity grid that also includes coal and nuclear generation located in neighbouring jurisdictions and in recent years roughly a third of electricity consumed in BC has been imported (BC Hydro, 2014; Kiani et al., 2013).

The present study is part of a larger project known as the Canadian Plug-in Electric Vehicle Study (CPEVS). This larger project examines the potential market for PEVs in Canada and aims to understand the impacts of PEV usage (including charging) under different scenarios. CPEVS includes a large-scale multimode survey of 1754 "Mainstream" new vehicle buyers (those that bought a conventional, gasoline powered vehicles) in 2013 in Canada, as well as a similar survey with 94 current PEV owners (or Pioneers) residing in British. The project also includes in-depth interviews with a small subgroup of respondents from each of the two larger survey samples. The present research project (or 699) is based on interviews with a subset of the "Mainstream" sample of new vehicle buyers in the Metro Vancouver region of British Columbia. Further detail on the full CPEVS project can be found in Axsen et al. (2015).

2.2. In-depth interviews and the qualitative approach

The qualitative interview methodology employed here is particularly well suited to the research objectives of this exploratory study. First, with this method the researcher can assess knowledge through interactive discussion, asking nuanced questions to clarify specific aspects of a participant's understanding. For example, if a participant were to express that he thought it was better to run his clothes dryer at night I could ask why and discover that he believed his electricity bill was based on time of use. Second, this methodology is ideal for identifying participants' perceptions as it allows space for complex and unanticipated answers while capturing the wider context and meaning behind responses that can be lost in large-scale quantitative surveys (Guba & Lincoln, 1994; McCracken, 1988). For instance, while I did not anticipate perceptions regarding the trustworthiness of the utility, participants were free to share these concerns in the interview along with ideological positions or stories of relevant past experiences that indicate how important the participant founds these concerns. Finally, I am able to explore the process of preference formation as it happens (if it happens) during the interview.

However, while the results of large-scale quantitative analyses can be generalized for a wider population, I must be careful in generalizing results from my smaller sample qualitative exploration to the broader target population. For this reason qualitative research is considered hypothesis generating rather than hypothesis testing (McCracken, 1988).

2.3. The interview protocol

Each interview conducted as part of this study followed a similar protocol. Each interview was between one and two hours long, attended by two researchers, and conducted between August 2013 and February 2014. The interviews were conducted in participants' homes, with one exception where the participant preferred to meet in a local café.In order to collect as much honest and relevant data as possible, I strove to develop trust, rapport, and a sense of openness, and to demonstrate sincerity, neutrality, and acceptance throughout the interviews. As well, though there was active interaction I was careful not to be obtrusive (McCracken, 1988). For example, if the respondent stated "Solar power is healthier," I might have later followed up by asking "What do you mean by solar is healthier?" rather than "Do you mean solar creates less air pollution?"

The interview protocol was semi-structured by design, using principles described by McCracken (1988) and others. I used a basic outline of topics to guide the interviews, yet questions were open-ended and the conversation was allowed to flow in a generally natural manner. This protocol is provided in full Appendix A and summarized below:

1. Vehicle ownership: The interview opened with a discussion of households' current vehicle ownership, and recent and anticipated vehicle purchasing decisions.
2. PEV knowledge: The interview followed with a discussion of different electric-drive vehicle types and participants' knowledge and experience with these vehicles. Interviewers then explained the different vehicle types as necessary using the information sheet provided in Appendix B.
3. PEV design game: participants completed a vehicle 'design game' adapted from the Mainstream vehicle buyers' survey. An example vehicle design game is provided in Appendix C, and further described below.
4. Knowledge of electricity sources: Interviewers asked participants about their knowledge of electricity sources and the current electricity system in British Columbia and provided basic explanations as needed.
5. Electricity source and UCC design games: Participants then completed design games based around the ideas of voluntarily paying higher electricity tariffs and accepting UCC in order to 'receive' GE. Interviewers provided an explanation of both UCC and GE. Examples of these can be seen in Appendix C.

6. Participant characteristics: In the final part of the interviews we discussed participants' personal values and lifestyles, paying particular attention to their perspectives on environmental concerns.

The technology information provided to participants prior to completing the PEV and electricity design games were carefully designed to minimize technical detail and to be as accessible as possible to participants.

2.4. Design games

In parts 3 and 5 of the survey protocol I used technology design games to stimulate discussion and encourage participants to think about different aspects of each case technology. The completion of these games also provided the data used to elicit participants' preferences. Design games are intended to provide a space for participants to consider various attributes of a technology in order to select a personalized version of the final product (Axsen & Kurani, 2010). These games are particularly useful in situations where the consumer has had limited experience making decisions regarding adoption of the technology – in other words, where their preferences are not previously established. In the interview context, these games allowed researchers to observe the preference construction process. Further, as these games were completed, the interviewers continually asked participants to 'talk through' the reasoning behind choices. Consequently, the data provided from these games contributed to three of my research objectives.

The games used in the interviews were tailored to each household by incorporating data collected through the Mainstream vehicle buyers survey. For example, Table 2 below shows the design space presented to a participant who reported in the survey that their expected next vehicle would be a Honda Civic with a purchase price of $25,000. In this game the participant was presented with essentially 10 different vehicle designs – the regular (conventional) Honda Civic, a hybrid version of this, and multiple versions of the plug-in hybrid and electric only vehicles, each with a different batter size. The implications of each design with regards to range, charging or refueling time, fuel efficiency, and price were provided for comparative consideration as each other attribute was considered.

Table 2: Example Plug-in Electric Vehicle interview design game attributes

Vehicle type	Electric Range	Recharge or Refuel Details	Gasoline Fuel Use	Purchase Price
Regular	none	Gas station 5 minutes	7.1L /100 km	$25,000
Hybrid	none	Gas station 5 minutes	4.3L /100 km	$26,070
Plug-in hybrid	Electric for the first: 16 km	3.0 hrs to charge from empty to full	None during battery range; 4.3L /100 km after	$27,100
	Electric for the first: 32 km	6.0 hrs to charge from empty to full		$27,440
	Electric for the first: 64 km	12.0 hrs to charge from empty to full		$28,130
Electric only	80 km	15.0 hrs to charge from empty to full	None	$29,600
	120 km	22.5 hrs to charge from empty to full		$31,490
	160 km	30.0 hrs to charge from empty to full		$31,440
	200 km	37.5 hrs to charge from empty to full		$33,380
	240 km	45.0 hrs to charge from empty to full		$37,160

Table 3 below shows the options presented in the GE and UCC design games to an example household that reported typically paying $75 per month on their electricity bill. In each game participants first chose a GE electricity source (or the “current mix”) and then a percentage GE that they would enroll in. For the GE game, increases in percent of GE corresponded with increases in their monthly electricity bill. For the UCC game, increases in percent of GE corresponded with decreases in the minimum amount of charge that would be guaranteed to remain in their PEVs’ batteries. For example, accepting a 90% guaranteed minimum charge would correspond with 25% GE. Accepting a 65% guaranteed minimum charge would correspond with 75% GE.

Table 3: Example Green Electricity and Utility Controlled Charging interview design game attributes

Choices		Outputs		
Electricity Source	Percent GE selected	Electricity Source Game	UCC Game	
		Monthly bill	Monthly bill	Guaranteed Minimum Charge
Solar	25%	$79.08	$75	90%
	50%	$83.15	$75	80%
	75%	$87.23	$75	65%
	100%	$91.30	$75	50%
Wind	25%	$79.08	$75	90%
	50%	$83.15	$75	80%
	75%	$87.23	$75	65%
	100%	$91.30	$75	50%
Small Hydro	25%	$79.08	$75	90%
	50%	$83.15	$75	80%
	75%	$87.23	$75	65%
	100%	$91.30	$75	50%
GE Mix	25%	$79.08	$75	90%
	50%	$83.15	$75	80%
	75%	$87.23	$75	65%
	100%	$91.30	$75	50%
Current	n/a	$75	$75	n/a

2.5. Data analysis

I used an inductive content analysis process to analyze interview data. I identified emerging themes within the interview transcripts (listening to recordings multiple times if necessary) and systematically grouped data into categories which highlighted commonalties and contrasts within the dataset. A thorough description of this process can be found in: Auerbach & Silverstein, (2003). For example, a given statement might be initially categorized as pertaining to "vehicle technology", and subsequently categorized in more detail according to vehicle type, and later into categories such as "perceived image" or "confusion." From these narrow categories inductive commonalities or "themes" became apparent such as the perception that "PEVs are strange" or

“Conventional hybrids can be plugged-in.” This methodology is particularly useful in addressing my research objectives of assessing participant knowledge and identifying key perceptions of the case technologies.

I also used what has been called the “investigator as instrument” technique to relate the transcript data to participants’ intended meanings and the context of the discussions (McCracken, 1988). The essence of this technique is that the researcher draws on their own experiences to interpret certain aspects of the data. Specifically, in my analysis I draw on non-verbal data to identify participants’ levels of certainty, sincerity, and interest. For example, uncertainty can be expressed with a rising inflection or a long pause that would not be reflected in the interview transcript. This is particularly useful for my research objective of assessing knowledge, confusion and uncertainty regarding PEVs and UCC.

Chapter 3.

Sample

3.1. Participant selection

Interview participants were drawn from respondents in the Mainstream new vehicle buyers' survey, specifically those residing in the Lower Mainland region of British Columbia that agreed to be contacted for further research. I followed a purposive selection process with the aim of accessing the experiences of a wide array of households, according to ranges of ages and incomes. As well, early interviews indicated that access to a reliable home parking space was critical to conceptualising vehicle charging scenarios and I consequently limited participants to those survey respondents that indicated having an assigned home parking space for one or more of their vehicles. When possible, I conducted interviews with all members of the household who would likely be involved in decisions. In total I interviewed 31 individuals representing 22 households, including 17 women and 14 men.

3.2. Participant details

Table 4 summarizes and compares the demographic distributions of the Mainstream British Columbia subsample, the 22 households that I interviewed, and census data for the region. Interview participants tended to be of higher income than the census population, slightly older than the full Mainstream vehicle buyers survey sample and significantly more highly educated than both the census population and the survey sample as shown in Table 4. Readers should bear these characteristics in mind when considering the findings below. However, the findings of a study such as this are not intended to be generalized for application to a wider population.

Table 4: Participant characteristics compared to Canadian Census and Mainstream vehicle buyers survey

	Census (BC)	Survey (BC)	Interview
Sample Size	4,400,057	538	22 households
Household Size			
1	28%	15%	36 % (8 households)
2	35%	42%	23% (5 households)
3	15%	19%	14% (3 households)
4+	22%	24%	27% (6 households)
Sex (of person filling out the survey)			
Female	51%	61%	55%
Age (of person filling out the survey)			
Under 35	30%	26%	23% (5 households)
35-44	18%	19%	23% (5 households)
45-54	20%	20%	18% (4 households)
55-64	19%	20%	33% (7 households)
65+	13%	15%	5% (1 households)
Highest level of education completed (of person filling out the survey)			
Other	59%	29%	1% (4 households)
College, CEGEP, some university or other non-univ.	22%	34%	9% (2 households)
University degree (Bachelor)	14%	27%	64% (14 households)
Graduate or professional degree	5%	11%	9% (2 households)
Household income (pre-tax)			
Less than $40,000	26%	17%	18% (4 households)
$40,000 to $59,999	19%	22%	9% (2 households)
$60,000 to $89,999	24%	29%	32% (7 households)
$90,000 to $124,999	17%	24%	27% (6 households)
Greater than $125,000	14%	9%	14% (3 households)
Residence ownership			
Own	-	76%	68% (15 households)
Rent	-	24%	32% (7 households)
Residence type			
Detached House	54%	62%	46% (10 households)
Attached House (e.g. Townhouse, duplex,etc.)	23%	15%	5% (1 households)
Apartment	21%	21%	50% (11 households)
Mobile Home	2%	2%	0%

Chapter 4.

Findings for Plug-in Electric Vehicles

"[W]hat's the deal here? You don't plug this in, the hybrid?" – Clair

In this chapter I present the results of my analysis regarding plug-in electric vehicles (PEVs). I describe my findings according to the three research objectives stated above (Section 1.4). I start by describing participants' knowledge of electric drive technology. In Section 4.2 I describe participants' perceptions of PEVs, including perceptions that are functional (pertaining to attributes with tangible consequences for the individual consumer such as losing time or saving money), symbolic (pertaining to more abstract attributes which carry social or emotional meaning), and societal (pertaining to consequences for the wider society). Finally, in Section 4.3 I present participants' preferences for this technology and describe how these preferences were formed.

4.1. Participant knowledge of plug-in electric vehicles

I identified three categories of participants based on their levels of knowledge (i.e., their awareness, familiarity, and understanding) regarding electric-drive vehicle technology that was demonstrated in the early stages of the interviews. An initial finding of this analysis is that familiarity and experience with hybrid-electric vehicles (HEVs) were important factors shaping participants' ability to understand PEV technology. As such, the categories I have identified are based on participants' knowledge of PEVs as well as HEVs. In Table 5 I present and explain these categories, which I name "Basic Knowledge", "Moderate Knowledge", and "High Knowledge" electric-drive vehicle knowledge, respectively. Below I explain the similarities and differences between these categories and what this means for participant learning about PEVs.

Table 5: Households categorized by knowledge of vehicle technology

<table>
<tr><th rowspan="2">Category of electric-drive vehicle knowledge</th><th rowspan="2">Households (pseudonyms)</th><th colspan="3">Knowledge of vehicle type</th></tr>
<tr><th>Hybrid-electric vehicles (HEVs)</th><th>Plug-in hybrid vehicles (PHEVs)</th><th>Battery electric vehicles (BEVs)</th></tr>
<tr><td>Basic Knowledge</td><td>Fay
The Mathews
Andreas
The Chens
Lei
Violet
Veronica
The Parks
The Morrettis
Christine
Al
The Dimirovics
Margaret
Clair</td><td>Aware of HEVs, but low familiarity and understanding</td><td rowspan="2">Not aware that PHEVs exist</td><td rowspan="3">Aware that BEVs exist, but no familiarity and limited understanding</td></tr>
<tr><td>Moderate Knowledge</td><td>The Youngs
Sandra
Omar
Kevin
The Nicolovs</td><td rowspan="2">Aware of HEVs with general familiarity and understanding</td></tr>
<tr><td>High Knowledge</td><td>Daryl
Liz
The Fengs</td><td>Aware of PHEVs with general familiarity and understanding</td></tr>
</table>

At the beginning of each interview, all 22 households were aware that battery electric vehicles (BEVs) exist; in other words, they knew that there are vehicles on the market which can be plugged-in and run on electricity rather than an internal combustion engine (Table 5). However, participants from all three categories had only an abstract idea of BEV technology. No households had direct experience with a BEV – none had ridden in a BEV and only one participant (Omar) reported having a cursory conversation about this vehicle type with a BEV owner. Ten households thought they could recall having seen a BEV, but this recollection was often uncertain. For example, Mr. Chen thought he had seen a Nissan Leaf (a BEV), but asked, “Is the Leaf electric or is it hybrid?” Mr. Young remembered seeing a Chevrolet Spark (available in both a gasoline vehicle and a BEV model) and remarked, “I'm pretty sure it's an electric vehicle… with a name like Spark it sounds like it's an electric." These types of uncertainties and misconceptions varied, but overall, perceptions of EVs amongst the 22 households were not based on direct experience.

Participants in the Basic Knowledge category are differentiated by their confusion regarding HEVs. Specifically, all 14 of these households had the impression that an HEV can be recharged using external electricity or that an HEV has separate extended electric drive capabilities like a PHEV. One participant, for example, expressed that seeing her friend's Prius C (an HEV model) has made her think she would like an to buy an HEV of her own, but noted "a common problem that I've noticed is… the charging part… it's kind of inconvenient sometimes." Similarly, Mr. Mathew's was concerned that "there might be a little bit of difficulty in recharging things if you're going on a long journey." Others from the Basic Knowledge category seemed to believe that driving an HEV entailed having some extended electric range followed by "gas back-up." As Fay remarked, "if you run out of electricity, you've got the gas anyway." All 14 of these households had some experience with HEVs (typically rides in a taxi or a friend's or neighbour's Toyota Prius) but they did not understand how this type of vehicle is operated. Because of their misconceptions regarding the operation of HEVs, these 14 households were not aware of PHEVs as distinct from HEVs.

The Moderate Knowledge category consists of 5 households who were more familiar with HEVs, yet still unaware of the existence of PHEVs. These participants had experiences with HEVs similar to those in the first category (e.g. riding in one as a passenger), but had a better understanding of how an HEV is operated. Omar, for example, had considered buying an HEV and discussed how this technology would be preferable to a BEV because he would not need to worry about charging or range limitations. Rather than confusing PHEVs with HEVs, participants in this category were simply not aware that PHEV technology existed. When asked about PHEVs, these households gave responses similar to Mrs. Nicolov who commented: "I know there are electrical, hybrid, and gas, but no, not this."

The High Knowledge category consists of three households who had experience with PHEVs and were the only participants who were aware of PHEVs as distinct from HEVs. All three had ridden in a Chevrolet Volt – Daryl and Mr. Feng each had an acquaintance who was a PHEV owner and had taken them for rides, while Liz had test driven a Volt on a visit to a Chevrolet manufacturing plant. All three had at least a basic understanding of how a PHEV is refueled and recharged, as well as how propulsion occurs in two distinct modes. These three households were clearly familiar with how a PHEV was distinct from an HEV. Notably, one of these households (Daryl) was an HEV owner.

Previous familiarity with HEVs was an important influence on how easily participants learned about PHEVs as the interviews progressed. As I described in Section 2.3, after the participants' initial level knowledge of the different vehicle types was established, the interviewers provided basic explanations of electric-drive technology to facilitate further discussion. The five Moderate Knowledge households (who understood how an HEV operates) were able to easily grasp how having the ability to plug in a PHEV would allow the vehicle to be powered by external electricity for some range, followed by HEV-like operation once the battery is depleted. However, this elementary understanding of a PHEV was more of a challenge for the 14 Basic Knowledge households – all participants in this category required more effort to understand differences between PHEVs and HEVs, even after the basic explanation of the different vehicle types was provided. For example, Clair at first appeared to grasp the contrasts between the varying types of electric drive but later asked, "[W]hat's the deal here? You don't plug this in, the hybrid?" Similarly, when discussing how the different vehicle options would work with her household's lifestyle, Mrs. Park expressed some uncertainty regarding PHEVs, saying "So just to clarify… let's say I didn't have time to charge it and I still had to drive it, it would still drive because it would just default to gas?" It seems that without having established an understanding of what HEVs are and how they are propelled, these households found it difficult to understand how PHEVs operate.

4.2. Participant perceptions of plug-in electric vehicles

Five distinct themes emerged amongst the perceptions of PEVs cited by participants: Range, Charging, Operating Costs, Novelty, and Environmental Impacts. In Table 6 below I present these themes along with participants' perceptions associated with each. For each perception I indicate in parenthesis whether this was perceived as positive or negative and in the corresponding columns I indicate the number of households who explicitly cited this and provide an example quote from the interviews. For instance, the Operating Costs theme includes the perception that “PEVs would save fuel money” which was explicitly mentioned by 13 households and is exemplified by a quote from Mr. Mathews who said, “I think the electricity would be a more economical way than paying the price at the pump.”

The format used to present my analysis of participants’ PEVs perceptions is intended to highlight important influences shaping their interest in PEV adoption. Note that the five themes are not perfectly discrete. For example, Range can overlap with Charging where the perception of insufficient range may be predicated on the belief that extending a PEV’s range with rapid or readily available charging is not possible. Further, Table 6 does not represent an exhaustive list of the participants’ perceptions of PEVs. Those listed below are only those which were explicitly mentioned by participants during the interviews and which appeared influential in shaping interest in the technology for at least one participant. I excluded other attributes that were mentioned where the participant seemed to assign little importance. For example, “unknown impact on electricity bill” was mentioned by four households but there was no indication that this significantly influenced PEV interest of any of those four (so these are not accounted for in Table 6). As well, perceptions of purchase price are not listed since these were expressed in reference to the prices presented in the design games (as described in Section 2.3) and not in reference to PEVs more generally.

Table 6: Participant perceptions of plug-in electric vehicles

Attribute theme	Perceptions	Number of households explicitly citing this	Example quotes
Range	BEV range is insufficient to reach key destinations (negative)	12	"Well, there's not a chance in hell you're going to Kamloops." – Al
	PHEV provides range extension (positive)	7	"You don't need to plug in [when] you drive between cities" – Mr. Dimirovic
	BEV range is sufficient (positive)	2	"80 [km] would be good because if I ever did need to go out of town, I'd rent a vehicle… I wouldn't have to worry about taking it. And 80 is a good range for local driving." – Kevin
	BEV range is risky (negative)	12	"All I picture is me being out in the middle of somewhere with no car running." – Christine
	PHEV provides "back-up" range (positive)	12	"I like the Volt type because I don't want to be stranded… if I have to stop by a gas station, I stop by a gas station." – Mr. Feng
Charging	Finding a convenient place to charge would be difficult (negative)	15	"[With a PEV] you've got to map out the city and decide, "Okay, well, I'm going over here but if I plug in here that means I've got to walk 15 blocks…"" – Al
	Charging a PEV requires too much time (negative)	7	"Or road trips or something – do you literally take your family and you sit there and you charge your car and try and entertain your kids for three hours?" – Christine
	Plugging in inconvenient (negative)	3	"And then, of course, when I get home, I have to plug it in. So it's just like for me, inconvenient." – Mr. Young
	Home charging is easier than going to a gas station (positive)	3	"[Y]ou come back home and you just charge it up again." – Kevin
Operating Costs	PEVs would save fuel money (positive)	19	"I think the electricity would be a more economical way than paying the price at the pump." – Mr. Mathews
	PEV ownership entails unknown maintenance costs (negative)	11	"I actually would do more research about how long this battery lasts." – Lei
Novelty	PEV technology is unestablished (negative)	10	"[W]hen I'm getting something that's $60,000, I want to get the technology that's tried and tested and that works." – Omar
	PEVs are strange (negative)	9	"Well, it's so different… this is a whole new idea." – Clair "[I]t just seems kind of… a little bit kind of out there." – Mrs. Chen
Environmental Impacts	PEVs reduce pollution (positive)	19	"I imagine environmentally they're probably really good." – Mr. Chen
	Possibly toxic batteries (negative)	4	"[W]hat do you do with the battery afterwards? … to recycle these things is just a bitch." – Al

The Range theme captures primarily functional perceptions specific to the two different types of PEVs. While two households expressed that the range of a BEV would be sufficient for their needs, 12 others expressed precisely the opposite. Typically, these latter participants referred to a destination that they would want to visit, explaining that this destination would be beyond the presumed maximum range of BEVs on the market (without stopping to recharge along the way). A related but distinct perception expressed by 11 households was that a BEV's limited range puts the driver at risk of being stranded, as exemplified by Christine's quote (Table 6) or by Mr. Feng's concern of a potential detour in his commute, rhetorically asking, "[A]m I pushing the last kilometre home?" On the other hand, perceptions of PHEVs under this theme are essentially the inverse of the perceived drawbacks of BEVs. Seven households stated that a benefit of a PHEV is that it would allow them to take longer trips, and 12 households mentioned that having the gasoline engine as a "back-up" to the electric battery was "safer" or a good thing to have "just in case."

The perceptions under the Charging theme are also functional, specifically relating to the convenience of charging both BEVs and PHEVs. For 15 households the perceived challenge of finding convenient places to charge away from home was seen as a drawback of PEV ownership. Seven households expressed that the time required to charge a PEV would be inconvenient. In each case this perception was more of a general idea of charging being a waste of time, rather than being based on a specific duration that was deemed unacceptable. For example, Violet laughed while she imagined plugging-in a PEV and having to "just wait around for like an hour or two – I don't know how long it takes." Finally, three households expressed that having to physically plug-in the vehicle was inconvenient. In contrast, another three households stated that it would actually be convenient to recharge at home rather than having to go to a gas station.

The Operating Costs theme includes two functional perceptions which also apply to both types of PEVs. The perception that PEV adoption would mean saving money on fuel was expressed by the vast majority of households (19 of 22). All participants who mentioned this benefit appeared to confidently believe that fuelling a vehicle with electricity would be at least somewhat cheaper than gasoline. However, many participants were less certain about what PEV ownership would mean in terms of maintenance costs. Eleven households stated that they would like to know how long the battery or the “electrical parts” last, or simply what the general maintenance schedule would be like with a PEV. For example, Omar wondered aloud, “[With a conventional vehicle you] do an oil change, you do all these things – what do you do in an electric car?”

While the first three themes are primarily functional considerations, the Novelty theme includes a functional and a symbolic perception. The functional aspect, expressed by 10 households, is that ‘PEV technology is unestablished. This perception is about the belief that PEV technology is unreliable or prone to fault, specifically because of its newness. As Daryl put it, he is often “a little antsy” with new technology until it “gets the bugs out of it.” In contrast, the largely symbolic perception under this theme refers to the image of the technology rather than its function. Nine households stated that they felt PEVs are strange in some way. For some this was a reference to the physical appearance of what they imagined a PEV to be; for example, Al thought PEVs would be “funny-looking little things.” Others were concerned that these vehicles are different from what they were accustomed to, as expressed in Clair’s quote from Table 6 (“Well, it's so different… this is a whole new idea”), or by Christine’s statement that “Not buying gas is weird.”

Finally, the Environmental Impacts theme includes two societal perceptions – perceptions which have implications beyond the individual consumer or household. Nineteen households stated that PEV adoption would mean less pollution. This attribute was typically cited with regards to ‘cleaner air’ or ‘helping the environment’; no participants explicitly mentioned reducing carbon emissions or addressing climate change. Four households expressed concern that PEV batteries might be an environmental drawback because they could be toxic or difficult to recycle.

4.3. Shaping preferences for PEVs

Following the conceptual framework (Section 1.3) consumers draw on their perceptions to construct preferences, and the construction of preferences can coincide with learning about a technology. Half of the 22 households interviewed expressed high levels of interest in adopting PEVs in the design games. This group of 11 households is defined as having High PEV Interest based on them choosing a PEV as their next vehicle purchase in the PEV design game. As shown in Table 7, two of these 11 High Interest households chose BEVs, while 9 chose PHEVs. Of the remaining 11 households that did not select a PEV, nine households are categorized as PEV Open – these households expressed that they might be open to PEV adoption in the future and in each case they preferred PHEVs to BEVs. Only two households stated that they would not consider adopting a PEV– these are categorized as PEV Opposed.

Table 7 shows how these categories of PEV interest (table rows) correspond to the levels of knowledge (following the Basic, Moderate, and High Knowledge groupings described in Section 3.1). Table 7 also shows the perceived PEV benefits and drawbacks that were influential in shaping interest in the technology for households in each category (following the perceived benefits and drawbacks identified in Section 3.2). The number of households influenced by a particular benefit or drawback can be less than the total number indicated as citing this benefit or drawback in Table 6 above. This is because participants can cite a perception without it having a significant influence on shaping their preferences. In my analysis, the level of influence of a particular perception is determined by what each participant expressed was important to their household. For example, Sandra (PEV Opposed) cited unknown maintenance costs as a drawback, but her opposition to PEV ownership was based on other considerations. Similarly, the Youngs (PEV Opposed), Omar (PHEV Open), and the Fengs (High PEV Interest) each cited the benefit of PEVs producing less pollution but this was not a significant factor shaping their respective interests in PEVs.

Table 7: Participant interest in PEVs

PEV Preference	Defined by	Total households (of 22)	Initial Electric-drive Knowledge	------------ Influential perceived PEV drawbacks ------------					--- Influential perceived PEV benefits ---			
				BEV Range	Tech un-established	Tech too "strange"	Charging inconvenient	Unknown maintenance costs	Home charging	PHEV range	Save fuel money	Less pollution
High Interest	Chose BEV in design game (High BEV Interest)	2	Basic (1) Mod (1)	0	0	0	0	0	2	0	2	2
	Chose a PHEV in design game (High PHEV Interest)	9	Basic (6) High (3)	9	4	2	0	0	1	9	8	8
Open	Did not choose BEV but open to future BEV purchase (BEV Open)	0	-	-	-	-	-	-	-	-	-	-
	Did not choose PHEV but open to future PHEV purchase (PHEV Open)	9	Basic (7) Mod (2)	9	5	4	5	5	0	9	9	0
Opposed	Opposed to PEV adoption under any circumstances	2	Mod (2)	1	1	2	1	0	0	0	0	0

The motivations behind High Interest in PEVs in general (both PHEVs and BEVs) included both functional and societal perceptions for 11 out of the 22 households. However, the relative importance of these different types of perceptions varied amongst participants in the High Interest category. For Liz, the perceived environmental benefit of less pollution was so important that other benefits such as fuel savings were not significant influences. Yet for the Fengs, recognized environmental benefits had essentially no impact on desire to adopt a PEV; instead, this household was focused on saving money through lower operating costs and, to a certain extent, having the option to charge at home and not have to go to a gas station. For others in this High Interest category both functional and societal benefits were seen as significant motivators – as Fay put it, “I save gasoline, and I save the environment, and if I can kill two birds at the same time, why not?”

As I noted in Section 3.2, perceived drawbacks related to BEV range are countered by perceived benefits related to the range of PHEVs. For the nine High PHEV Interest households shown in Table 7 (as well as all nine of the PEV Open households) the preference for PHEVs over BEVs was consistently associated with the differences in range. For example, when asked why her household preferred a PHEV to a BEV, Mrs. Moretti cited the “range extension” perception, saying, “[You get] the best of both worlds… You could still go on longer trips, and … on a daily basis we don't travel very far, so we'd really be running on electricity.” Further illustrating the importance of range perceptions, both of the High BEV Interest households selected vehicles with 80km ranges, expressing that although this range imposed some limitations, it was sufficient for their needs. In Kevin’s words, “80 [km] would be good because if I ever did need to go out of town, I'd rent a vehicle… 80 [km] is a good range for local driving.”

For four of the High PHEV Interest households, the preference for a PHEV over a BEV was also based partly on the feeling that the ‘unestablished technology’ drawback of electric drive was less of a concern when the vehicle also had a gasoline engine. This could be both functional and symbolic. Veronica explained that with the PHEV “if the battery fails, you still have the gasoline option whereas [with a BEV], when it fails, it fails.” For Veronica and the Mathews the concern about PEVs being ‘strange’ was also alleviated by having the familiarity of an internal combustion engine. Referring to both of these issues of PEV novelty, Mr. Mathews told the interviewers that his preference for a PHEV over a BEV was partly because, in his words, “Maybe I'm just traditional enough that I don't like to be putting all my eggs in the electric basket.”

In Section 3.1 I described how at the beginning of the interviews only three households were aware of PHEVs as a distinct type of vehicle. Nonetheless, as shown in Table 7, nine households selected a PHEV in the design game and all households indicated as PEV Open preferred PHEVs over BEVs. It is clear that for many participants, an initial lack of awareness was not a barrier to developing interest in the technology once the basic concept of PHEVs was explained.

While the households listed as PEV Open in Table 7 were influenced by a number of perceived drawbacks, hesitance to adopt a PEV in the design game was particularly based on concerns about unknown maintenance costs or the perception that electric-drive technology is unestablished. For example, when asked what might increase his household's interest in adopting a PEV, Mr. Chen replied, "I'd have to look into it more [to determine if] the savings in terms of the fuel would balance out… whatever maintenance costs are associated." Similarly, Omar told the interviewers, "I think if we were gonna make that decision, we'd want to know that the price per kilometre, whatever the metric is, is significantly lower when you're buying electric vs. buying gas. And I don't know that it is."

Only two households would not consider adopting a PEV (listed as PEV Opposed in Table 7). These participants placed essentially no importance on pro-environmental attributes of the technology. Both stated that climate change was not anthropogenic and directly stated that they were not environmentally-oriented people (in Mr. Young's words he is "not a nature type or a dirt muncher"). Both of these households also seemed to be strongly influenced by the perception that PEVs are strange. As Sandra put it, "the electric, to me, just seems a bit out there." In fact, for Sandra, this symbolic perception was so important that no other aspects of PEVs were significant influences.

Chapter 5.

Findings for Utility Controlled Charging

“That gets pretty complicated, when you start talking about [balancing the grid].”
– Andreas

In this chapter I present the results of my analysis regarding utility controlled charging (UCC) as a means of supporting green electricity (GE). As with Chapter 4, I describe my findings according to the three research objectives stated above (Section 1.4). I start by describing participants’ knowledge of issues relevant to supporting GE through UCC. In Section 5.2 I describe participants’ functional, symbolic, and societal perceptions relating to UCC. In Section 5.3 I present participants’ preferences for this technology and describe how these preferences were formed.

5.1. Participant knowledge of utility controlled charging

After discussing vehicles, the interviews moved to a general discussion of GE sources (solar photovoltaic, wind turbines, and small-scale hydro) and of the current electricity system in British Columbia. Once a participant’s awareness and understanding of these issues was generally apparent, the researchers provided explanations of these issues and introduced the UCC concept.

At the outset of the interview, 20 of the 22 households had only a basic level of knowledge regarding how the electricity consumed in British Columbia is generated (in terms of awareness familiarity and understanding). Specifically, these 20 households were not aware that the province is part of an interconnected electricity grid, and that this grid includes coal and nuclear generation (whereas the remaining two households were aware of these characteristics of the electricity consumed in British Columbia). Further, these 20 households were either unaware (eight households), uncertain (eight households), or mistaken (four households) about what sources are used to produce electricity within British Columbia. The eight households who were unaware explicitly stated that the source of electricity simply did not concern them. For example, Veronica said, “I pay the bill but I don’t really think about it” and Mr. Young told the interviewers, “I don't care where my electricity comes from as long as I get my electricity.” The eight who were uncertain were aware that most electricity comes from hydro-electric generation, but these households were uncertain in this belief, and unsure of the other sources of generation. For example, Liz stated: “I don't know how much wind energy we're using in BC. I don't think it's a lot. I mean my understanding is the electricity is coming from water. Is that right?” Finally, the four households who were mistaken stated that electricity used in British Columbia comes only from hydro-electric generation.

In contrast, all participants were aware of the existence of different types of green electricity sources discussed in the interviews (solar photovoltaic, wind turbines, and small-scale hydro). Further, the intermittency of GE sources was readily apparent to most participants. For example, Andreas was quick to point out that wind “comes in spurts” and with solar panels “if it's not sunny out, they don't really work, right?” Similarly, Daryl highlighted that solar is at least more predictable than wind.

However, no participant was previously aware of the UCC concept and more than half (14 households) had trouble understanding how UCC would facilitate integrating GE sources into the electricity grid. Specifically, these 14 households could not easily conceptualise the function of electricity storage in balancing the intermittency of GE sources, and it was an even greater challenge for these households to extend that thinking to imagine how UCC could increase the potential of GE sources. For example, Andreas struggled to understand the explanation given: “that gets pretty complicated when you start talking about [balancing the grid].” Similarly, Clair stated that the idea was “futuristic” and Christine exclaimed “Oh God” (in confusion) as the UCC concept was explained. . In contrast, the remaining eight households were more easily able to understand the concept of UCC once it was explained to them.

5.2. Participant perceptions of utility controlled charging

Through my analysis I identified five themes of how participants perceived GE and UCC: Societal Impacts, Feasibility, Functional Uncertainty, UCC Service, and Supporting GE. These themes and the associated perceptions are presented in Table 8 following the same format used for PEVs above. Again, the perceptions presented in this table are only those which were explicitly mentioned by participants during the interviews and which appeared influential in shaping interest in the technology for at least one participant.

Table 8: Participant perceptions of Utility Controlled Charging

Attribute theme	Perceptions	Number of households explicitly citing this	Example quotes
Societal Impacts	Wind energy is natural or environmentally friendly (positive)	7	“We already get wind… and if you can make something work with something that's already there that isn't harming the Earth, why not?” – Liz
	Wind turbines may harm wildlife (negative)	6	“[T]hey were saying it might affect some birds” – Mr. Feng
	Wind turbines are noisy or disruptive (negative)	5	“Apparently, the wind, the turbines, I've heard that they can be really noisy” – Mr. Young
	Solar energy is natural or environmentally friendly (positive)	4	“It's more environmentally friendly” – Veronica
	Solar panels have a large lifecycle footprint (negative)	3	“[T]here's a lot of problems with solar power too because those panels, once they don't work, it's really hard to get rid of them” – Kevin
	Small hydro is natural or environmentally friendly (positive)	2	“The small dams, they're pretty benign.” – Al
	Small hydro may be harmful to ecosystems (negative)	4	“These… what are they called, run of the river or something like that? I don't know how good they are for the salmon and other fish.” – Mrs. Moretti
Feasibility	Solar technology is not practical (negative)	10	“I just like solar, but being in the west coast and the lack of sun, I don't think it's too feasible.” – Mr. Young
	Solar technology has potential (positive)	5	“Solar is every year becoming cheaper and cheaper” – Mr. Nicolov
	Wind energy is unreliable (negative)	5	“If there's no wind, you won't have electricity.” – Mr. Moretti
Functional Uncertainty	Uncertain impact of UCC on PEV batteries (negative)	3	“[I would] want to make sure that that's not hurting my battery.” – Mr. Feng
UCC service	Requires too much trust in administration (negative)	7	“Like, what if I had all these plans… and I thought I was getting 80 [% guaranteed minimum charge] and then they gave me 50?” – Christine
	Loss of control (negative)	9	“I don't like having no control over… knowing how much the car's gonna be [charged]” – Veronica
Supporting GE	Supporting GE is a good deed (positive)	8	“[I]t's kind of like… [I] clear my conscience” – Christine
	GE and PEVs go together (positive)	3	“Like having an electric car and the green electricity, I mean you're walking the walk” – Liz

Participants had both positive and negative perceptions of GE sources with regards to their environmental impacts. All three GE sources, and especially wind and solar, were perceived by some participants as being “environmentally friendly” or “natural.” For example, Mr. Chen told the interviewers, “So if I was looking solely at what I thought was more green and what was more I guess ethical, it would be the wind and solar.” Similarly, Mr. Mathews felt positively about GE sources because, in his words, “those are gifts that we've got… light, wind, water currents.” However, all three GE sources were also associated with possible negative environmental impacts. Four households expressed concern that small hydro might harm, as Lei put it, “the habitat of nice creatures that live in the water”. Three households stated that the manufacturing or disposal of solar panels might be environmentally harmful. Six households said that wind turbines might have negative environmental impacts because of collisions with birds or disruptions to wildlife more generally. Finally, five households also expressed that wind turbines could have direct negative impacts for humans as a result of noise emitted during their operation. For example, Mr. Young recalled having heard about a community where “there was some real opposition because… the sound of it was really just bothering the surrounding people, the neighbours.”

The Feasibility theme captures societal perceptions regarding the performance of GE and UCC technology – independent of environmental impacts. Five households stated that wind energy seemed unreliable – as Mr. Feng explained “Sometimes you want the power when there's no wind.” Similarly, ten households expressed that solar generation may not be practical because of either doubts regarding the general ability of solar technology to efficiently create electricity, or (for seven households) concern regarding a lack of sun in British Columbia – in Clair’s words, “Solar's not feasible mainly because of our climate I would think.” However, five households voiced more positive perceptions of solar technology’s potential. For example, Mr. Mathews told the interviewers “[British Columbia is] not noted for having an excess of sunshine, but we have light. I think that's great, and I think the more it's used, probably the less expensive it will be.” Further, Daryl pointed out that with solar “At least you know it's always gonna be around… [whereas] with windmills, you still gotta worry about getting some wind.”

The Functional Uncertainty theme contains one functional perception – specifically, the perceived drawback that if UCC were to involve vehicle-to-grid transfer of electricity it might harm PEV batteries. This perception was expressed by three households, each of whom had moderate or high PEV knowledge at the outset of the interviews (as described in Section 3.1) and had little difficulty understanding the UCC concept (this group also includes the two households who were most knowledgeable about the current electricity system). For these technologically knowledgeable participants the drawback was the uncertainty of the impact of UCC on a PEV's battery. For example, Mr. Nicolov expressed his concern saying, "I need to know [if] it's good for my battery, for battery life."

The UCC Service theme includes two perceptions relating to the implementation of UCC programs rather than the technology itself (i.e., the service rather that the technical aspects of GE and UCC). Both of these perceptions are negative. Seven households expressed that a lack of trust in the utility was a drawback. For example, Omar was concerned that he would "have no way of validating that… [the utility is] not buying [the electricity] from Alberta from the coal…" Similarly, Al's apprehension regarding UCC was apparent as he rhetorically asked, "What happens when the computer glitches, and I go downstairs and I go, 'Oh, my car's not charged'?" The second perception in this theme – expressed by nine households – involved a feeling of discomfort regarding the idea of relinquishing control over PEV charging. This discomfort was not because of lack of trust in the utility, but simply because these participants preferred to handle the charging themselves. As Andreas put it, "If I want it charged, I want to know that it's charged."

With regards to Supporting GE, eight households explicitly articulated positive perceptions. These participants expressed that supporting GE would contribute to a greater good. For example, when Daryl was asked why he would be willing to pay more for green electricity he responded, "Because it's better for the environment. It's simple as that. I'm not opposed to paying more to help our world." Relatedly, three of these households expressed that the idea of linking GE with PEVs intuitively made sense – as Christine rhetorically asked, "[W]hat's the point of putting non-green electricity into your electric car?"

5.3. Shaping preferences for green electricity and utility controlled charging

In Table 9 below I have categorized participants according to their willingness to accept UCC. These categorizations are based on participant responses during the design games (described in Section 2.4). Households shown as having High Acceptance of UCC chose to support GE by agreeing to reduce the guaranteed minimum charge in their (hypothetical) PEVs' batteries to either a 50% or 65%. Households categorised as Medium Acceptance were willing to grant the utility 10 to 20 % of their charge. Households categorised as UCC Opposed would not accept any reduction in guaranteed minimum charge. Those categorized as N/A (not applicable) were opposed to PEV adoption and therefore did not complete the UCC design games. Within each category I have further separated households by their preferred source of GE. In Table 9 I present counts of the households influenced by perceived benefits and drawbacks distilled from the perceptions described in Section 3.1 above.

Table 9: Participant Preferences for UCC

UCC Preference	Defined by	Total HH (of 22)	GE source	------------Perceived UCC drawbacks ----------------				--------Perceived UCC benefits -----------		
				Negative environmental impacts	Limited GE feasibility	Lack of trust	Loss of control	Environmental benefits	Positive symbolic aspects	Positive GE feasibility
High Acceptance	Chose 50-65% guaranteed minimum charge in UCC design game	5	5 mix	-	2	-	-	5	3	1
Medium Acceptance	Chose 80-90% guaranteed minimum charge in UCC design game	9	2 solar 3 wind 4 mix	2	7	2	6	9	3	1
Opposed	Would not accept any UCC in design game	6	6	1	2	3	4	3	-	1
N/A	Opposed to PEV adoption	2	2	-	-	-	-	-	-	-

Five households were willing to accept a high level of UCC (50-65% guaranteed minimum charge). All five households were motivated by the perceived environmental benefits of different GE sources – for instance, Daryl explained, he wanted to support GE because he did not “want to see things destroyed” with large-scale hydro dams. Three of these households were also influenced by related symbolic benefits of GE. For example, Violet said “I feel like I'm doing a good deed myself by giving up this much [of my PEV’s charge] to have the green energy.” Similarly, Liz explained that supporting GE was “doing my part” and “running electric cars on green electricity makes sense.” All five households preferred a mix of GE sources rather than any one of wind, solar, or small hydro on its own.

Nine households were willing to accept a moderate level of UCC (80-90% guaranteed minimum charge). All nine participants were also motivated by perceived environmental benefits of supporting GE, and three were motivated by the related symbolic benefits as well. However, those environmental and symbolic benefits were generally less important for these households relative to the High Acceptance group. For example, Mr. Park expressed his muted enthusiasm for supporting GE saying that it would only be necessary “if there are no more rivers to dam.” Further, five of these households were influenced by the perceived drawback of relinquishing control – as Christine put it “I think 50 [% guaranteed minimum charge] is just like… too unpredictable for me.” Two were also concerned that it may not be wise to trust the utility to provide the agreed upon guaranteed minimum charge – in Al’s words, “What happens when the computer glitches, and I go downstairs and I go, ‘Oh, my car's not charged’? That would really suck.” These drawbacks combined with the limited appeal of GE meant that participants in this category were somewhat restrained in their willingness to accept UCC.

The six households who would not accept any UCC can be further grouped into two groups: three households who were opposed because they were not inclined to support GE, and three households who were supportive of GE but were strongly deterred by perceived drawbacks of UCC. The first group evaluated GE as being of limited importance and therefore not attractive enough to overcome perceptions of mild drawbacks. For example, the Fengs were only mildly concerned about mistrust in the utility and the impact of UCC on their PEV's battery but were not at all motivated by societal benefits of supporting GE. In fact, Mr. Feng expressed that his household would consider accepting UCC if there were a functional benefit, saying "Well, if I'm getting a discount, I'd be looking at it..." In contrast, the second group who would not accept UCC saw GE as attractive, yet their acutely negative evaluations of the perceived drawbacks of UCC deterred them from supporting it in this way. For two of these households the concern was primarily about, in Veronica's words, "having no control over… knowing how much the car's gonna be [charged]." For the Mathews the primary reason was because it required too much trust in the administrator. As Mr. Mathews explained, "I don't find the concept bad, but… something…could go wrong. I mean, things are misread… there's some kind of bureaucracy gets in there, and you may find yourself at odds with it."

Table 9 also indicates the particular source of GE that participants chose to support – either solar, wind, small hydro, or a mix of the three. Of the 12 households that accepted some degree of UCC, two households chose solar, three chose wind, zero chose small hydro on its own, and nine households chose a mix of GE sources. Perceived negative social or environmental impacts of particular GE sources were influential for many participants when selecting between these. For example Lei selected wind because she was concerned about the negative environmental impacts of solar panels and small hydro development. The Nicolovs selected solar because they were concerned about the negative environmental impacts of small hydro and because of the noise they associated with wind turbines. The Youngs also chose solar because of this concern about wind turbines – in Mr. Young's words, "I picked solar over wind [because] solar is totally quiet…. I've heard that [wind turbines] can be really noisy and can cause issues."

Perceptions related to the functionality of particular GE sources also influenced participants' selections. Five of the eleven households who selected a mix of GE sources were influenced by a concern that individual sources would not be reliable or effective on their own. As Kevin explained, "I'd have to go with a mix because we don't get enough sunlight, and even the wind, we get a fair amount but… [it] comes in spurts". The concern about the ability of solar panels to produce sufficient or reliable electricity was influential enough for two households to reject this source entirely – in Clair's words, "Solar, I don't know that it'd even be on the table where we are, so it would have to be wind and small hydro." On the other hand, Andreas selected solar as his preferred source of GE because of concern about the reliability of wind.

Chapter 6.

Discussion and conclusion

Consumer adoption of plug-in electric vehicles (PEVs) and acceptance of utility controlled charging (UCC) could be an important part of a larger transition to low carbon technologies and subsequent deep reductions in greenhouse gas emissions (Williams et al., 2012). In this study I explore how consumers construct preferences for these emerging pro-environmental technologies. My analysis is qualitative and focuses on consumer knowledge (which may be non-existent or imperfect) and perceptions (which may be functional, symbolic, or societal). I drew from primary data collected through in-depth interviews with 22 households in British Columbia, Canada who had previously completed the “Mainstream” vehicle owners (i.e. those that bought a conventionally-fuelled new vehicle in the last 5 years) survey described in Axsen et al. (2015). My research objectives were to (1) assess participant knowledge of the case technologies (awareness, familiarity, and understanding), (2) identify participants’ key functional , symbolic, and societal perceptions of the case technologies (including evaluations), and (3) explore how preferences for PEVs and UCC are shaped by participants’ knowledge and perceptions.

6.1. Initial knowledge of plug-in vehicles and utility controlled charging

I defined knowledge as what a consumer knows about the technology – including awareness (the extent to which they are conscious that a technology or an attribute exists), familiarity (how well acquainted they are with the details of a technology), and understanding (their comprehension of a technology’s implications and how it operates). Following my conceptual framework, consumers draw on their knowledge as they make decisions about a technology, and for emerging technologies (such those examined here) knowledge is likely to be non-existent (due to lack of awareness) or imperfect.

Indeed, I find that the majority of participants began the interviews with low levels of knowledge regarding PEVs. Nineteen of the 22 households were unaware of plug-in hybrid electric vehicles (PHEVs) as a distinct type of vehicle. This lack of knowledge regarding PHEVs corresponds with the results of the Mainstream vehicle buyers survey where the majority of respondents (>68%) were confused about how specific examples of different types of electric-drive vehicles were fuelled (Axsen et al., 2015). Similar confusion about PHEVs is also described by Caperello and Kurani (2011) who report that some participants in a PHEV trial remained “mystified” with how this type of vehicle operates, even after weeks of using one. My present findings provide greater detail regarding how Mainstream consumers may struggle to comprehend PHEVs. Specifically, my analysis highlights that confusion regarding conventional hybrids (such as the belief that a conventional hybrid can be plugged-in) can block understanding of what a PHEV is and how it functions.

I also find that no interview participants were previously aware of UCC (or the general concept of controlled charging) and the majority had very low knowledge regarding electricity, making it difficult for them to understand the function of UCC technology. Twenty of the 22 households were not aware that British Columbia is part of an interconnected electricity grid which includes coal and nuclear generation. Further, these participants were unaware, uncertain, or mistaken about what sources are used to produce electricity within British Columbia. For example, four households stated that they believed all electricity used in the province comes from hydro and eight more stated that they simply did not know where their electricity came from. Knowledge of electricity sources is rarely considered in the literature on green electricity valuation; although, some Finnish consumers interviewed by Salmela and Varho (2006) also expressed uncertainty about the origin of the electricity they consume and how this differs from green electricity sources . Here I provide further evidence that deeper examination of consumer knowledge for both technologies is warranted in valuation research, that is, before assessing consumer perceptions and preferences.

6.2. Perceptions of plug-in vehicles and utility controlled charging

My conceptual framework defines perceptions as what a consumer thinks about a technology – including the attributes they perceive and how these are evaluated. Perceptions can be functional (pertaining to attributes with tangible consequences for the individual consumer such as losing time or saving money), symbolic (pertaining to more abstract attributes which carry social or emotional meaning), or societal (pertaining to consequences for the wider society). Many previous studies have focused more on consumer perceptions of functional attributes (e.g. Hackbarth & Madlener, 2013; Krause et al., 2013; Parsons et al., 2014), and somewhat on societal attributes (e.g. Hansla et al., 2008; Noppers et al., 2014), but only rarely on symbolic attributes (e.g. Heffner et al., 2007; Noppers et al., 2014; Schuitema et al., 2013).

I find that participants cited numerous functional perceptions. However, most functional perceptions were regarding PEVs, where participants perceived potential benefits related to saving money on fuel (19 out of 22 households) which have been noted in many other studies (e.g. Axsen et al., 2013; Hidrue et al., 2011; Krause et al., 2013). Another functional perception was that the range of battery only vehicles is insufficient to reach certain destinations (12 households), which is also well supported by numerous studies (e.g. Dimitropoulos et al., 2013; Hackbarth & Madlener, 2013; Lieven et al., 2011). Participants in the present study also cited inconveniences related to charging both types of PEVs, such as having to find a place to charge (15 households), having to dedicate too much time to charging (seven households), and having to physically plug-in the vehicle (three households). These concerns are consistent with multiple studies finding that consumers value reduced charging time (Carley et al., 2013; Hackbarth & Madlener, 2013; Hidrue et al., 2011). In short, it is clear that functional perceptions are important to consumer preferences for PEVs. Functional considerations were less prevalent regarding UCC, where the only primarily functional perception of UCC was a concern (expressed by three households) that this technology may harm PEV batteries (which has not been explored in previous literature). I also find that participants cited symbolic perceptions regarding both technologies.. Nine out of 22 households expressed that PEVs are “strange.” This particular finding is unique to the present study, although it is perhaps connected to feelings of embarrassment reported by Schuitema et al. (2013) and Graham-Rowe et al. (2012) which consumers can associate with PEV adoption. For UCC, the key symbolic perceptions related to lack of trust in the utility (seven households) and a feeling of "loss of control" (nine households). To my knowledge the concern regarding the trustworthiness of the utility has not been reported elsewhere in relation to UCC; however, in relation to consumer adoption of green electricity tariffs Ozaki (2011) and Salmela and Varho (2006) have found similar concerns about whether the utility can be trusted to provide the agreed upon service. Perceptions of loss of control for UCC are also noted from the larger Mainstream vehicle buyers survey (Axsen et al., 2015; Bailey & Axsen, 2015). In that survey respondents were asked if UCC would "take control away from me in a way that I would not like" (and 39% agreed with the statement – here I add the insight that for interview participants, the disliking of control loss was generally based on an emotional sense of discomfort.

Finally, participants in this study also cited several societal perceptions of the case technologies. Participants perceived both PEVs and supporting green electricity to be generally environmentally friendly (19 and 17 of 22, respectively), as has been reported in similar studies (e.g. Axsen et al., 2013; Graham-Rowe et al., 2012; Ozaki, 2011). However, not all societal perceptions were positive. For example, seven households were concerned that wind turbines could harm wildlife, which broadly aligns with Bergman et al.'s (2006) finding that many consumers are willing to pay for reduced wildlife impacts from renewable energy more generally. As well, four households were concerned about possible negative environmental impact of PEV batteries, similar to concerns reported by Graham-Rowe (2012) where some interview participants questioned the lifecycle footprint of the technology.

6.3. How preferences for the case technologies were shaped

Preferences are defined here as consumers' general attitudes towards choosing one technology ahead of alternative options. Following the conceptual framework, consumers' preferences may not always be pre-existing or static, especially when the choices they are faced with involve emerging (novel) technologies or products which they are not aware of or familiar with. In other words, consumers may construct their preferences as they learn about a technology and its attributes (Bettman et al., 1998; Slovic, 1995).

I find that lack of initial knowledge was not a barrier for participants developing positive preferences for PEVs and UCC, once these technologies were explained in the interviews. Six households expressed high interest in adopting PHEVs and nine more were open to this in the future even though none of these participants were aware of the technology at the beginning of the interviews. Thirteen households were willing to accept some degree of UCC despite not initially being aware of the technology or the potential benefits of supporting GE. Of course, this low level of knowledge might prove to be a barrier to technology adoption in the market—as consumers are not likely to buy technologies that they are not aware of. Some previous research has found a positive correlation between initial knowledge and preferences for PEVs (Krause et al., 2013) and GE (Diaz-Rainey & Ashton, 2011). However, to my knowledge no previous studies have examined how consumer preferences for these technologies have developed in consumers with low initial knowledge.

All three types of perceptions (functional, symbolic, and societal) could be influential in the development of respondents' preferences for PEVs—though patterns varied across individuals. For nine of the 11 households with high interest in PEV adoption, both the functional perception that a PEV would save the owner money on fuel, and the societal perception that PEVs were environmentally friendly were important motivators. However, for one household with high interest in PEV adoption only functional perceptions mattered, and for one other household only perceived environmental benefits were influential. This heterogeneity is consistent with related research where both Mainstream consumers and PEV owners have indicated varying motivations behind positive PEV preferences (Axsen et al., 2015). The symbolic perception that electric drive technology is strange was a crucial deterrent for the two households who would not consider adopting a PEV.

Nine of the 11 households who had high interest in adopting a PEV preferred a PHEV, which is consistent with other studies of potential Mainstream PEV buyers (e.g.

Axsen & Kurani, 2013; Axsen et al., 2015; Carley et al., 2013). Preferences for PHEV were influenced by functional and symbolic perceptions. All households who preferred a PHEV were positively motivated by perceptions relating to range limitations of BEVs and the "gas back-up" of PHEVs. For four households, this PHEV preference was also based partly on the feeling that the 'unestablished technology' drawback of electric drive was less of a concern when the vehicle also had a gasoline engine. Further, for two households the symbolic perception of "strangeness" also helped shape preference for PHEVs over BEVs since the familiarity of having an internal combustion engine made PHEVs comparatively less strange. The reasons for preferring one of these PEV types over another are not typically examined in the literature. Notably, however, Schuitema et al. (2013) find that the negative symbolic perception of PEVs being embarrassing was more often linked to BEVs than to PHEVs.

For UCC I find that symbolic and societal preferences were particularly influential in the development of preferences. In this study UCC was presented to participants as a means to support green electricity; therefore, the perceived environmental benefits of different green electricity sources were the primary motivators behind positive preferences for UCC. Symbolic perceptions were the most important deterrents to accepting UCC. In particular, perceptions regarding loss of control and lack of trust in the utility influenced the development of many participants' preferences for this technology. Five households were willing to accept a high amount of UCC – with the only benefit being the support of green electricity. This differs from the version of UCC examined by Parsons et al., (2014) were the only benefits presented to consumers were financial (i.e. in terms of bill savings). As such, Parson et al.'s conclusions regarding the high levels of financial incentives necessary for consumers to accept UCC should be interpreted with the recognition that societal perceptions found here can also provide motivation.

6.4. Implications and suggestions for future research

Given the qualitative nature of my study's design, I must be careful in generalizing results to a wider population. That said, results do highlight important considerations regarding the formation of consumer preferences for the case technologies. These insights hold significant implications for policymakers, industry, and researchers.

Policymakers may aim to promote these technologies through information provision or financial incentives. With regards to information provision, my findings demonstrate that misunderstanding is widespread among Mainstream consumer for both case technologies, as well as highlighting some specific areas of limited knowledge that information campaigns focus on (e.g. awareness of PHEVs). Providing information to consumers may be in fact be an important step in efforts to support the adoption of PEVs and enrollment in UCC programs. However, my own research does not explore what channels of communication and social influence might be most effective in filling this "knowledge gap", where Axsen et al. (2013) indicate that mass "diffusion" of information might not be as effective as the interpersonal sharing of information within established and trusted social networks. With regards to financial incentives, my findings regarding the importance of symbolic perceptions suggest that these may not always be as effective as some stakeholders expect. Consumers concerned about strangeness of PEVs or trustworthiness of the utility might weigh those concerns more heavily than otherwise attractive financial benefits.

Industry (including utilities) can also draw on my findings regarding consumer knowledge to identify areas of focus for communication efforts. PEV manufacturers might consider comprehensive warranties to help address negative perceptions that electric drive technology is unestablished and associated with unknown maintenance costs. In terms of UCC programs, electric utilities might consider administering UCC through a third party to see if this could address concerns regarding the trustworthiness of the utility. Similarly, a UCC program that includes an option to temporarily opt-out might help allay concerns related to of loss of control.

Future research could also explore consumer reactions to these suggestions as well as test key findings of this study at a larger, quantitative scale (e.g. large survey) to determine how they might be applied to a wider population. Additionally, the low knowledge discovered amongst interview participants indicates that researchers ought to be careful when interpreting results of large scale surveys that don't take knowledge into account, such as those reporting consumer intent to purchase PEVs or willingness to support green electricity (e.g. Carley et al., 2013; Hansla et al., 2008). If survey respondents are unaware of the case technology (or have low or mistaken knowledge) then an elicited preference might be false or unstable. Such research can be improved by carefully designing survey instruments and questionnaires to first assess respondents' background knowledge, and then to carefully inform respondents of the technology to a degree at which their preferences can be expressed (as I followed in my present qualitative study).

Consumer adoption of PEVs and support of GE could play a significant role in making deep reductions in greenhouse gas emissions. My findings highlight specific influences on the construction of consumer preferences for these technologies which are often overlooked. Research and policy ought to carefully consider the roles of knowledge and different types of perceptions in shaping consumer preferences in order to understand how we might facilitate a transition to low-carbon technologies.

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Appendix A.

Interview outline

Overview

0.	**Opening**	**~10 min**
1.	**Vehicle Perceptions**	**~20 min**
2.	**Talking through Vehicle Design Games**	**~20 min**
3.	**Perceptions of Electricity Sources**	**~20 min**
4.	**Talking through Electricity Source Design Game**	**~15 min**
5.	**UCC and Charging Choice Game**	**~20 min**
6.	**Lifestyle**	**~15 min**

****Note: this is a rough guide only – discussions are not be limited the content nor the structure of the below.**

Opening

- Turn recorder on
- Introduce study and interviewers
- Have participant read and sign consent form

Part 1: Vehicle perceptions.

- ☐ Tell me about the last vehicle you bought? What made you choose this?
  - ➲ What aspects did you consider? What was most important to you?
  - ➲ Were you thinking about how you would use it? How did that affect your choice?
  - ➲ Do you like this vehicle? Why or why not?
- ☐ Did you think about an electric vehicle?
  - ➲ What type? A plug-in vehicle or hybrid?
  - ➲ Tell us about these; did they seem attractive to you? Which? Why or why not?

**[give vehicle type explanations sheet – explain]

- ☐ Where have you heard about electric vehicles?
  - ➲ Do you have any direct experience with electric vehicles? Please explain.
  - ➲ Have you talked with friends or coworkers about them?
  - ➲ Did you do any research about them when you were buying your last car? Since?
- ☐ What do you think are the positive and negative characteristics of electric vehicles?
  - ➲ How could they be improved?

- ☐ Would you be willing to purchase an electric vehicle?
    - ➲ Under what conditions (price, performance, variety, recharge infrastructure, etc.)?

Part 2: Talking through the vehicle design games.

**[give vehicle design game sheet - explain]

**[Talk through available options – give numbers as appropriate]

- ☐ So which of those 4 vehicles would you choose? Why?
- ☐ Can you tell me more about that selection?
    - ➲ Why is it better than the other options?
- ☐ What would need to change for you to choose a plug-in hybrid or an electric only?

So imagine you did have a PEV – if the conditions were right…

- ☐ How do you imagine using it? Would the rest of your household agree? Is that realistic for everybody?
    - ➲ What would it be like day-to-day to drive that? What types of things would you have to keep in mind?

Part 3: Perceptions of electricity sources.

Let's keep thinking about that PEV. I am wondering specifically about charging.

- ☐ Did you think about charging the PEV when playing the "design game"? What were you thinking?
    - ➲ Now that I ask you, what do you think about? What concerns come up?
- ☐ What about the electricity source? Have you thought of where your electricity comes from?
    - ➲ What are the sources of the electricity you use at home?
    - ➲ Does that matter to you?
- ☐ Are you familiar with the idea of "green electricity"? What does this mean to you?
    - ➲ What specific sources?
    - ➲ What is the benefit to these?
- ☐ Where have you heard about this? Have you looked into it anywhere? Have you ever talked about it with people? Friends, coworkers, family, others?

**[give green electricity explanation print-out – explain]

- ☐ Which of these sources would you prefer to get your electricity from?
    - ➲ Why not the others?
- ☐ What do you think are the pros and cons of green electricity?
    - ➲ Do you know of any difficulties associated with it?

Part 4: Talking through the electricity source design game.

This is a version another one of the design games from the survey. **[indicate electricity design game sheet]

So you've told us that for a source of green electricity you would choose ____________.
And you said in the survey that your electricity bill was about ____ per month. Is that about right?

What we want to know is if you would be willing to pay a little more on your monthly bill to increase the amount of green electricity you're using.
[indicate game sheet] You can see the prices here… [complete game]

Part 5: UCC and Charging Choice Game
[continued from part 4 conversation] So we want to hear more about what you think about electricity sources, and we want to relate this to what you think about electric vehicles.
Now, imagine again you've got that PEV we were talking about… [explain guaranteed minimum charge]
So take a look at this… **[give charging choice game 1 – fill in responses] … You've told us that you would choose ____ for the type of green electricity, and you might pay ___ to get ___ percent of it. This assumes that your PEV would be charged as normal, so you would have 100% as your guaranteed minimum charge.
**[give charging choice game 2] – here we ask you to trade-off between guaranteed minimum charge and percent of green energy
**[give charging choice game 3] – here we ask you to trade-off between minimum charge and price. Green electricity is no longer in the mix.

Conclusions:
Now that we know about your electricity, and your car, in the few minutes left we'd like to know about you.

- ☐ How would you describe yourself? What kinds of things interest you?
  - ➲ What kinds of activities do you do in your free time?
- ☐ What is important to you?
- ☐ Do you generally do things to help the environment?
  - ➲ Like what?
  - ➲ What about that appeals to you?
- ☐ What does it mean to "act green"?
  - ➲ What specific things?
  - ➲ Why would people do that?
- ☐ Do these things influence your decisions regarding electric vehicles or green electricity?

Appendix B.

Technology information sheets

Vehicle type explanation

Vehicle Type		Refuel or Recharge?		Mode of Operation
		Gasoline	Electricity	
Regular gasoline		☑		**Gasoline only**: • This vehicle uses fuel like a *typical* gasoline vehicle.
Hybrid		☑		**Gasoline only:** • A small battery and electric motor assist the engine to give help the hybrid use *less* fuel per 100km than a regular gasoline vehicle.
Plug-in Hybrid		☑	☑	**Battery & Gasoline:** • With a fully charged battery, the vehicle is powered by *electricity* for the first 16 to 64 kilometres. The vehicle then *automatically switches* to **gasoline.** Like a hybrid, when using gasoline, it uses *less* fuel per 100km than a typical gasoline vehicle. • The vehicle must be periodically *plugged into* a normal outlet or recharge station to be powered by the battery.
Electric			☑	**Battery only:** • The vehicle is powered by *electricity* for 80 to 240 kilometers. The battery recharges by *plugging* it *into* an electrical outlet or recharge station. This vehicle cannot use gasoline.

Green electricity definition

Sources of green electricity include wind, small hydro (typically run-of-the-river), tidal, solar, geothermal, and biomass-fuelled power sources. Green electricity sources typically have little or no greenhouse gas emissions from their fuel source. They do not create other types of pollution (e.g. smog) or negative health impacts.

For the purpose of this study, we use the term "green electricity" to refer only to electricity that is generated by the following 3 most common sources, or a mix of some or all of these:

Wind:

As the wind blows, it spins large turbines. The spinning movement is turned into electricity by a generator.

Solar:

Solar panels absorb the sun's energy. This energy is converted in the solar panels to create electricity.

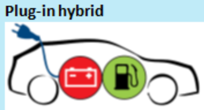
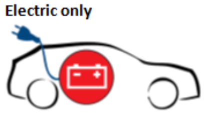
Small Hydro:

Small sections of rivers are diverted through pipes. In the pipes, water turns a generator to produce electricity. The diverted water is then fed back into the river. When we refer to this we do NOT include large-scale dams.

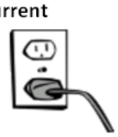
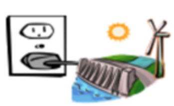
Appendix C.

Example interview game sheets

Vehicle Design Game – Sedan

Vehicle type	Electric Range	Recharge or Refuel Type	Gasoline Fuel Use	Purchase Price	Your Choice
Regular 	none	Gas station 5 minutes	7.1L /100 km	$__25,000___	☐
Hybrid 	none	Gas station 5 minutes	4.3L /100 km	$_26,070__	☐
Plug-in hybrid 	Electric for the first: ☐ 16 km + $2,100 ☐ 32 km + $2,440 ☐ 64 km + $3,130	☐ Type 1 (normal) + FREE ☐ Type 2 (6 x faster) + _$1000_	4.3L /100 km	Base Price $25,000 Range cost +$ Charging cost +$ Total = $	☐
Electric only 	Electric only for: ☐ 80 km + $4,600 ☐ 120 km + $6,490 ☐ 160 km + $6,440 ☐ 200 km + $8,380 ☐ 240 km + $12,160	☐ Type 1 (normal) + FREE ☐ Type 2 (6 x faster) + _$1000_	none	Base Price $25,000 Range cost +$_______ Charging cost +$_____ Total = $ ___________	☐

Charging choice game #1

Charging Style	Source of Green Electricity	% of green electricity	Guaranteed Minimum Charge	Monthly Electricity Bill	Your Choice
Current 	Your Current Mix	Your current mix	100%	$35	☐
New 	☐ Wind ☐ Solar ☐ Small Hydro ☐ Mix	☐ 25% → 90% ☐ 50% → 80% ☐ 75% → 65% ☐ 100% → 50%		$35	☐