

Exploring Antecedents to Environmentally-Consequential Consumer Choices and Behaviors

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ABSTRACT

This dissertation presents two essays that explore the antecedents of consumer decision-making when choices or behaviors have significant environmental consequences. The first essay involves theoretical development and experimental testing of a conceptual model describing the process by which a car-buyer evaluates the choice between an electric vehicle (EV) and a gasoline vehicle, while the second essay consists of empirical analysis of a large panel dataset of household-level 15-minute interval electricity consumption data to identify the drivers of different behavioral response patterns to electric utility requests for energy conservation on hot summer afternoons.

The first essay is motivated by the observation that increased consumer adoption of battery-powered EVs is important for commercial and environmental reasons, but EV adoption is currently inhibited by both an up-front price disadvantage and the inconveniences associated with battery recharging. The research presented in the first essay leverages the Theory of Reasoned Action as well as the literature on identity signaling to develop a model on how consumers with interests in the environmental and/or technological implications of EV ownership evaluate the potential purchase of an EV versus a conventional automobile. The model generates ten pairs of hypotheses that are tested via estimation of a structural equation model using data from three online

experiments. Bayesian pooling of the three sets of estimated path analysis coefficients finds considerable support for the conceptual model. These pooled results show that EV ownership signals the owner's concern about both environmental protection and technology advancement, but the effect of the environmental signal on EV purchase likelihood is positive whereas the effect of the technology signal on EV purchase likelihood is negative. Moreover, in addition to lowering EV purchase likelihood via a direct effect, the perceived inconveniences associated with EV ownership (e.g., needs for battery charging) offset the negative effect of technology signaling on EV purchase likelihood, while the corresponding interaction of inconvenience with environmental signaling value was found to be not significant. Meanwhile, a larger EV price premium had a direct negative effect on EV purchase likelihood but did not moderate the effects of either technology signaling value or environmental signaling value on EV purchase likelihood. Among other findings, specific knowledge about how EVs affect technological advancement has a direct positive influence on EV purchase likelihood. However, all downstream effects of specific knowledge about EVs effects on environmental protection are mediated by perceptions of EV effectiveness in benefitting the environment.

Meanwhile, the second essay investigates consumer behavior concerning household electricity consumption. Utilities use demand response (DR) programs to induce customers to reduce electricity consumption during selected hot summer afternoons when power generation supplies may be challenged to satisfy regional demand levels. The research presented in the second essay leverages panel data on electricity consumption from households in a community where an experimental pro-social DR

program was conducted to explore drivers of household responses to utility requests to voluntarily reduce electricity consumption. Analysis of the panel data shows that, on average, households with solar rooftops respond differently to utility DR notifications than non-solar households: solar households reduce electricity consumption as requested by the utility, whereas non-solar households receiving the same request actually increase electricity consumption. However, although solar households respond favorably to DR notification, they also consume significantly more electricity than non-solar households during most hours. These empirical results – greater responsiveness to DR notifications, but otherwise higher levels of electricity consumption – beg reconciliation and explanation. An experimental research study is proposed for a future examination of alternative psychological explanations for the observed differences in behavioral responses between solar and non-solar households.

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GENERAL AUDIENCE ABSTRACT

This dissertation presents two essays that explore how and why individuals make decisions with environmental consequences. The first essay investigates how and why individuals choose to purchase a higher-cost big-ticket durable good (i.e., an electric vehicle) that results in substantially lower air emissions over the lifetime of the product, while the second essay investigates how and why individuals make environmentally-friendly behavioral decisions (i.e., conserving electricity on a hot summer afternoon) when the stakes are modest and transitory.

The first essay discusses the findings from three experiments in which on-line survey respondents were asked to imagine being in the market to buy a new car and then indicate how likely they would buy an electric vehicle (EV) rather than an otherwise identical gasoline automobile. Before indicating EV purchase likelihood, participants were informed to assume different levels of price premium and inconvenience (e.g., associated with battery recharging) resulting from EV ownership. Participants were also asked a series of questions to measure their attitudes about environmental protection and technology advancement, as well as the ability of EVs to help both of those dimensions of social progress. Of particular interest, participants were asked how much driving an EV sends a public signal of the owner's commitment to environmental and technology

improvement. Among other findings, statistical analysis of the data collected from these experiments indicates that EV ownership sends a strong signal of the owner's commitment to both environmental protection and technology advancement. However, the environmental signal of EV ownership positively influences EV purchase likelihood, whereas the technology signal of EV ownership negatively influences EV purchase likelihood. Of further interest, this negative relationship between technology signaling value and EV purchase likelihood is offset by the perceived inconveniences associated with EV ownership (i.e., battery charging), such that the negative effect of technology signaling on EV purchase likelihood can be overcome if the prospective EV buyer also believes EV ownership is highly burdensome.

The second essay presents the findings from analysis of 15-minute interval electricity consumption data during the summer of 2021 from 307 households in a master-planned community that was the site of an experimental utility demand response (DR) program. In this community, at 2 pm on seven particularly hot weekday afternoons that summer, the local electric utility issued a DR text message to a randomly-selected subset of households, asking them to conserve energy between 4 and 8 pm in order to help alleviate tight supplies of power generation. Any difference in average electricity consumption patterns between households that were asked to reduce electricity consumption (i.e., "treatment" households) and those that were not asked (i.e., "control" households) can be considered a "DR effect": a change in behavior induced by the utility's request to reduce electricity consumption. While initial analysis of the electricity consumption data revealed no DR effects, subsequent identification and segmentation of solar households (i.e., households with rooftop solar electricity production systems) from

non-solar households enabled discovery of statistically-significant DR effects for both solar and non-solar households. Of particular interest, while solar households responded to the utility's DR text message in the intended manner by reducing electricity consumption, non-solar households responded by increasing electricity consumption instead. Experimental research is planned to investigate why solar households and non-solar households respond so differently to the same message from the utility.

To my wife, Mary Lucci, without whom I would never have revived (much less completed) my Ph.D. studies, and without whom my life journey would be so much less meaningful and rewarding.

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So now here I am, at sixty-one years of age, finally closing the loop. Thank you one and all for helping me along the way.

"The problem of identity is always a problem, not just a problem of youth."

Norman Maclean

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CHAPTER ONE

Dissertation Overview

1.1 Introduction

This dissertation presents two essays that explore, in two different consumption contexts, factors that drive environmentally consequential choices and behaviors. The first essay develops and experimentally tests a set of hypotheses regarding the factors that influence the likelihood of a consumer making an environmentally-preferable choice, specifically choosing an electric vehicle (EV) over a conventional gasoline powered automobile. The hypotheses stem from a conceptual model based on the Theory of Reasoned Action (Fishbein and Ajzen 1975) and on the notion of identity signaling (Bénabou and Tirole 2011; Escalas and Bettman 2005), and are tested in three experimental studies. Bayesian pooling of the findings shows that environmental and technology commitment as well as knowledge about EVs underpin signaling behavior and influence EV purchase likelihood. Moreover, the findings also show that the higher price of an EV price and the added inconvenience in usage associated with an EV (due to battery charging needs) affects EV purchase likelihood.

The second essay focuses on environmentally consequential choices in a different context: consumer decisions to reduce electricity consumption on hot summer afternoons, in response to requests made by the local utility in a demand response (DR) program. The research examines highly granular secondary data on electricity consumption for a set of households in a focal development. The data were gathered during an extended field experiment conducted by the utility during the summer of 2021 in which selected households were placed in treatment (those who received DR requests via text message) and control (those who did not receive DR

requests) conditions on seven different occasions. The results show intriguing differences in the electricity consumption patterns for households with and without rooftop solar photovoltaic systems in response to the utility's DR requests. An experimental study that further explores the factors driving these response differentials is proposed for future research.

The remainder of this chapter provides the background and motivation for this research, followed by a summary of the conceptual and empirical work undertaken for each of the two essays.

1.2 Background and Motivation

Over the course of history, it is inarguable that technological advancements have been vital in driving improvement of the human condition. Given the increasing pace of technological advancement and how much inventions and innovations have affected (and are affecting) the world, much academic research in recent decades has centered on how and why people adopt new technologies (Bass 1969; Rogers 2003).

Even so, in his classic essay "The Tragedy of the Commons", Hardin (1968) noted that pollution is among the class of human problems that cannot be solved solely by technological advancements but instead also require "change in human values or ideas of morality" (p. 1243). In other words, while new technologies have been necessary for the achievement of significant environmental improvements in recent decades, technological advancements alone are insufficient for producing environmental improvements. Environmental improvements also require shifts in human choices and behaviors.

Human cognitions and motivations underlie choices and behaviors: the combination of core beliefs and habitual thought processes unique to each individual shape perceptions of both (1) one's current situation and (2) future prospects that might result from alternative courses of

action in response to their situation. The linkages from thought to action have been extensively explored in the past half-century by many researchers in the behavioral sciences, spawning a long list of theories well-supported by empirical and experimental evidence in a wide variety of contexts. A comprehensive review of cognitive and motivational theories aiming to explain behavioral choices is beyond the scope of the present review, but a short list includes the Theory of Reasoned Action (Fishbein and Ajzen 1975) and its successor the Theory of Planned Behavior (Ajzen 1991), Self-Determination Theory (Deci and Ryan 1985), and Value Theory (Schwartz 1992).

The past half-century has also witnessed the emergence of environmental matters as a significant topic of interest to social science researchers. Many observers date elevated interest in environment protection back to the seminal work of Carson (1962). Since then, a substantial body of research has coalesced in the new field of environmental psychology (Steg and de Groot 2019), investigating the conceptual relationships between human cognition – encompassing beliefs, assessments, thoughts, and decision-making – and the environmental impacts resulting from the choices made and behaviors undertaken as a consequence of cognition. Much of this research is motivated by a search to understand the mystery summarized in the title of the recent book by DeSombre (2018): “Why Good People Do Bad Environmental Things”.

With very few exceptions (thankfully), no-one wakes up in the morning aiming to deliberately do harm to the planet. Yet, each day, everyone engages in behaviors that in fact do harm the planet, even if the negative impacts are negligible on an individual basis. Collectively, summing over billions of people, these tiny individual impacts can aggregate to significant worldwide impact.

Perhaps no environmental concern exhibits this phenomenon in a more consequential way than climate change. Gradually disrupting life on the planet along multiple dimensions for virtually every species, climate change is arguably the biggest challenge now facing the world (United Nations 2021), and it will remain a massive challenge for the next several decades. To meaningfully address climate change, net levels of carbon emissions stemming from human consumption of fossil fuels must be reduced to zero within the next three decades (International Energy Agency 2021). Virtually everyone on the planet consumes fossil fuels constantly – not just through their personal mobility choices, but also through their continuous purchases of electricity, the fuels they use for heating and cooking, and the freight associated with the products they buy. Climate change is a slowly-worsening environmental specter that stems from an accumulation of infinitesimal contributions from literally billions of independent decision-makers across the globe.

The above observation by (1968) implies that humankind cannot rely solely on the invention of new technologies to fully mitigate the planetary damages stemming from the human actions that are driving climate change. Any major reduction in carbon emissions associated with human activity will also require major behavior changes for major segments of humanity. At minimum, it will require mass adoption of new products and services – often enabled by technological advancements – wherein billions of adopters must accept incurring the expenditure of both additional time and effort to learn the new practices and techniques that are required to use these new products and services in ways that reduce emissions. In addition to adopting new environmentally-friendlier products and services, consumers will also likely need to dramatically change daily activities – many of which are ingrained and thus difficult to alter – in ways that might be perceived as inconvenient (at least during an initial adjustment period).

The bulk of the discourse pertaining to the abatement of carbon emission reductions from the world's population has been guided by conventional economic theory. It is persuasively argued by many parties ((Boyce 2018); (Klenert et al. 2018); (Tvinnereim and Mehling 2018)) that the imposition of an appropriate "price" on carbon emissions would effectively influence both investment and behavioral decisions in ways that reduce emissions and address climate change economically-efficient ways. However, conventional economic theory is principally founded upon assumptions that agents in the market make rational decisions. In work that formed the basis for his later being awarded the Nobel Prize in Economics, Simon (1982) proposed the concept of "bounded rationality." In another stream of work that was also recognized with a Nobel Prize, Becker (1962) recognized that conventional economic theory could not explain repeated findings of seemingly-irrational behaviors in the marketplace, wherein consumers make decisions that appear to outside observers as suboptimal.

The research above formed the basis of the emerging field of behavioral economics (Cartwright 2018). Among the phenomena investigated under the umbrella of behavioral economics are such common foibles of human decision-making as the use of simplifying heuristics to speed up decision-making (Tversky and Kahneman 1974), asymmetric perceptions of gains and losses (Kahneman and Tversky 1979), consideration of losses and gains in separate mental accounts (Thaler 1985; Prelec and Loewenstein 1998), and preference reversals influenced by information presentation (Tversky 1977; Tversky and Kahneman 1986). Not only do the principles of behavioral economics derived from this body of research often provide an underlying explanation of choices and behaviors that defy the assumption of rationality intrinsic to conventional economic theory, but they also explain why consumers resist changing choices and behaviors that are often demonstrably irrational.

Overcoming consumer resistance to change is a central theme for this research because consumer resistance to change is anathema to addressing climate change effectively. To zero out carbon emissions, innumerable consumers will have to make new and different product choices and engage in a variety of new and different behaviors. From a climate standpoint, many of their current choices and behaviors are suboptimal – and also are likely subject to significant resistance to change. While behavioral economics is helping produce better understanding of why consumers often make seemingly irrational choices, it also provides the rationale for information-based interventions – what Thaler and Sunstein (2008) have termed “nudges” – that impose little or no economic cost while also increasing the likelihood of consumers making “better” choices both for themselves and for society at large.

Although inspired by prior and ongoing work in behavioral economics, the research presented in this dissertation aims to contribute to the body of knowledge on how and why consumers make product choices and undertake everyday behaviors that have adverse environmental consequences. The findings should help marketers and policy makers to develop interventions that have the potential to change behaviors to ones that are more climate-friendly, and produce positive environmental outcomes, without incurring significant societal costs or negatively affecting the individual’s perceived quality of life.

At the same time, this research does not aim to undermine arguments in favor of carbon pricing as an appropriate policy response to the threat of climate change. Behaviorally rooted interventions to induce emission-reduction actions cannot be a substitute for but instead can be a supportive complement to climate policy based on sound economic principles. An effective carbon pricing regime would aid behavioral interventions in driving changes in investments and behavior to reduce carbon emissions, and effectively implemented behavioral interventions

should result in lower carbon prices. Policies to meaningfully address climate change remain controversial (Nascimento et al. 2024), largely due to public perceptions in many nations and cultures that the economic burdens created by the implementation of climate policy would be too high. Since at least part of the resistance to the adoption of carbon pricing policies stems from concerns that the cost of inducing desired changes in investments and behaviors would be higher than is socially or politically tolerable, behavioral interventions that can increase the likelihood of volitional carbon-reducing actions by market participants should lower the carbon price necessary to achieve targeted emission reductions.

Ultimately, for a successful global response to the rapidly worsening prospects of climate change, it is important to significantly increase the incidence of environmentally-beneficial choices and behaviors that significantly reduce carbon emissions. Today, companies in virtually all sectors of economic activity are developing and offering an ever-growing spectrum of environmentally-friendly options with smaller carbon footprints. While it is good news that the number of environmentally-beneficial choices facing consumers is expanding, it is equally important that consumers also more frequently select the growing number of possible pro-environmental choices. Otherwise, not only will these new environmentally-friendlier products and services fail in the marketplace, but the desired planetary climate change outcomes associated with continued large volumes of global carbon emissions will not be attained.

Accordingly, those who market environmentally-beneficial alternatives must improve their ability to surmount barriers to consumer adoption – not just any explicit price disadvantages but also the non-economic factors that inhibit change from the *status quo* – if they are to be more widely selected as part of an effective global response to the climate change threat. Marketers will need to better understand how best to craft messages and present information considered

during consumer choice, to better exploit behavioral phenomena that positively influence the likelihood of selecting more environmentally-friendly alternatives, while avoiding messages and information that reduce the likelihood of selecting more environmentally-friendly alternatives. It is imperative that those marketing environmentally-friendly products and services are more successful in their efforts. As Berners-Lee (2019) titled his book, “There Is No Planet B”.

With the above as context, this dissertation is comprised of two essays that explore antecedents of environmentally-consequential choices and behaviors in different consumer choice contexts and using different research methodologies. Each of these two essays is summarized below.

1.3 Overview of Essay One

The first essay of this dissertation describes research undertaken to assess the factors that influence the likelihood of a consumer making an environmentally-preferable choice when deciding upon a big-ticket long-lived capital good with significant implications on carbon emissions for many years to come. The specific context is the choice between an electric vehicle (EV) and a conventional automobile.

The emergence of battery-powered EVs as a viable option in personal vehicle choices is one of the most consequential phenomena occurring in the world today. From a commercial standpoint, the rise of EVs is transforming a large fraction of the global industrial economy. From an environmental standpoint, automobile use for personal mobility represents about a quarter of emissions associated with global fossil fuel combustion (Bharadwaj 2015). As a result, the pace of EV adoption is a pivotal issue to many parties and for multiple reasons. It is therefore valuable to conduct research in the aim of better understanding the antecedent factors affecting the pace of EV adoption.

A new automobile is one of the largest investments that most consumers make, and it is a choice that has important emissions implications over a time horizon of many years. The pace of EV adoption will be dictated by consumer willingness to buy an EV rather than a conventional vehicle the next time the decision is made to buy a new car. Although EVs offer advantages over conventional vehicles, car-buyer willingness to purchase an EV may be negatively affected by two primary disadvantages EVs pose relative to conventional vehicles: a higher purchase price and greater inconvenience associated with recharging (Shi, Sethi, and Çakanyildirim 2022). These two disadvantages – a combination of economic considerations and convenience considerations – may depress interest in purchasing an EV (Naughton 2024). Hence, efforts to reduce these negative impacts should be informed by an understanding of exactly how these two impediments negatively influence EV purchase likelihood.

To investigate this topic, a conceptual model was developed to explore how assessments made by prospective car-buyers during their evaluative process, along with their perception of the major disadvantages associated with buying an EV (higher price and greater inconvenience), affect the dependent variable EV purchase likelihood. The model organizes the relevant factors influencing this complex decision-making process in three distinct ways. First, it arranges several evaluative constructs – ideological commitment, perceptions of EVs as being an advancement to that ideological commitment, perceptions of the signaling value of EV ownership towards that ideological commitment – in a sequence with both direct and indirect (i.e., mediated) pathways to EV purchase likelihood. Second, the model arranges these evaluative constructs in similar ways for two parallel domains of personal interest (commitment) that may influence purchase likelihood of an EV: environmental protection and technology advancement. Third, the conceptual model stipulates that the two critical impediments to EV

selection – higher price and greater inconvenience – moderate the sequentially-mediated pathway to EV purchase likelihood.

The pathways in the conceptual model are presented as formal hypotheses and then tested in three experiments conducted with study participants drawn from commercial web panels. Multiple items were developed to measure each of the relevant constructs in the model. The data from these three experiments were then empirically analyzed using a path analytical model that tested ten pairs of hypotheses (parallel hypotheses for environmental commitment and commitment to technology advancement). The results of the three experiments were fairly consistent with each other. To more fully reconcile the findings across the three experiments, a Bayesian pooling of the results (Winkler 1981) was undertaken to derive a single set of coefficients for the conceptual model utilizing the data from the three experiments.

This Bayesian pooling revealed significant support for the conceptual model. First, the twin impediments to EV adoption – higher price and greater inconvenience – were both found to negatively affect EV purchase likelihood. The hypotheses associated with the relationships involving the sequentially-mediated constructs for both the environmental and technology pathways in their effects on EV purchase likelihood were also well supported by the empirical findings.

Notably, the findings also revealed selected asymmetries between the environmental and technology pathways. As expected, the environmental signaling value attributed to EV ownership positively affects EV purchase likelihood: owning an EV thus appears to send a signal that the owner is concerned about environmental protection, and further that this signal is viewed favorably by a prospective EV owner. On the other hand, the technology signaling value attributed to EV ownership negatively affects EV purchase likelihood: while owning an EV does

also appear to send a signal that the owner is committed to technological advancement, this signal is viewed negatively by a prospective EV owner. In colloquial terms, it is good to be seen as “green” and EV ownership signals greenness, but it is undesirable to be seen as “geeky” and EV ownership signals geekiness.

Moreover, while the interaction between environmental signaling and inconvenience of EV ownership was not significant, the corresponding interaction between technology signaling and inconvenience was found to be positive. When perceived inconveniences are sufficiently high, the positive effect on EV purchase likelihood can overcome the negative direct effect of technology signaling on EV purchase likelihood. Meanwhile, the EV price premium did not moderate the effect of either environmental signaling value or technology signaling value on EV purchase likelihood.

Finally, while specific knowledge about EVs in the technological advancement domain has a direct positive influence on EV purchase likelihood, this does not appear to be the case in the environmental domain. All downstream effects of specific knowledge about EVs with respect to environmental protection are mediated by the perceptions of EV effectiveness in benefiting the environment. A consumer perceives the implications of EV ownership on environmental impact entirely through the lens of how well EVs reduce emissions. Thus, understanding how EVs benefit the environment does not directly affect EV purchase likelihood, but instead is mediated by the belief that EVs benefit the environment.

Chapter 2 provides a more detailed discussion of this study and its findings, and also discusses the academic, practitioner and policy implications of the study results. There is considerable food for thought in how marketers should position the environmental and technological benefits of EVs so as to remove perceptual barriers and stimulate adoption.

1.4 Overview of Essay Two

The second essay of this dissertation focuses on environmentally-consequential choices in a different context: consumer decisions to reduce electricity consumption on hot summer afternoons, in response to requests made by the local utility in a demand response (DR) program. The research examines highly granular secondary data on electricity consumption for a set of households in a focal development in one of the mountain states. The data had been gathered during an extended field experiment conducted by the utility during the summer of 2021 in which selected households were placed in treatment (DR requests) and control (no DR requests) groups on seven different occasions.

DR programs exist to help electric utilities maintain reliable grid operations when regional electricity demands rise to such high levels that available generation supplies are barely adequate. Under these conditions, small voluntary reductions in electricity consumption by many customers in a region during a few hours can significantly reduce the prospect that the utility will be required to ration electricity supplies via rotating outages (a.k.a. load-shedding). In the future, as electricity supplies from the grid become more reliant on intermittent zero-carbon sources (e.g., solar and wind), DR programs will become increasingly critical for utilities to preserve reliable grid operations.

Among the wide array of DR program designs, pro-social DR programs (Pratt and Erickson 2020) represent a particularly interesting category of DR in which the utility communicates to customers an upcoming need for electricity consumption reduction, purely appealing to the customer's willingness to perform what is essentially a favor for the region. Accordingly, a customer's response to a pro-social DR program is not explicitly motivated by economic considerations, but rather by a combination of affective and cognitive considerations

about the appropriate electricity consumption behaviors to undertake, given the individual's overall beliefs and their personal circumstances at the time of the request. As Pratt and Erickson (2020) note, pro-social DR programs can be seen as a prototypical “nudge” in the terminology of behavioral economics (Thaler and Sunstein 2008), wherein changing the way the customer views the situation through cleverly-designed information provision changes the customer's behavioral choices in a manner that is more pro-social.

The research in this essay exploits panel (both time series and cross-sectional) data on household electricity consumption that has been gathered from an experimental pro-social DR program launched and managed by an electric utility in a new master-planned housing community in a suburb of a large metropolitan area in the Western U.S. In this program, the utility can declare a “DR event” on any weekday during the summer months. As a practical matter, the utility declares a DR event only on days in which ambient weather conditions are very hot and humid, which in turn produce very high levels of regional air conditioning demand in the late afternoon hours. When the utility decides to declare a DR event for a certain day, it sends a text notification at 2 pm (1) informing the recipient that the regional electricity grid will be experiencing strains in meeting anticipated demands in the upcoming afternoon, and (2) asking the recipient to voluntarily reduce electricity consumption between 4 pm and 8 pm local time (henceforth referred to as the “DR window”).

Crucially, to assess the ability of these requests to induce changes in consumer behavior, the utility is managing the DR program as a randomized controlled trial (RCT) experiment (Stolberg, Norman, and Trop 2004). For each DR event, the utility randomly selects half of the households in the community to receive a DR notification text, with the remaining half of the households not receiving any such text. Thus, for any given DR event, households receiving a

DR notification text are considered to be in the “treatment” condition, while households not receiving a text are in a corresponding “control” condition. Randomization of household selection to the treatment condition occurs independently for each DR event, so that across DR events, there is zero correlation between households and treatment condition to which they are assigned. This minimizes the possibility of systematic differences between the control and treatment households for a given DR event. The RCT design of the DR program and the homogeneity of the household profiles within this community suggests that statistically significant differences in observed electricity consumption between treatment (DR text notification) and control (no DR notification) households should be attributable to the DR notification (versus other sources of endogeneity).

The dataset analyzed in this research contains electricity consumption data – the amount of electricity being purchased by the household from the electric utility – electronically retrieved in 15-minute intervals from the electricity meter attached to each household in the community. These longitudinal electricity consumption data span the 114 days from June 1, 2021 to September 22, 2021, and contain 10,944 consecutive 15-minute intervals. After data cleansing, 307 households remained with electricity consumption data throughout the entire timespan to be used for analysis. Given observations for each household at 10,944 consecutive 15-minute intervals during the timespan, the panel dataset used in the analysis contained 3,359,808 observations (307 x 10,944). During the summer 2021 timespan of the dataset, the utility invoked seven DR events.

The objective of the empirical analysis was to identify the possible existence of a DR “effect” on the seven DR event days, as indicated by statistically significant differences in electricity consumption between treatment households that received the DR notification relative

to control households that received no notification. Statistical analysis consisted of panel regressions with fixed effects, wherein the dependent variable was household electricity consumption for each 15-minute time increment and the independent variables were a series of dummy variables to account for (1) the 24 different hours of the day (during which electricity consumption varies considerably on a dependable pattern) and (2) whether the household was assigned to the treatment or control condition for that DR event day.

Initial investigation of each of the seven DR event days revealed no obvious pattern of DR effects: estimated coefficients for the treatment effect dummy variables were not statistically different from zero. However, a closer examination of the data revealed that there were two segments of households with distinctly different daily electricity consumption patterns: solar households and non-solar households. The differences in electricity consumption patterns between solar and non-solar households tended to mask DR effects. After controlling for these differences using dummy variables to distinguish solar versus non-solar households, subsequent analyses revealed robust DR effects that differed for solar and non-solar households.

Consistent with having pro-environmental credentials, solar households reduced electricity consumption after receiving a DR notification from the utility. However, non-solar households showed an increase in their electricity consumption after receiving the identical DR notification. Additional empirical analysis of the household electricity consumption data revealed that solar households – while responding favorably to DR notifications – consumed substantially more electricity than non-solar households outside of DR events. In other words, solar households behaved more pro-environmentally during DR events, but otherwise behaved less favorably from an environmental perspective. This finding echoes the conclusions of prior work (Stolberg, Norman, and Trop 2004; Deng and Newton 2017; Qiu, Kahn, and Xing 2019;

Beppler, Matisoff, and Oliver 2023; Aydın, Brounen, and Ergün 2023) showing that gross household electricity consumption in fact is higher for households with installed rooftop PV systems.

This empirical analysis thus reveals sharp differences in electricity consumption patterns between solar and non-solar households that deserve further research attention. Two of the identified consumption patterns are particularly puzzling.

First, why might solar households lower their electricity consumption in response to DR notifications, but be less attentive to their electricity consumption behavior during other hours? Perhaps these households have an implicit commitment to energy conservation that is activated by the DR notification and elicits reduced electricity consumption behaviors? Higher levels of consumption during other (non-DR) hours may simply reflect larger homes and/or a stock of appliances/devices that naturally consume more electricity. Alternatively, perhaps solar households exhibit a form of moral licensing (Monin and Miller 2001) whereby they reason that their costly prior investment in a rooftop solar device entitles them to be less attentive to their day-to-day energy consumption?

Second, why do non-solar households counterintuitively increase (rather than reduce) electricity consumption in response to a DR request? Perhaps non-solar households place more emphasis on the implicit message embedded in the DR notification that the upcoming afternoon will be hot and uncomfortable, thus justifying to themselves an increase in air conditioning utilization. As a non-solar household in a relatively affluent development that emphasizes energy efficiency, they may be less committed to energy conservation, and hence less likely to respond favorably to the DR notification. The behavioral economics underpinning of these

puzzling empirical results on electricity consumption phenomena deserve further investigation in future research.

Chapter 3 discusses in detail the findings from this empirical analysis and concludes by outlining the design of a future experimental study to address potential explanations of these unexpected electricity consumption phenomena at solar and non-solar households.

CHAPTER TWO

Influences of Self-Identity and Signaling on Electric Vehicle Adoption

2.1 Introduction

One of the most important contemporary developments is the emergence of battery-powered electric vehicles (EVs) as a viable personal vehicle option. From a commercial standpoint, EVs are transforming a large part of the global economy. Over a trillion dollars (Lienert 2022) is being invested by auto manufacturers and the supporting supply chain to bring new EV models to market and expand EV production capacity. Meanwhile, profound shifts are occurring in the multi-trillion dollar energy sector: oil companies are losing market share to the electricity sector (World Economic Forum 2023), which in turn will require significant expansion of both generating capacity and delivery infrastructure to meet EV charging needs (Brigham 2023). For many of the world's largest industrial corporations, and the untold number of enterprises worldwide that serve them, the financial stakes associated with the pace of EV adoption are extremely high.

The environmental stakes associated with the pace of EV adoption are also very high. Climate change is driven by emissions of greenhouse gases (GHGs) that mostly originate from burning fossil fuels that power the world's economy. In order to avoid severe planetary damage, the nations of the world have agreed in principle that they must effectively eliminate human-caused GHG emissions by mid-century (International Energy Agency 2021). Since road transportation is responsible for about a quarter of the GHG emissions associated with global fossil fuel combustion (Bharadwaj 2015), one of the most important pathways to eliminate GHG emissions in a few decades involves shifting the world's automotive fleet from petroleum-based

fuels to using EVs recharged by electricity produced from zero-carbon sources. Although the carbon footprint associated with manufacturing an EV is usually higher than for a conventional vehicle, the per-mile carbon footprint of the EV is much lower, so that the resulting total emissions profile of an EV is up to 70% lower over the vehicle's lifecycle (McKerracher 2024). If climate change mitigation goals are to be achieved, it is thought that the transition from petroleum-based automobiles to EVs must be complete in roughly two decades (Nature 2023) – a daunting prospect.

The pace of EV adoption is therefore a pivotal issue to many parties and for multiple reasons. Although some stakeholders (e.g., oil companies) may prefer that EV adoption remains sluggish, many others would prefer an acceleration in EV adoption rates. Since EV adoption rates would be largely driven by consumer willingness to buy an EV (versus a conventional vehicle) on future purchase occasions, this research focuses on the factors that may influence individual consumers to purchase a battery-powered EV rather than a conventional automobile powered by an internal combustion engine (ICE) that consumes petroleum-based fuels (e.g., gasoline).

The automobile purchase process has received significant attention in the marketing literature (Punj and Staelin 1983; Sullivan, Jones, and Reynolds 2020) as well as in other related literature (e.g., Fujita et al 2022). These studies document that the decision-making process associated with the purchase of a vehicle is multi-faceted, including consideration of both quantifiable factors (e.g., price, fuel economy, acceleration, range, cargo space, etc.) and highly subjective factors (e.g., aesthetic appeal, comfort, ability to provide enjoyable driving experiences, signaling of social status, etc.). Notwithstanding these complexities, research has shown that car-buyer willingness to purchase an EV is negatively affected by two primary

disadvantages EVs pose relative to conventional vehicles: higher purchase price and greater inconvenience associated with recharging (Shi, Sethi, and Çakanyildirim 2022).

First, EVs have a higher purchase price than conventional vehicles – a factor that deters EV purchases by prospective car-buyers (Carley et al 2013). The average transaction price for an EV in the U.S. in July 2023 was about \$5,000 higher than that of the average gasoline-powered vehicle (Valdes 2023). However, the true magnitude of an EV’s price premium over an otherwise-identical ICE counterpart is difficult to estimate because auto manufacturers change the features of the variants to mask the true cost differential between producing an EV or its ICE twin (Hittinger 2023).

Table 2.1: EV Price Premiums for Cars on Sale in United States

ELECTRIC VS. GAS VEHICLE PRICE COMPARISON					
18-Jul-23					
OEM	Gas Model	Electric Model	Gas MSRP	Electric MSRP	Price Premium
BMW	330i	330e	\$ 43,800	\$ 44,900	\$ 1,100
BMW	330i xDrive	330e xDrive	\$ 45,800	\$ 46,900	\$ 1,100
BMW	530i	i5	\$ 57,900	\$ 66,800	\$ 8,900
Genesis	G80 3.5T Sport AWD	Electrified G80	\$ 65,750	\$ 79,255	\$ 13,505
Hyundai	Kona SEL	Kona SEL	\$ 23,950	\$ 37,300	\$ 13,350
Hyundai	Kona Limited	Kona Limited	\$ 28,950	\$ 41,550	\$ 12,600
Jaguar	F-PACE R Dynamic S P400	I-PACE R Dynamic HSE EV400	\$ 66,500	\$ 72,000	\$ 5,500
Mercedes	GLB SUV	EQB SUV	\$ 39,800	\$ 52,750	\$ 12,950
Mini	Cooper S	Cooper SE	\$ 29,100	\$ 30,900	\$ 1,800
Volvo	XC40	XC40 Recharge	\$ 36,350	\$ 53,550	\$ 17,200
					\$ 8,801 Average

As Table 2.1 shows, among the few vehicle models on offer (as of the summer of 2023) in the U.S. by auto manufacturers with both electric and ICE powertrains, the MSRP difference between an EV and a comparable ICE vehicle ranged from \$1,100 to \$17,200, averaging \$8,800 among 10 auto models. Even after government subsidies that encourage EV adoption (Sheldon, Dua, and Alharbi 2023) the EV price premium is generally substantial relative to the overall price of an automobile – which averaged about \$48,000 in the U.S. in 2023 (Valdes 2023).

Second, EVs require car-owners to tolerate substantially more inconveniences associated with battery recharging than is associated with refueling an ICE vehicle (Graham-Rowe et al 2012; Rabinowitz et al 2023). These inconveniences are especially pronounced while on an extended trip away from home (Domonoske 2023). Not only is it harder to find a place to recharge an EV than to find a traditional service station for refueling a conventional vehicle – a phenomenon that has widely become known as “range anxiety” (Pevac et al 2019) – but even when an operable recharging point is found, fully recharging the batteries of an EV requires far more time than refilling an ICE vehicle fuel tank (Dixon et al 2020). It is challenging to quantify the subjectively-perceived inconveniences associated with EV recharging (Rabinowitz et al 2022). Moreover, EVs offering the best recharging performance (when using the relatively scarce fast-charging equipment) require about 10 minutes for a 100-mile addition of range (Randall 2023), whereas refueling an ICE automobile for substantially less than 10 minutes extends its range by several hundred miles.

These two sets of disadvantages – a combination of economic considerations and convenience considerations – depress interest in purchasing an EV (Naughton 2024). However, most observers expect these twin impediments to EV adoption will diminish over time. The price premium associated with EVs is expected to decline as batteries become cheaper (Goldman Sachs 2023). Meanwhile, the inconveniences associated with EV charging – especially when traveling longer-distances – should decline as public charging infrastructure becomes more widespread (Telang et al. 2021). However, the pace at which these two disadvantages may diminish is uncertain, and they may never completely be eliminated. A better understanding of how these two impediments negatively influence EV purchase likelihood may enable EV manufacturers and marketers to effectively counter their effects.

EVs still represent a minority share of automobile sales (Bullard 2024), and their adoption patterns should reflect processes described in Rogers' theory of adoption and diffusion of innovations (Rogers 2003). Contemporary EV buyers may therefore be viewed as "early-adopters". Furthermore, because EVs are generally perceived as being environmentally-friendly (Barbarossa, De Pelsmacker, and Moons 2017) and technologically-innovative (Heffner, Kurani, and Turrentine 2007), arguably the two most important segments among early-adopter EV buyers are (1) those who are committed to environmental protection and (2) those who are committed to technology advancement. Buyers in these two early adopter segments may view the twin disadvantages associated with EVs (price and inconvenience) differently. Hence, even if the adoption processes are structurally similar for these two early-adopter segments, the nature and direction of their effects may differ significantly.

The research described herein aims to strengthen understanding of how the twin impediments of higher price and additional inconvenience associated with EVs interrelate to the various subjective assessments that car-buyers must make, not only about the automobiles under consideration but also about themselves. The decision between a battery-powered EV and an ICE vehicle must therefore be viewed through the dual lenses of environmental concern and interest in technological advancement.

The remainder of this essay is structured as follows. Section 2.2 reviews the relevant literature, which informs the development in Section 2.3 of a conceptual model describing how prospective buyers process and assess the price and inconvenience disadvantages of EVs when making a purchasing decision. Section 2.4 presents ten pairs of hypotheses that formally capture the relationships between theoretical model constructs to be tested using data collected from survey-based experiments. Section 2.5 describes survey design and procedures used in the

experiments to gather data. The empirical results from three independent but similar experiments are presented in Section 2.6, while Section 2.7 presents an integrative discussion of the results from the three experiments, based on a Bayesian pooling of the results. The real-world implications of these findings are presented in Section 2.8. Section 2.9 offers some suggestions for additional research to extend the work presented herein, and Section 2.10 provides some concluding remarks about how this research contributes to the body of knowledge relevant to both academics and practitioners.

2.2 Literature Review

A significant body of research has begun to accumulate on the factors that influence EV adoption, as reviewed by Rezvani et al (Rezvani, Jansson, and Bodin 2015) and Salari (Salari 2022). See also Fujita et al (2022). While the body of prior work touches upon many related topics, no published literature directly investigates the sequential nature of assessments made by a prospective car-buyer when assessing the appeal of purchasing an EV. In particular, the existing literature does not explicitly consider (1) the simultaneous ability of EV ownership to cater to environmental protection concerns and interest in technological advancement and (2) the impact of the twin disadvantages of EVs relative to traditional ICE vehicles: higher price and greater inconveniences associated with recharging.

The body of scholarly knowledge most important to review for this research addresses matters of consumer choice within the broader academic field of marketing. From the consumer choice domain, this review organizes the literature by discussing prior work that has shown how (1) product purchases and ownership signal an individual's identity, (2) environmental concern and technology enthusiasm drive both identity and signaling through purchases, and (3) an individual's values and beliefs shape their attitudes, then their intentions, and then finally their

behaviors. In each of these three sections, prior research that specifically relates to EVs will be highlighted. A synthesis of these three literatures provided the basis of the conceptual model that was developed (see Section 2.3) and the corresponding hypotheses (see Section 2.4) that were empirically tested in this research.

2.2.1. Product Purchases and Ownership Signal Identity

It has long been recognized that there is a linkage between an individual's identity in the world and their choices of affiliation, including their possessions – that is, their product purchases. As William James (James, 1890, p. 291) wrote over 130 years ago, “a man's Self is the sum of all he can call his own.” Levy (Levy 1959) observed that “all commercial objects have a symbolic character, and making a purchase involves an assessment – implicit or explicit – of this symbolism.” (p. 119). Belk (1988) built upon this realization by tying a product's symbolism to the self, stating that “our possessions are a major contributor to and reflection of our identities.” (p. 139).

This linkage between product choice and self-identity can thus be conceived as a signal: product choices often communicate a signal about the consumer's own identity, in large part because of the values that the firm supplying the purchased products has signaled to the public through advertising (Wernerfelt 1990). This linkage between product choice and signal has been explored and substantiated both in the behavioral field (Escalas and Bettman 2005) and in economics research (Bénabou and Tirole 2011). In many respects, the signaling that stems from ownership of a product expresses an individual's differentiation from others. Prior research has shown that individuals often seek to differentiate themselves from others to convey a more distinctive identity, and furthermore to signal this distinctiveness through their product choices (Vignoles, Chrysochoou, and Breakwell 2000). Identity signaling behavior may involve self-

signaling without regard to external others (Prelec and Bodner 2003) or more commonly reflect efforts to signaling an identity to others (Berger and Heath 2007; Gal 2015).

Signaling one's identity through product ownership is especially pronounced with respect to the purchase of an automobile, one of the most visible possessions of all. Over 100 years ago, automobiles were already widely viewed as a status symbol (Morewood 1993). Steg (2005) identified that car use fulfills important symbolic functions for the car's owner. Escalas and Bettman (Escalas and Bettman 2005) described how automobiles signaled not only identity but also membership in an esteemed ingroup: "if I consider myself an intellectual and my member group of intellectuals tends to drive Volvo automobiles, I also may choose to drive a Volvo car as a symbol of how intellectual I am." (p. 379). With respect to EVs, Burgess et al (2013) highlighted how EV owners are especially susceptible to being stereotyped when publicly observed driving their EVs.

2.2.2. Commitments to Environment and Technology Signaled Through Purchases

Consumers express their individual distinctiveness in some domains more than others via signals generated by product choices in those domains of greater personal importance to them (Berger and Heath 2007). In the words of Kleine et al (1993), "the more important an identity to us, the more attractive its associated products." (p. 209). Thus, it follows that some consumers may be motivated by a desire to send a signal of their exceptional commitment to environmental protection via their choice of products widely seen to be environmentally-friendly, while others may want to signal their technical sophistication via their choice of products widely seen to be highly innovative.

In his doctoral dissertation, Griskevicius (2008) echoed the phrasing of Veblen (1899) to coin the term "conspicuous conservation" to describe situations where "status motives can lead

people to...choose products that have prosocial, green features.” (p. iii). In subsequent work, Griskevicius, Tybur, and Van den Bergh (2010) found that conspicuous conservation increases when two critical factors are at play: (1) the purchase is made in public rather than privately (i.e., can be seen as a signal), and (2) the cost of the environmentally-favorable product is higher. Reflecting further upon both factors, Brick et al (2017) showed that conspicuous conservation applies not just to product purchases but also to ongoing (and publicly visible) use of the product. Meanwhile, Sexton and Sexton (2014) and Berger (2019) provided evidence that a price premium was essential to conspicuous conservation; this is logical, as even customers lacking strong commitment to the environment would select the environmentally-favorable choice if its price were not higher. Along similar lines, Van der Werff et al (2014) reported that green signals are more powerful to the extent that people had to pay more or work harder to demonstrate greenness.

In the specific context of EVs, Barbarossa et al (2017) found that green self-identity significantly influenced EV purchase likelihood, while White and Sintov (2017) showed not only that EVs possess environmental symbolism but that the perceptions of such symbolism by a prospective car-buyer is a very strong predictor of EV adoption. Peters et al (2018) found evidence that the linkage between EV adoption and green identity was bi-directional: “the more people adopted an EV for environmental reasons, the stronger their environmental self-identity, in turn increasing the likelihood that they engaged in other sustainable energy behaviours.” (p. 234).

Meanwhile, the motivation for a consumer to purchase a product founded upon a new technology has its own signaling dynamics. Rogers (2003) noted that “the desire to gain social status” was an important motivation for an individual to adopt an innovation (p. 230). Venkatesh

and Brown (2001) noted that “the desire for social outcomes is more important for earlier adopters than later adopters” (p. 75). Wood and Hoeffler (2013) found that “the use of new high-tech products can be a surprisingly effective social signal of one’s ‘tech-savvy’ and personal innovativeness.” (p. 1254). This touches upon the notion of “coolness” as an important motivator for consumers to adopt new technologies (Kerner and Pressman 2007). However, too much coolness may not be a good thing: Arbore et al (2014) noted that positive signaling impact associated with an innovative technology is not necessarily monotonic: “its symbolic value might become negative, turning from a facilitator of adoption into an impediment” (p. 87) as the signal goes beyond being “cool” (a socially-desirable descriptor) to being “geeky” (a descriptor connoting social awkwardness).

Technology enthusiasm has long been known to be a key factor in EV adoption: Ewing and Sarigollu (2000) determined that marketing of EVs (at least during the early years) may be more effective if targeted to “actively concerned” individuals, to whom “the EV should be positioned as an innovative vehicle and not directly compared with the gasoline-powered car.” (p. 114). Subsequent research further substantiates that commitment to technological advancement positively affects interest in purchasing an EV (Jabeen et al 2012; Morton, Anable, and Nelson 2016; Salari 2022).

Although environmental signaling and technology signaling reflect different dimensions, it should be noted that many environmentalists are also technologically-savvy (and vice versa). Reducing one’s environmental footprint often entails enthusiastic adoption of a new technology that produces lesser environmental impact. As such, being (and being seen as) an environmental leader often means being (and being seen as) an early adopter of new technology. Noppers et al (2014) examined this point using a study with EVs as context and concluded that “sustainable

innovations may symbolize a ‘green image’ for people who endorse environmental values or ‘sustainability-oriented’ values, while they may symbolize innovativeness or uniqueness for people who are keen to be early adopters.” (p. 60). Along similar lines, Plötz et al (2014) reported that their survey respondents who indicated a preference for EVs were more likely to agree with both of two statements: (1) it was important for them to drive a car that harms the environment as little as possible and (2) they enjoy trialing technical innovations even if not yet widely used.

2.2.3. Values and Beliefs Shape Attitudes, Intentions, and Behaviors

The research reviewed above shows that product ownership can play an important role in affirming personal identity and in signaling that identity to others, and that such instrumentality may be particularly strong in the domains of environment and technology. Thus, an individual’s commitment to protecting the environment and to advancing technology provide the respective values that shape attitudes and ownership intentions for products that yield environmental benefits and are technologically innovative. To the extent that an individual knows (or believes) that the focal product possesses features that promote these key values, the individual harbors a positive attitude toward the product, perceives its identity signaling potential, and displays product ownership intentions.

The Theory of Reasoned Action (TRA) developed by Fishbein and Ajzen (1975) provides a platform for examining the above process. TRA proposes a highly-generalizable model of behavior in which an individual’s deepest-held values and beliefs shape attitudes relevant to the context at hand, which in turn affect intentions to act within that context. Reflecting its adaptability, TRA has been widely used and cited across many academic disciplines. Much of the research related to environmental protection or technology adoption

reviewed in Sections 2.2.1 and 2.2.2 are applications of TRA or its variants and extensions such as the Theory of Planned Behavior (Ajzen 1991).

In the more specific context of the EV purchase decision, other researchers have looked to TRA as a basis for examining how the factors that affect purchase likelihood interrelate. Thus, MacInnis, Krosnick, and McDonald (2023) reference TRA in asserting that “purchasing an EV is most likely the result of an intention to make such a purchase” (p. 2), and subsequently develop a conceptual framework influenced by TRA. More substantively, building upon the work of Wang et al (2016) involving similar survey data in China, Alzahrani et al (2019) employed a model based on TRA to predict purchase likelihood of hybrid electric vehicles in Saudi Arabia, finding that the effect of environmental concern on purchase likelihood is mediated through both attitudes and social norms.

The present research, including the conceptual model developed below, differs in three major ways from the TRA-based investigations of EV purchase likelihood cited above (Wang et al 2016; Alzahrani, Hall-Phillips, and Zeng 2019). First, the prior studies were limited to consideration of the prospective car-buyer’s environmental commitment, without consideration of their commitment to technology advancement. Second, the prior research did not investigate the effects of identity-signaling on EV purchase likelihood. Third, the prior research did not examine how the two primary disadvantages associated with EVs (higher price and their greater inconvenience) influence EV purchase likelihood. Because of these differences, this research fills a gap in the prior literature.

2.3 Conceptual Model

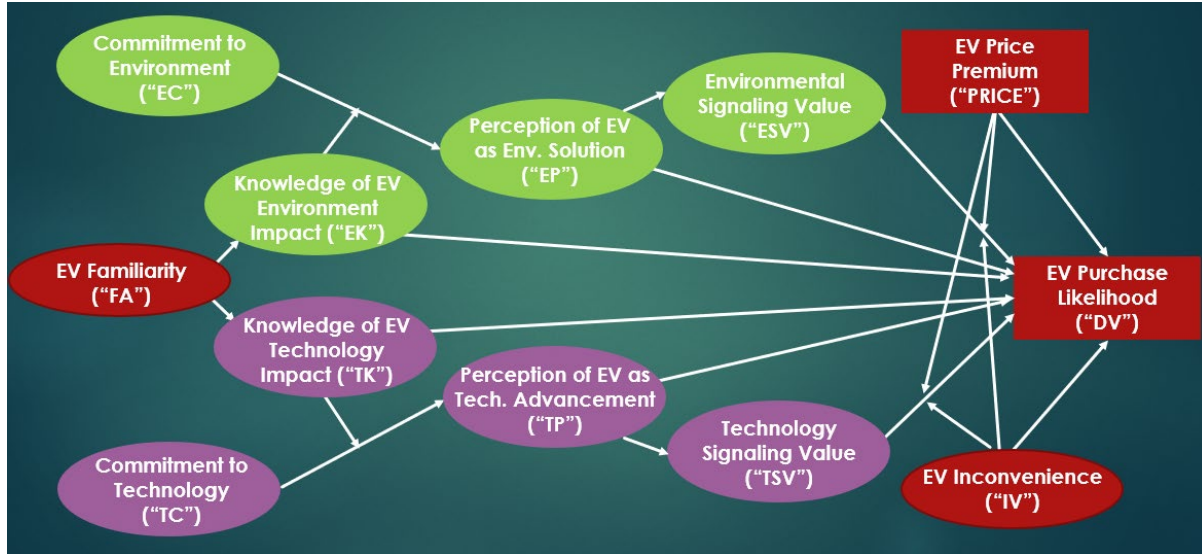
The conceptual model presented herein was developed to explore how multiple subjective assessments made by prospective car-buyers during their evaluative process, along

with their perception of the major disadvantages associated with buying an EV (higher price and greater inconvenience), affect EV purchase likelihood. Thus, the dependent variable of interest for this research is EV purchase likelihood - a subjective assessment of the intention to buy an EV. Given the significant expense and importance involved, an EV purchase is expected to engage high involvement and deliberative processing. As such, TRA provides an appropriate platform for the development of a conceptual model that organizes the factors influencing an individual's evaluations of alternative vehicle options. Thus, the relationships embodied in the model are formally captured in a set of hypotheses that are empirically tested in experiments involving human participants.

The model organizes these factors in three distinct ways. First, it arranges several evaluative constructs in a sequence, as informed by TRA, with both direct and indirect (i.e., mediated) pathways to EV purchase likelihood. Second, the conceptual model uses this sequencing of constructs to describe the evaluation processes in the two parallel value domains: environmental protection and technology advancement. These evaluative processes culminate in parallel assessments of the identity signaling value of EV ownership in the two domains. Third, the conceptual model stipulates that the two critical impediments to EV selection – higher price and greater inconvenience – moderate the sequentially-mediated pathways to EV purchase likelihood.

The conceptual model is presented in Figure 2.1 below. This is followed by a discussion of each of the three organizing principles of the conceptual model, in the order presented above.

Figure 2.1: Conceptual Model



2.3.1. Sequential Mediating Assessments Culminating in EV Purchase Likelihood

The TRA postulates an evaluation process that is fundamentally sequential: values and beliefs affect attitudes, which affect intentions. Accordingly, the conceptual model assumes that the prospective car-buyer reaches a subjective assessment of their EV purchase likelihood (a behavioral intention) in a series of steps. The assessment occurs in the context of the car-buyer’s general familiarity with EVs, which provides specific knowledge (a set of beliefs) that are pertinent to the EV purchase decision. The beliefs in each focal domain of concern combine multiplicatively with the person’s ideological commitment (values) in that focal domain to produce an assessment of the extent to which the EV’s provides a solution to the focal ideological concern (an “attitude” in TRA terms). In turn, this drives an assessment of how much owning an EV serves as an identity signal (to themselves and others) about their commitment to the focal ideological concern. Importantly, the model implies both direct and indirect paths from each construct to EV purchase likelihood. The indirect paths to EV purchase

likelihood imply mediation through other intervening constructs in a sequential chain. These issues are discussed further in Sections 2.7 and 2.8.

2.3.2. Commitments to Environment Protection and Technology Advancement

The conceptual model posits two sets of serial mediation pathways that are structurally similar: one associated with a car-buyer's concern for environmental protection (presented in green in Figure 2.1), and the other associated with a car-buyer's concern for technological advancement (presented in purple in Figure 2.1). Note that the choice between an ICE vehicle and an electric vehicle has significant ramifications in two domains of personal commitment (values): environmental protection and technological advancement. From an environmental standpoint, EVs are generally seen as having a substantially lower emissions footprint than a conventional ICE vehicle (powered by petroleum-based fuels). From a technological standpoint, EVs represent a significant (i.e., more than incremental) innovation that requires automobile owners to learn and utilize new behaviors (especially pertaining to recharging) for effective use. Thus, when deciding between an ICE vehicle and an electric vehicle, a car-buyer is inevitably (even if only subconsciously) pressed to think about their parallel commitments to environmental protection and technological advancement.

2.3.3. EV Disadvantages as Moderators of Signaling Value Effect on Purchase Likelihood

The two primary disadvantages associated with buying an EV – the higher purchase price and the added inconvenience associated with recharging – should unambiguously reduce EV purchase likelihood in the car-buying decision. The question is whether these disadvantages attenuate EV purchase likelihood in ways other than a direct negative relationship. In the conceptual model, the negative impacts of higher EV price and greater EV inconvenience are posited to affect EV purchase likelihood by moderating how the identity signaling value of EV

ownership influences EV purchase likelihood. In other words, both the EV's price premium and the extra inconvenience associated with EV ownership are expected to influence the relationship between the identity signaling value of EV ownership (commitment to environmental protection and technology advancement) and EV purchase likelihood.

2.4 Hypotheses

The conceptual model organizes the posited inter-construct relationships along specific hypothesized pathways that depict directional relationships (positive or negative). Specifically, two sets (for environmental protection and technology advancement concerns, respectively) of ten hypotheses are advanced for empirical testing. These are described next in the general order of their appearance in the conceptual model.

2.4.1. Sequential Mediative Pathways

The sequential pathways of evaluative constructs originate with ideological commitment. The first pair of hypotheses relate to the effect of ideological commitment on perceptions of EVs as benefiting that ideological commitment. The strength of the car-buyer's ideological commitment (to either environmental protection or technological advancement) should positively influence the car-buyer's perceptions of EVs (given that EV's are viewed to benefit both commitment domains).

- **H1a: Environmental commitment has a positive impact on perceptions of EVs as an environmental solution.**
- **H1b: Technology commitment has a positive impact on perceptions of EVs as a technological advancement.**

Because EVs are widely seen to be both more environmentally-friendly and more technologically-advanced than ICE vehicles, it is also assumed that a car-buyer's familiarity with

EVs should positively influence knowledge about how EVs favorably affect each of the two relevant ideological commitment domains (environmental protection and technological advancement).

- **H2a: EV familiarity has a positive impact on knowledge about the environmental implications of EVs.**
- **H2b: EV familiarity has a positive impact on knowledge about the technological implications of EVs.**

In turn, specific knowledge about the implications of EVs on the two domains of ideological concern should directly and positively affect EV purchase likelihood. In other words, the more that a car-buyer knows about the (generally positive) impact of EVs for each focal concern, the higher the likelihood of an EV purchase.

- **H3a: Knowledge about an EV's environmental implications will have a positive impact on EV purchase likelihood.**
- **H3b: Knowledge about an EV's technological implications will have a positive impact on EV purchase likelihood.**

In addition to its direct effect on EV purchase likelihood, specific knowledge about the implications of EVs on a domain of concern should interact positively with the degree of ideological commitment when assessing the EV's instrumentality for that commitment. In other words, ideological commitment matters more when specific knowledge level about the EV's implications on that commitment is higher (versus lower).

- **H4a: Knowledge about an EV's environmental implications and commitment to environmental protection have a positive interactive impact on an individual's perception that EVs are an environmental solution.**

- **H4b: Knowledge about an EV's technological implications and commitment to technology advancement have a positive interactive impact on an individual's perception that EVs are a technological advancement.**

It intuitively follows that a car-buyer's assessment of how much an EV supports their ideological commitments should have a direct positive effect on EV purchase likelihood.

- **H5a: An individual's perception that EVs are a beneficial environmental solution will have a positive impact on EV purchase likelihood.**
- **H5b: An individual's perception that EVs are a beneficial technological advancement will have a positive impact on EV purchase likelihood.**

Moreover, a car-buyer's assessment of how much an EV supports a focal ideological commitment should have a direct positive effect on the individual's perception of how strongly EV ownership signals this ideological commitment.

- **H6a: An individual's perception that EVs are a beneficial environmental solution has a positive effect on the individual's assessment of how strongly EV ownership signals their commitment to environmental protection.**
- **H6b: An individual's perception that EVs are a beneficial technological advancement has a positive effect on the individual's assessment of how strongly EV ownership signals their commitment to technological advancement.**

The conceptual model now posits a difference in the subsequent relationships along the environmental and the technology pathways. Logically, it is expected that the effects of EV signaling value on EV purchase likelihood will be positive for environmental signaling, because being seen as "green" (i.e., highly concerned about environmental protection) is widely assessed

to be a “good thing”. However, prior work (Arbore, Soscia, and Bagozzi 2014) has shown that the effects of EV signaling value on EV purchase likelihood may be negative for technology signaling. If perceptions of an individual’s technology commitment change from “coolness” to being a “geeky” obsession, the negative connotations may adversely influence EV purchase likelihood. This dissociation of the ideological pathways is captured in the hypotheses below.

- **H7a: The strength of the signal provided by EV ownership about an individual’s commitment to environmental protection has a direct positive effect on EV purchase likelihood.**
- **H7b: The strength of the signal provided by EV ownership about an individual’s commitment to technology advancement has a direct negative effect on EV purchase likelihood.**

2.4.2. Pathways Moderated by EV Purchase Disadvantages

The two disadvantages associated with purchasing an EV were the associated higher price and greater inconvenience related to charging. Both disadvantages are expected to negatively affect EV purchase likelihood.

- **H8a: EV price premium will have a direct negative effect on EV purchase likelihood.**
- **H8b: Perceived EV inconvenience will have a direct negative effect on EV purchase likelihood.**

In addition to the direct effects described by H8a and H8b, each disadvantage of EV ownership is expected to moderate the relationship between signaling value of EV ownership and EV purchase likelihood. A higher EV price premium is expected to amplify the identity signaling effect of EV ownership on EV purchase likelihood. Thus, as EV price premium

increases, the effects of identity signaling value on EV purchase likelihood (see H7a and 7b) will strengthen, becoming more positive for environmental protection and more negative for technology advancement.

- **H9a: For environmental protection, EV price premium will have a positive interactive impact on the relationship between identity signaling value and EV purchase likelihood.**
- **H9b: For technology advancement, EV price premium will have a positive interactive impact on the relationship between identity signaling value on EV purchase likelihood.**

Similarly, the greater usage inconvenience associated with EVs is expected to amplify how the identity signaling effect of EV ownership affects EV purchase likelihood. In other words, as EV price premium increases, the identity signaling value of EV ownership will have a stronger effect on EV purchase likelihood (see H7a and 7b), becoming more positive (negative) for environmental protection (technology advancement).

- **H10a: For environmental protection, greater usage inconvenience will have a positive interactive impact on the relationship between identity signaling value and EV purchase likelihood.**
- **H10b: For technology advancement, greater usage inconvenience will have a positive interactive impact on the relationship between identity signaling value and EV purchase likelihood.**

2.5. Experimental Design

Three experiments, similar in their core design, were used to test the ten pairs of hypotheses discussed above. Respondents, recruited for a small compensation from the Prolific

web panel, were presented with an automobile purchase scenario that involved choosing between an EV and a conventional ICE vehicle. Respondents answered a series of questions that measured the conceptual model constructs as well as their likelihood of purchasing the EV rather than the ICE vehicle. The study design and the associated survey instruments were approved by the Virginia Tech Institutional Review Board.

The following subsections describe the methodology used in measuring the study constructs, creating the survey instrument, procedural logistics, and the analyses that were conducted.

2.5.1. Construct Measurement

Testing the conceptual model faced a common challenge in social science research that is succinctly described by Staelin (1979): “the theory of interest is stated in terms of unobservable constructs while the variables used to test the model are fallible measures of these constructs” (p. 307). See also see also Kline (2009) and Freeze and Raschke (2007). Note that most of the constructs forming the core of the conceptual model – commitment to the environment or technology, familiarity about EVs, specific knowledge about EVs, perceptions about EVs as an advancement, the signaling values associated with EV ownership, perceptions of EV inconvenience – cannot be measured directly on any objective scale. As such, following methods commonly used in social science research, measures of the model’s latent (unobservable) constructs were constructed by using multiple Likert-scaled items for each construct (Kline 2009). The self-reported answers to these scale items provided reflective (as opposed to formative) measures of each construct. As Freeze and Raschke (2007) point out, “reflective measures are caused by the latent construct, whereas formative measures cause the latent construct” (p. 1482).

The core constructs in the conceptual model (see Figure 2.1) are commitment to environmental protection (technology advancement); familiarity with EVs; knowledge of the environmental (technology) impact of EVs; perceptions of EVs as benefitting environmental protection (technology advancement); the environmental (technology) commitment signaling value of EV ownership; and perceptions of EV inconvenience. Multiple measures are used to tap the various aspects of the construct, so as to collectively produce a reliable and valid measure of the construct. Convergent validity in construct measurement is evaluated by calculating the Cronbach alpha for the construct's items – a composite estimate of the extent to which the items correlate (Cortina 1993). Discriminant validity (;Shaffer, DeGeest, and Li 2016; MacKenzie 2001; Anderson and Gerbing 1988) was also examined to ensure that the model constructs were meaningfully differentiated. Appendices 2.1 through 2.3 respectively report the specific items used to measure each construct in each of the three experiments, along with the corresponding Cronbach alpha values assessing the convergent validity of the construct. The specific wording of items was refined based on pretests conducted during the exploratory phases of this research. Similar wording and question structures were used for the parallel environmental and technology paths so that the constructs featuring on each path were directly-comparable and could be attributed to the specific differences in respondent attitudes between the environmental and technological aspects of the model. Additional statistical assessments pertaining to the quality of construct measurement in the three experiments are presented in Section 2.7.1.

2.5.2. Survey Instrument

The text from the survey instruments (including the specific items used to measure each construct) in the three experiments can be found in Appendices 2.1 through 2.3, respectively. Each item was posed as a statement, and respondents indicated their level of agreement with the

statement on a 7-point Likert scale (1 – disagree, 7 – agree). Within each panel, the items were presented in random order to mitigate potential biases introduced by question order. As previously noted, items designated to measure comparable constructs in the two focal domains (environment and technology) were similarly worded. Although there were minor variations, all three experiments followed a similar procedural sequence, with EV purchase likelihood as the dependent variable of interest. One difference of note is that EV usage inconvenience was not manipulated in Experiment 1 but was manipulated in Experiments 2 and 3. Experiments 2 and 3 also used higher price premium numbers for both low and high levels of the manipulation. A description of the survey flow used in all three experiments follows.

After a brief introduction, study participants were asked a series of questions pertaining to three prior sets of beliefs they brought to the survey: (1) their personal commitment to the environment, (2) their personal commitment to technological advancement, and (3) their familiarity with EVs. These belief questions were asked up-front to avoid the study premise influencing self-reported assessments about basic attitudes regarding EV purchases. Only after reporting these prior beliefs were study participants made aware of the study premise.

Each participant was then asked to imagine that they (1) were in the market to purchase a new car, (2) had selected their preferred car model, and (3) had to choose between an EV and an equivalent conventional gasoline-powered version. It was emphasized that the two vehicles being evaluated were identical in all respects, other than the intrinsic powertrain difference. An attention check confirmed the participant's understanding of the choice they were to evaluate.

Participants were then randomly assigned to one of multiple between-subject conditions. In all three experiments, participants were randomly assigned to conditions in which the EV price premium over the gasoline-powered vehicle was presented at one of two values, one of

which was lower than the other (i.e., a “low” price condition or a “high” price condition). The inconveniences associated with EV ownership were measured (but not manipulated) in Experiment 1, but in Experiments 2 and 3 were manipulated either as lower (“moderate”) or higher (“significant”) with participants randomly assigned to either the lower or higher inconvenience condition. Embedded attention checks ensured that participants attended to and understood the condition-specific price and inconvenience information associated with the condition to which they were randomly assigned. Each participant was then asked to indicate their EV purchase likelihood (“How likely is that you would choose to purchase the battery-powered EV over the gasoline-powered version?”) on a 7-point Likert scale (1 – unlikely, 7 – likely).

After eliciting the dependent variable of interest, the survey asked study participants to indicate their level of agreement on a 7-point Likert scale (1 – disagree, 7 – agree) to seven panels of multiple statements that captured the remaining constructs in the conceptual model. The seven panels addressed the following constructs: (1) self-reported knowledge of the environmental attributes of EVs, (2) self-reported knowledge of the technological attributes of EVs, (3) perceptions of EVs as being good for the environment, (4) perceptions of EVs as being good for technological advancement, (5) perceptions of EV ownership as a signal of the owner’s environmental commitment, (6) perceptions about EV ownership as a signal of the owner’s commitment to technological advancement, and (7) perceptions about the inconveniences associated with EV ownership.

The survey concluded with several customary demographic questions, followed by a statement of appreciation for the participant. Each participant was compensated \$1.50 (raised to

\$1.75 for Experiment 3) for their time. Median completion time was 9 minutes, implying an hourly wage of \$10.00 (\$11.67).

2.5.3. Study Logistics

Although certain elements differed between the survey instruments used (see Appendices 2.1 – 2.3), the logistics for all three studies were similar. Study participants were recruited from the Prolific web panel and were screened for eligibility using four conditions. Each participant was required to (1) be a U.S. resident (to mitigate potential for cross-cultural heterogeneity); (2) be aged between 30 and 45 (in prime car-buying years, while avoiding the potential reticence for EV adoption that might be expressed by older buyers reluctant to experiment with a significantly different vehicle type); (3) own a gasoline vehicle (to avoid including respondents who were already EV “converts”); and (4) report an annual household income of at least \$50,000 (i.e., sufficiently affluent to afford the purchase of a new EV). Participant recruiting targeted at least 75 participants per condition, based on statistical power considerations. Question Pro was used as the software platform for survey administration, data collection and the creation of Excel datasets for analysis.

As discussed further below in the discussion of each experiment in Section 2.6, the raw data gained from each experiment was first cleansed to eliminate substantially incomplete responses or data deemed to be of dubious quality due to failed attention checks. Subsequently, measures for each construct were calculated from the cleansed raw data and then (as discussed further in Section 2.7.1) checked for convergent and discriminant validity; convergent validity was assessed by calculating Cronbach alpha among the multiple items used to measure the construct, while discriminant validity was assessed by examining cross-construct correlations to ensure that none were so high as to hinder distinction.

2.5.4. Structural Equation Modeling

An initial attempt was made to use structural equations modelling (SEM) to estimate simultaneously (Anderson and Gerbing 1988; Yuan and Chan 2002) both the postulated structural paths and the measurement model implicit in the model's constructs using maximum likelihood (ML) optimization techniques (MacKenzie 2001). The path model specified the relationships between the constructs posited in the conceptual model, while the measurement model encompassed a set of reflective items that capture how each (unobservable) latent construct relates to each reflective measure of the construct. However, due to the complexity of the path model (10 latent constructs with direct and interactive effects) and the measurement model (four to six reflective measures for the various constructs), when considered together simultaneously, computational techniques were unable to find a satisfactory level of convergence in the parameter estimates. This inability to arrive at stable estimates under these circumstances is not an uncommon problem (see e.g., (Yuan and Chan 2002; (Madhanagopal and Amrhein 2019).

In view of the difficulties encountered with the simultaneous estimation of the path and measurement models, the analysis focused on estimating the path model using single measures of the constructs formed by averaging the corresponding multiple measures to form a single measure of each construct. This path analysis approach was successfully implemented using the PROC CALIS procedure in SAS (see Madhanagopal and Amrhein 2019).

2.6. Three Experimental Studies

This section presents the results of each of the three experiments. Summary facts about the three experiments are presented in Table 2.2.

Table 2.2: Overview of the Three Experiments

	Experiment 1	Experiment 2	Experiment 3
Data collection	Feb. 6-7, 2023	Aug. 9-31, 2023	Oct. 12-26, 2023
Sample size	N=283	N=398	N=402
# of experimental conditions	2	4	4
EV price premium	Manipulated: • Low: \$1,000 • High: \$5,000	Manipulated: • Low: \$2,000 • High: \$10,000	Manipulated: • Low: "modest" \$2,000 • High: "significant" \$10,000
EV inconvenience	Elicited via a panel of Likert-scale questions	Manipulated: • Low: "modest" • High: "significant"	Manipulated: • Low: "modest" • High: "significant"

The main findings of each of these three experiments are presented briefly in each of the following subsections to provide an initial sense of the results. Subsequently, in Section 2.7, a more detailed discussion addresses construct reliability and validity, as well as a discussion of the empirical findings when the data from across the three experiments is pooled.

2.6.1. Experiment 1

Participants in Experiment 1 were randomly assigned to one of two possible conditions, formed by manipulating the text presenting the EV’s price premium to be either low (\$1,000) or high (\$5,000). In other words, variance in the EV price premium construct of the conceptual model was directly achieved by experimental manipulation and would hence be represented in the data as a dummy variable (0 for the low price condition, 1 for the high price condition). However, perceived inconvenience associated with EV ownership was not manipulated, and (as detailed more fully in Appendix 2.1) data on this construct was gathered by asking participants a set of eight 7-point Likert items, which were then averaged to form a single measure of the EV inconvenience construct.

On February 6-7, 2023, 357 participants were recruited from the Prolific web panel. However, 84 participants were excluded from the dataset because these respondents either (1)

failed one or more of the subsequent attention checks embedded in the survey instrument, or (2) dropped out of the experiment before completing it. The remaining (N=283) participants (39% female, average age = 36.4) populated the high price premium (N=128) and the low price premium (N=155) conditions respectively. The data from these participants were first tested for construct validity and then subjected to a SEM analysis (using PROC CALIS in SAS) to develop estimates of the relationships described in the conceptual model. The overall model fit statistics were as follows:

Fit Function	10.9174
Chi-Square	3078.7201
Chi-Square DF	78
Pr > Chi-Square	<.0001
Z-Test of Wilson & Hilferty	45.1073
Hoelter Critical N	10
Root Mean Square Residual (RMR)	1.6042
Standardized RMR (SRMR)	0.2350
Goodness of Fit Index (GFI)	0.6454

Table 2.3 presents a summary of the estimated path coefficients from Experiment 1 and the p-values associated with their corresponding significance tests.

Table 2.3: SEM Estimation Results from Experiment 1

FROM		TO	Estimate	Standard Error	t Value	Pr > t
EV Familiarity (FA)	==>	Env Knowledge (EK)	0.09926	0.05896	1.6835	0.0923
EV Familiarity (FA)	==>	Tech Knowledge (TK)	0.14711	0.05826	2.525	0.0116
Env Commitment (EC)	==>	Env Perception (EP)	-0.6856	0.07536	-9.0974	<.0001
Tech Commitment (TC)	==>	Tech Perception (TP)	-0.582	0.09884	-5.8884	<.0001
ECxEK	==>	Env Perception (EP)	1.24667	0.06328	19.6996	<.0001
TCxTK	==>	Tech Perception (TP)	1.14667	0.08875	12.9204	<.0001
Env Perception (EP)	==>	Env Signal Value (ESV)	0.67197	0.03266	20.5744	<.0001
Tech Perception (TP)	==>	Tech Signal Value (TSV)	0.65415	0.03407	19.2015	<.0001
Env Knowledge (EK)	==>	EV Purch Likelihood (DV)	0.05098	0.04897	1.041	0.2979
Tech Knowledge (TK)	==>	EV Purch Likelihood (DV)	0.12099	0.04883	2.4779	0.0132
Env Perception (EP)	==>	EV Purch Likelihood (DV)	-0.0226	0.07241	-0.3114	0.7555
Tech Perception (TP)	==>	EV Purch Likelihood (DV)	0.17665	0.06958	2.5386	0.0111
Env Signal Value (ESV)	==>	EV Purch Likelihood (DV)	0.1504	0.06588	2.2831	0.0224
Tech Signal Value (TSV)	==>	EV Purch Likelihood (DV)	-0.1449	0.06455	-2.245	0.0248
Inconvenience (IV)	==>	EV Purch Likelihood (DV)	-0.4809	0.07968	-6.0347	<.0001
PRICE	==>	EV Purch Likelihood (DV)	-0.3528	0.16921	-2.0851	0.0371
PricexESV	==>	EV Purch Likelihood (DV)	0.46797	0.25245	1.8537	0.0638
PricexTSV	==>	EV Purch Likelihood (DV)	-0.1965	0.24712	-0.7951	0.4265
IVxESV	==>	EV Purch Likelihood (DV)	-0.0279	0.14805	-0.1886	0.8504
IVxTSV	==>	EV Purch Likelihood (DV)	0.33113	0.14497	2.2841	0.0224

As Table 2.3 shows, SEM estimation revealed that a substantial majority of the causal pathways in the conceptual model were statistically significant and provided general support for the relationships hypothesized in the conceptual model. Among direct effects on EV purchase likelihood, only knowledge about EVs in the environmental domain (“EK”) and perceptions about EVs as an environmental solution (“EP”) failed to show statistical significance; among the interaction terms, only the interactions between EV price premium and technology signaling value (“Price x TSV”) and between perceived EV inconvenience and environmental signaling value (“IV x ESV”) failed to show significance.

Although the results of Experiment 1 were encouraging, perceived EV inconvenience was measured rather than manipulated, which raised questions about the underlying drivers of

these perceptions. It was therefore deemed desirable to examine the stability of these results in an experiment wherein EV inconvenience was explicitly manipulated (rather than merely elicited subjective responses) along with the manipulation of the EV price premium. This motivated a second experiment in which EV inconvenience was directly manipulated, in addition to being measured via a modified set of items to elicit participant responses on perceived EV inconvenience.

2.6.2. Experiment 2

Experiment 2 involved an experiment in which participants were randomly assigned to one of four possible conditions in a 2x2 design. In addition to manipulating the text presenting information about the EV's price premium to be either low (\$2,000) or high (\$10,000), the text presenting information on EV ownership inconveniences explicitly addressed EV recharging needs to result in either "modest" (i.e., low) inconveniences or "significant" (i.e., high) inconveniences. Thus, both EV price premium and EV inconvenience were represented in the conceptual model as dummy variables (low = 0, high = 1). Note that the magnitudes of both price premium manipulations were double those in Experiment 1 (low from \$1,000 to \$2,000, high from \$5,000 to \$10,000) so as to increase variance among responses between the conditions.

Participants for Experiment 2 were recruited from the Prolific web panel during the period August 9 to September 31, 2023. Of the 469 participants, data from 71 were removed due to failed attention checks or premature termination of the survey. Data from the remaining (N=398) participants (52 % female, average age = 35.8) populated the four study conditions as follows: high price premium – high inconvenience (N=100); low price premium – high inconvenience (N= 91), high price premium – low inconvenience (N= 93); low price premium –

low inconvenience (N= 114) respectively. The data from these participants were first tested for construct validity and then subjected to a SEM analysis (using PROC CALIS in SAS) to develop estimates of the relationships described in the conceptual model. The overall model fit statistics were as follows:

Fit Function	12.1289
Chi-Square	4815.1546
Chi-Square DF	78
Pr > Chi-Square	<.0001
Z-Test of Wilson & Hilferty	55.3628
Hoelter Critical N	9
Root Mean Square Residual (RMR)	1.9370
Standardized RMR (SRMR)	0.2440
Goodness of Fit Index (GFI)	0.6404

Table 2.4 presents a summary of the estimated path coefficients from Experiment 2 and the p-values associated with their corresponding significance tests.

Table 2.4: SEM Estimation Results from Experiment 2

FROM		TO	Estimate	Standard Error	t Value	Pr > t
EV Familiarity (FA)	====>	Env Knowledge (EK)	0.09852	0.0497	1.9822	0.048
EV Familiarity (FA)	====>	Tech Knowledge (TK)	0.17297	0.0487	3.5528	4E-04
Env Commitment (EC)	====>	Env Perception (EP)	-0.9983	0.0694	-14.379	<.0001
Tech Commitment (TC)	====>	Tech Perception (TP)	-0.7716	0.0933	-8.2742	<.0001
ECxEK	====>	Env Perception (EP)	1.48457	0.0598	24.8372	<.0001
TCxTK	====>	Tech Perception (TP)	1.33813	0.0844	15.8587	<.0001
Env Perception (EP)	====>	Env Signal Value (ESV)	0.66168	0.0282	23.451	<.0001
Tech Perception (TP)	====>	Tech Signal Value (TSV)	0.63235	0.0301	20.9947	<.0001
Env Knowledge (EK)	====>	EV Purch Likelihood (DV)	0.05965	0.0315	1.8937	0.058
Tech Knowledge (TK)	====>	EV Purch Likelihood (DV)	0.10717	0.0316	3.3943	7E-04
Env Perception (EP)	====>	EV Purch Likelihood (DV)	0.05128	0.0464	1.1047	0.269
Tech Perception (TP)	====>	EV Purch Likelihood (DV)	0.09187	0.0443	2.073	0.038
Env Signal Value (ESV)	====>	EV Purch Likelihood (DV)	0.44491	0.0413	10.7674	<.0001
Tech Signal Value (TSV)	====>	EV Purch Likelihood (DV)	-0.3492	0.041	-8.5232	<.0001
Inconvenience (IV)	====>	EV Purch Likelihood (DV)	-0.4733	0.0461	-10.265	<.0001
PRICE	====>	EV Purch Likelihood (DV)	-0.0569	0.095	-0.599	0.549
PricexESV	====>	EV Purch Likelihood (DV)	-0.257	0.1486	-1.7297	0.084
PricexTSV	====>	EV Purch Likelihood (DV)	0.25503	0.1461	1.7452	0.081
IVxESV	====>	EV Purch Likelihood (DV)	-0.3391	0.0634	-5.3489	<.0001
IVxTSV	====>	EV Purch Likelihood (DV)	0.31673	0.0653	4.8508	<.0001

The results of Experiment 2 were somewhat less supportive of the hypotheses than those of Experiment 1. Notably, the direct effect of EV price premium on EV purchase likelihood – which should be negative – was not statistically significant. This was particularly surprising since the magnitudes of the two price premium conditions had been doubled from Experiment 1 (low: \$1,000, high: \$5,000) to Experiment 2 (low: \$2,000, high: \$10,000). It is possible that the new and stronger manipulation of EV inconvenience lowered the salience of the price manipulation in Experiment 2, despite the higher price premium levels utilized in the manipulation.

Some empirical support is available for this conjecture in that (1) the average of the inconvenience construct items (measuring perceived EV inconvenience) in Study 2 were a full point higher (on a 7-point Likert scale) than the self-reported measure in Study 1; (2) there was a strongly significant interaction between inconvenience and technology signaling value (“IV x TSV”); and (3) there was also a strongly significant interaction between inconvenience and environmental signaling value (“IV x ESV”). In order to explore this issue further, a third experiment was launched with a slightly revised survey instrument in which the price premium manipulation was made more overtly salient for prospective participants.

2.6.3. Experiment 3

Like the second experiment, Experiment 3 employed a survey in which participants were randomly assigned to one of four possible conditions in a 2x2 design: EV price premium low (stated to be a “modest” \$2,000) or high (stated to be a “significant” \$10,000), and EV inconvenience also low or high, as manipulated by changes in text to be read by the respondent. This inconvenience manipulation was implemented as a text statement about EV charging inconveniences incorporating a (fictitious) quote from a (fictitious) expert with a name suggesting an EV skeptic (“Rusty Sampson”) or an EV enthusiast (“Jason Foster”) for the low and high conditions respectively.

Participants for Experiment 3 were recruited from the Prolific web panel during the period October 12 to October 26, 2023. Data from the (N=402) participants (59% female, average age = 35.9) populated the four study conditions as follows: high price premium – high inconvenience (N=91); low price premium – high inconvenience (N= 104), high price premium – low inconvenience (N= 121); low price premium – low inconvenience (N= 86) respectively. After confirming construct validity, the data were subjected to a SEM analysis (using PROC

CALIS in SAS) to estimate the hypothesized relationships. The overall model fit statistics were as follows:

Fit Function	12.0688
Chi-Square	4839.5973
Chi-Square DF	78
Pr > Chi-Square	<.0001
Z-Test of Wilson & Hilferty	55.4878
Hoelter Critical N	9
Root Mean Square Residual (RMR)	1.8367
Standardized RMR (SRMR)	0.2273
Goodness of Fit Index (GFI)	0.6387

Table 2.5 presents a summary of the estimated path coefficients from Experiment 3 and the p-values associated with their corresponding significance tests.

Table 2.5: SEM Estimation Results from Experiment 3

FROM		TO	Estimate	Standard Error	t Value	Pr > t
EV Familiarity (FA)	===>	Env Knowledge (EK)	0.21285	0.04768	4.4646	<.0001
EV Familiarity (FA)	===>	Tech Knowledge (TK)	0.28954	0.04575	6.3287	<.0001
Env Commitment (EC)	===>	Env Perception (EP)	-0.71345	0.07277	-9.8045	<.0001
Tech Commitment (TC)	===>	Tech Perception (TP)	-0.82293	0.10143	-8.1133	<.0001
ECxEK	===>	Env Perception (EP)	1.21748	0.0634	19.2033	<.0001
TCxTK	===>	Tech Perception (TP)	1.34447	0.09308	14.4446	<.0001
Env Perception (EP)	===>	Env Signal Value (ESV)	0.59925	0.032	18.7238	<.0001
Tech Perception (TP)	===>	Tech Signal Value (TSV)	0.64308	0.02929	21.9591	<.0001
Env Knowledge (EK)	===>	EV Purch Likelihood (DV)	-0.0415	0.03631	-1.1427	0.2531
Tech Knowledge (TK)	===>	EV Purch Likelihood (DV)	0.19269	0.03628	5.3117	<.0001
Env Perception (EP)	===>	EV Purch Likelihood (DV)	0.09961	0.04851	2.0531	0.0401
Tech Perception (TP)	===>	EV Purch Likelihood (DV)	0.07186	0.05018	1.432	0.1521
Env Signal Value (ESV)	===>	EV Purch Likelihood (DV)	0.09949	0.04509	2.2067	0.0273
Tech Signal Value (TSV)	===>	EV Purch Likelihood (DV)	0.03073	0.04717	0.6515	0.5147
Inconvenience (IV)	===>	EV Purch Likelihood (DV)	-0.58383	0.04616	-12.6472	<.0001
PRICE	===>	EV Purch Likelihood (DV)	-0.03569	0.11039	-0.3233	0.7464
PricexESV	===>	EV Purch Likelihood (DV)	0.14848	0.20516	0.7237	0.4692
PricexTSV	===>	EV Purch Likelihood (DV)	-0.25786	0.20451	-1.2608	0.2074
IVxESV	===>	EV Purch Likelihood (DV)	0.06284	0.09828	0.6394	0.5225
IVxTSV	===>	EV Purch Likelihood (DV)	-0.01273	0.09848	-0.1293	0.8971

The results of this third experiment also showed a somewhat scattered set of results. Among the perceptual antecedents in the conceptual model, only knowledge about the implications of EVs on technological advancement (“TK”), perceptions about EVs as an environmental solution (“EP”), and environmental signaling value associated with EV ownership (“ESV”) indicated significant effects. Of the two disadvantages to EV ownership, only inconvenience (but not price) showed a significant negative effect on EV purchase likelihood. The environmental (but not technological) signaling value of EV ownership showed a direct effect on EV purchase. However, no significant effects were observed for the four interactions between the two disadvantages of EV ownership and the two signaling values (environment and technology) associated with EV ownership.

2.7. Discussion of Results

Given the complexity of the conceptual model presented in Section 2.3 and the seemingly variable pattern of results from the three experiments, a framework was developed to reconcile the results of the three experiments to facilitate drawing some overall conclusions regarding the hypotheses to be tested. The discussion below organizes the findings across the three experiments to produce a more coherent assessment of the results with respect to the hypotheses tested and the overall meaningfulness of the conceptual model.

2.7.1. Statistical Assessment of Data from the Three Experiments

Before distilling the results from the three experiments, it is first worthwhile to review summary statistics associated with the measurement of the key constructs of the conceptual model. Table 2.6 presents the means and standard deviations of the model constructs obtained from the data gathered in all three experiments.

**Table 2.6: Sample Means (Standard Deviations)
for Model Constructs from Experiments 1-3**

	Experiment 1	Experiment 2	Experiment 3
EV Purchase Likelihood (DV)	4.58 (1.91)	3.86 (1.99)	3.80 (2.00)
Familiarity with EVs (FA)	2.55 (1.34)	2.24 (1.25)	2.49 (1.33)
Environmental Commitment (EC)	5.52 (1.26)	5.23 (1.36)	5.28 (1.28)
Technology Commitment (TC)	5.06 (1.32)	4.81 (1.33)	4.92 (1.34)
Environmental Knowledge (EK)	5.51 (1.10)	5.47 (1.12)	5.50 (1.05)
Technology Knowledge (TK)	5.72 (0.94)	5.75 (0.94)	5.84 (0.87)
Environmental Perceptions (EP)	5.48 (1.34)	5.45 (1.42)	5.44 (1.30)
Technology Perceptions (TP)	5.29 (1.03)	5.06 (1.12)	5.02 (1.13)
Environmental Signaling Value (ESV)	4.67 (1.54)	4.43 (1.62)	4.60 (1.57)
Technology Signaling Value (TSV)	4.48 (1.48)	4.19 (1.53)	4.34 (1.52)
EV Inconvenience	4.30 (1.52)	5.35 (1.41)	5.20 (1.29)

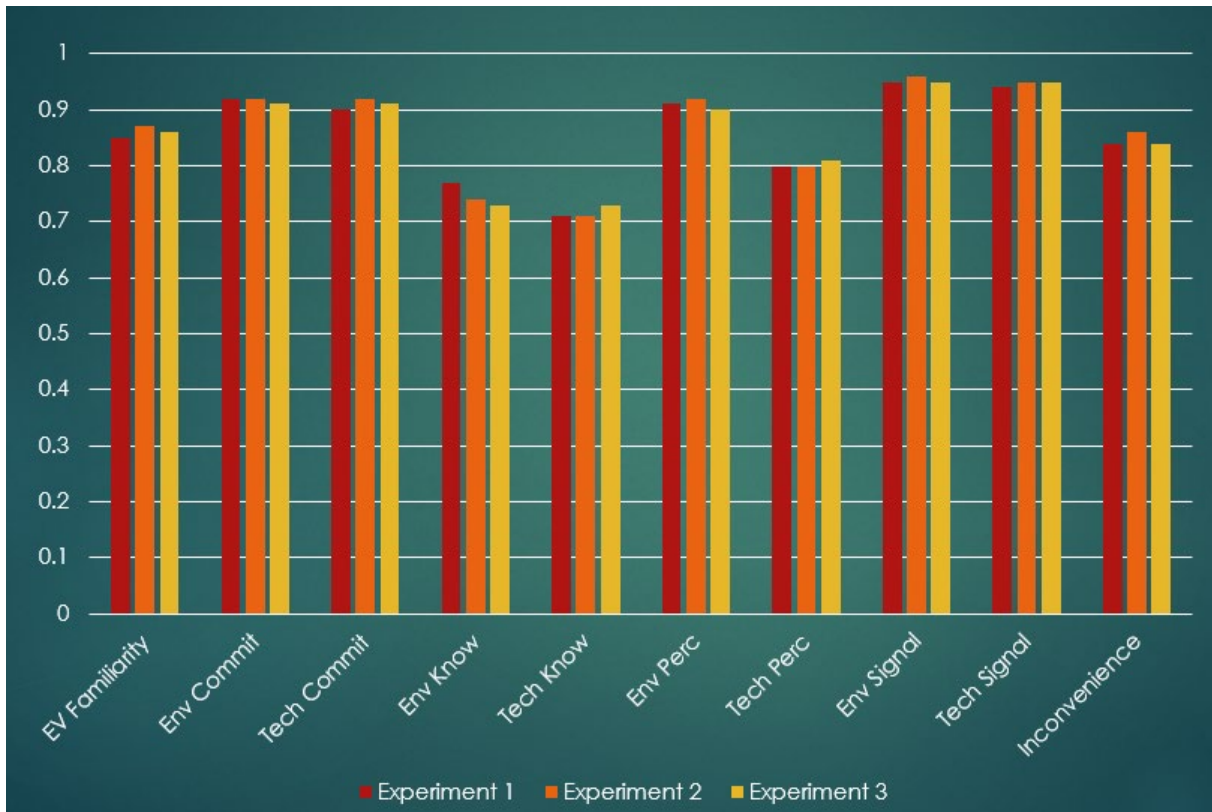
Table 2.6 reveals that the mean of EV purchase likelihood (the dependent variable in this research) declined significantly ($p < 0.001$) between Experiment 1 (4.58) and both Experiment 2

(3.86) and Experiment 3 (3.80). This is to be expected, as the level of the EV purchase price premium was increased (low from \$1,000 to \$2,000; high from \$5,000 to \$10,000) after Experiment 1, making EV ownership less desirable in both price conditions in the latter experiments. The mean reported value for perceived EV inconvenience also increased significantly ($p < 0.001$) from Experiment 1 (4.30) to both Experiment 2 (5.35) and Experiment 3 (5.20), reflecting the overt manipulation of inconvenience in the latter two experiments. Otherwise, the means of the remaining constructs did not vary significantly between the three experiments. Notably, familiarity with EVs was consistently reported to be relatively low (averaging between 2.24 and 2.55 across the three experiments), signaling value associated with EV ownership tended to average in the 4.2-4.7 range, and the other constructs (concerning ideological commitment, specific knowledge about EVs and perceptions about EV effectiveness in cause advancement) all tended to have means near or above 5.0.

Demonstrating the reliability of construct measurement in this research, Cronbach alphas for each construct (shown in Figure 2.2) exceeded 0.80 for all constructs except the two associated with specific knowledge (knowledge of EVs implications on environmental protection and knowledge of EVs implications on technological advancement). For those two constructs, Cronbach alphas were in the range of 0.71-0.77, generally deemed to be at or above acceptable levels for basic research (Nunnally 1978; Cortina 1993).

;

Figure 2.2: Cronbach Alphas to Assess Reliability of Each Model Construct



As noted previously, several of the constructs in the model are closely-related perceptual concepts, sometimes causally-related. As such, care was taken to examine the discriminant validity of the measures collected for the focal constructs in the conceptual model across the three experiments. Table 2.7 presents the inter-construct correlations when averaged across the three experiments.

Table 2.7: Average Correlations Between Constructs Across Three Studies

	EC	TC	FA	EK	TK	EP	TP	ESV	TSV
Env Commitment (EC)	1.000	0.404	0.212	0.452	0.425	0.338	0.401	0.468	0.349
Tech Commitment (TC)		1.000	0.402	0.367	0.456	0.250	0.445	0.299	0.465
Familiarity with EVs (FA)			1.000	0.134	0.203	0.040	0.249	0.163	0.270
Env Knowledge (EK)				1.000	0.780	0.767	0.685	0.621	0.519
Tech Knowledge (TK)					1.000	0.609	0.682	0.550	0.555
Env Perceptions (EP)						1.000	0.684	0.646	0.481
Tech Perceptions (TP)							1.000	0.624	0.645
Env Signaling Value (ESV)								1.000	0.783
Tech Signaling Value (TSV)									1.000

Table 2.7 shows that most pairwise correlations between constructs are satisfactorily low ($r < 0.60$), with no pairs having a correlation $r > 0.80$ – a level considered problematic because the constructs share about 64% of their variance (Hodson 2021). Of note, all three environment-technology pairs of constructs (environmental knowledge vs. technology knowledge, environmental perception vs. technology perception, and environmental signaling value vs. technology signaling value) exhibit correlations of $r > 0.68$. Also, the correlations between EV knowledge and EV perceptions also exceed $r > 0.68$ for both environmental ($r=0.77$) and technology ($r=0.69$) concerns. Although these correlations are relatively high, they may simply reflect the fact that available information about EVs is generally positive about the impact of EVs on both environmental protection and technology advancement. In any event, the correlations shown in the above table are not alarming by contemporary research standards.

2.7.2. SEM Estimation Results from the Three Experiments

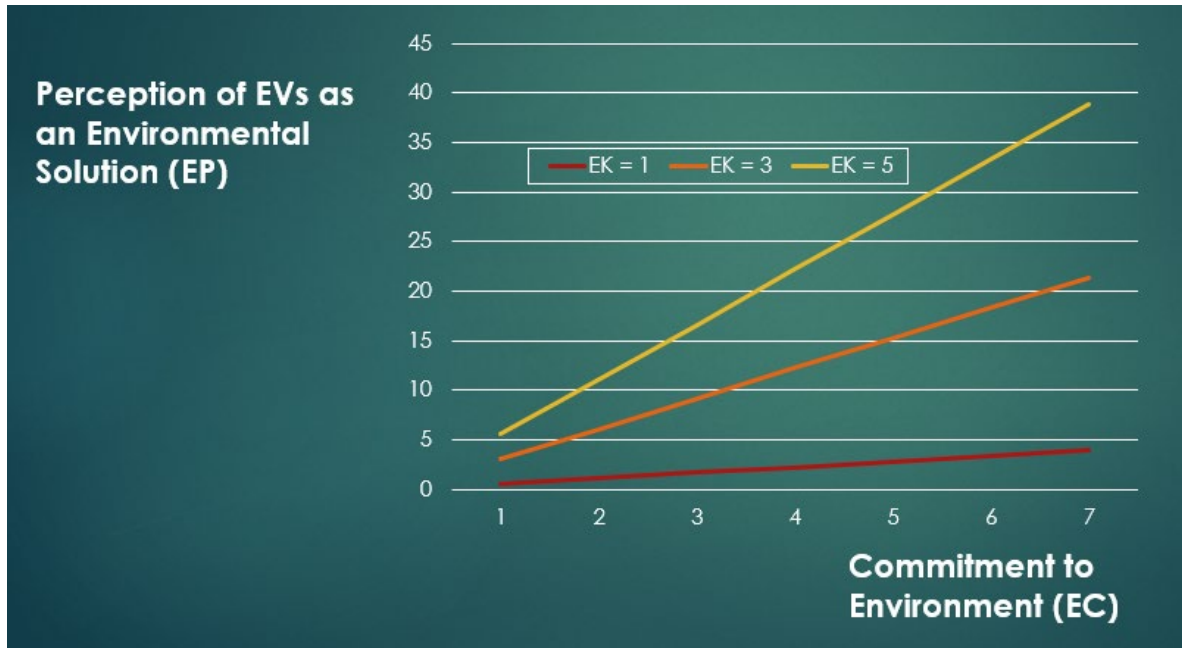
Aside from some of the discrepancies noted earlier, the three experiments revealed a generally consistent set of findings in support of the set of relationships proposed in the conceptual model. Table 2.8 provides a consolidated presentation of the coefficient estimates and their statistical significance that were reported separately in Tables 2.3, 2.4 and 2.5.

environmental protection (technological advancement) should positively influence the perception that EVs benefit the cause of environmental protection (technological advancement). However, rote interpretation of the coefficient estimates for this direct effect gives the impression that the relationship is negative and statistically significant degree ($p < 0.01$) in all three experiments for both the environmental and technology pathways. However, when the interaction term (linking to knowledge about EVs) is considered along with the direct effect, the findings show that – in totality – there is a positive relationship between ideological commitment and perception of EVs being favorable to that commitment. This finding holds for both the environmental and technology pathways.

Note that the total effect of ideological commitment on perceptions of EVs being favorable to that commitment is the sum of (1) the direct effect on perceptions and (2) the joint (interactive) effect of the ideological commitment and of knowledge about EVs that is pertinent to the commitment. The positive effect of the interaction term (crossing ideological commitment to a cause with knowledge about the implications of EVs to that cause) dominates the negative direct effect of ideological commitment. Thus, the total effect of ideological commitment on perceptions of EVs being favorable to that commitment is positive.

This important point is illustrated for the environmental pathway in Figure 2.3 below, showing that the relationship between environmental commitment and perceptions of EVs as an environmental solution is always positive, even when knowledge about the EVs impact on the environment is at its lowest possible level ($EK=1$). In summary, the relationship is such that perceptions of EVs advancing a cause increase when commitment to the cause increases (and also as cause-pertinent knowledge of EVs increases).

Figure 2.3: Positive Relationship Between Environmental Commitment and Perceptions of EVs as an Environmental Solution



Therefore, it is reasonable to claim that H1a and H1b are supported in their logical implication that commitment to a cause and greater cause-pertinent knowledge about EVs increase perceptions of EVs as a benefit to that cause.

Although the empirical results discussed above from all three experiments are largely supportive of the hypotheses on the upstream portion of the conceptual model, the results for the downstream portion are more mixed. On a positive note, some elements of the conceptual model, specifically in relation to the dependent variable, were supported by all three experiments. For instance, the direct effect of inconvenience on EV purchase likelihood was strongly negative in all three experiments, thus supporting H8b. Also, the direct effect of technology knowledge on EV purchase likelihood (H3b) and the direct effect of environmental signaling on EV purchase likelihood (H7a) were both found to be positive as expected across all three experiments.

However, there were also several inconsistencies in the findings across the experiments. For example, the expected negative direct effect between price and EV purchase likelihood (H8a) was significant in Experiment 1, but not in Experiments 2 and 3. In other instances, some model constructs (environmental knowledge, environmental perception, technology perception, and technology signaling) showed relationships that were not consistently significant across the three experiments. Finally, as noted earlier, the estimated coefficients for the four interactions between the twin impediments to EV adoption (price and inconvenience) and the twin signaling values (environment and technology) were also not consistent across the studies. These inconsistencies weakened the ability to draw robust inferences regarding some of the model relationships.

2.7.3. Bayesian Pooling of the Results

To holistically examine the evidence generated in the three experiments, the three sets of model estimates were subjected to Bayesian pooling using procedures developed by Winkler (1981). The procedures enabled distilling the three sets of coefficient estimates (and their associated standard errors) from the three independent experiments into a single pooled set of estimates (with associated standard errors) for use in hypothesis testing. The coefficient estimates resulting from regression analyses of multiple datasets are weighted by their respective precisions (reciprocal of variance) to obtain a single estimate of the coefficient, along with an associated precision that is the sum of the respective precisions of the estimated coefficients. The method is similar to the single-paper meta-analysis approach (McShane and Böckenholt 2017) that pools the results of multiple studies within a single paper to obtain a single estimate of a target effect of interest.

To apply the Bayesian pooling approach, the first step is to standardize all data for all relevant variables from each experiment’s dataset. A standardization methodology referred to as “Formula Z₂” (Milligan and Cooper 1988) was employed, because the conventional z-score transformation methodology commonly used for standardization produces negative data values associated with observations of below average magnitude, and negative data values are highly undesirable when interpreting coefficient estimates associated with interaction terms – of which there are several in the conceptual model tested in this research.

Following standardization as above, each of the datasets from the three experiments was subjected again to SEM estimation. Table 2.9 presents the estimated coefficients and their statistical significance levels when using standardized data from each of the three experiments.

Table 2.9: Estimated Path Coefficients After Data Standardization

Path From	Path To	Hypothesis	Experiment 1	Experiment 2	Experiment 3
Familiarity (FA)	Env Knowledge (EK)	H2a: positive	0.099*	0.101**	0.201***
Familiarity (FA)	Tech Knowledge (TK)	H2b: positive	0.147**	0.189***	0.274***
Env Commitment (EC)	Env Perception (EP)	H1a: positive	-0.686***	-1.017***	-0.705***
Tech Commitment (TC)	Tech Perception (TP)	H1b: positive	-0.582***	-0.791***	-0.814***
ECxEK	Env Perception (EP)	H4a: positive	1.247***	1.478***	1.210***
TCxTK	Tech Perception (TP)	H4b: positive	1.147***	1.356***	1.331***
Env Perception (EP)	Env Signaling Value (ESV)	H6a: positive	0.672***	0.615***	0.599***
Tech Perception (TP)	Tech Signaling Value (TSV)	H6b: positive	0.654***	0.607***	0.634***
Env Knowledge (EK)	EV Purch Likelihood (DV)	H3a: positive	0.051	0.013	-0.022
Tech Knowledge (TK)	EV Purch Likelihood (DV)	H3b: positive	0.121**	0.166***	0.183***
Env Perception (EP)	EV Purch Likelihood (DV)	H5a: positive	-0.023	0.113**	0.076
Tech Perception (TP)	EV Purch Likelihood (DV)	H5b: positive	0.177**	0.068	0.083*
Env Signaling Value (ESV)	EV Purch Likelihood (DV)	H7a: positive	0.150**	0.171***	0.091**
Tech Signaling Value (TSV)	EV Purch Likelihood (DV)	H7b: negative	-0.145**	-0.121***	0.036
Inconvenience (IV)	EV Purch Likelihood (DV)	H8b: negative	-0.481***	-0.552***	-0.587***
Price	EV Purch Likelihood (DV)	H8a: negative	-0.353**	-0.103	-0.056
PricexESV	EV Purch Likelihood (DV)	H9a: positive	0.468*	-0.267*	0.158
PricexTSV	EV Purch Likelihood (DV)	H9b: positive	-0.197	0.280*	-0.253
IVxESV	EV Purch Likelihood (DV)	H10a: positive	-0.028	-0.187	0.086
IVxTSV	EV Purch Likelihood (DV)	H10b: positive	0.331**	0.171	-0.035
* p < 0.10					
** p < 0.05					
*** p < 0.01					

These revised estimates and their standard errors were then used to generate a single pooled estimate of the coefficients and standard errors associated with each relationship of interest in the conceptual model. The results of Bayesian pooling, along with the results from the three individual experiments, are presented below in Table 2.10.

Table 2.10: Estimated Path Coefficients from Bayesian Pooling

Path From	Path To	Hypothesis	Experiment 1	Experiment 2	Experiment 3	Pooled
Familiarity (FA)	Env Knowledge (EK)	H2a: positive	0.099*	0.101**	0.201***	0.135***
Familiarity (FA)	Tech Knowledge (TK)	H2b: positive	0.147**	0.189***	0.274***	0.205***
Env Commitment (EC)	Env Perception (EP)	H1a: positive	-0.686***	-1.017***	-0.705***	-0.795***
Tech Commitment (TC)	Tech Perception (TP)	H1b: positive	-0.582***	-0.791***	-0.814***	-0.714***
ECxTK	Env Perception (EP)	H4a: positive	1.247***	1.478***	1.210***	1.307***
TCxTK	Tech Perception (TP)	H4b: positive	1.147***	1.356***	1.331***	1.264***
Env Perception (EP)	Env Signaling Value (ESV)	H6a: positive	0.672***	0.615***	0.599***	0.633***
Tech Perception (TP)	Tech Signaling Value (TSV)	H6b: positive	0.654***	0.607***	0.634***	0.633***
Env Knowledge (EK)	EV Purch Likelihood (DV)	H3a: positive	0.051	0.013	-0.022	0.011
Tech Knowledge (TK)	EV Purch Likelihood (DV)	H3b: positive	0.121**	0.166***	0.183***	0.159***
Env Perception (EP)	EV Purch Likelihood (DV)	H5a: positive	-0.023	0.113**	0.076	0.066***
Tech Perception (TP)	EV Purch Likelihood (DV)	H5b: positive	0.177**	0.068	0.083*	0.102***
Env Signaling Value (ESV)	EV Purch Likelihood (DV)	H7a: positive	0.150**	0.171***	0.091**	0.136***
Tech Signaling Value (TSV)	EV Purch Likelihood (DV)	H7b: negative	-0.145**	-0.121***	0.036	-0.073***
Inconvenience (IV)	EV Purch Likelihood (DV)	H8b: negative	-0.481***	-0.552***	-0.587***	-0.552***
Price	EV Purch Likelihood (DV)	H8a: negative	-0.353**	-0.103	-0.056	-0.137***
PricexESV	EV Purch Likelihood (DV)	H9a: positive	0.468*	-0.267*	0.158	0.025
PricexTSV	EV Purch Likelihood (DV)	H9b: positive	-0.197	0.280*	-0.253	0.031
IVxESV	EV Purch Likelihood (DV)	H10a: positive	-0.028	-0.187	0.086	-0.028
IVxTSV	EV Purch Likelihood (DV)	H10b: positive	0.331**	0.171	-0.035	0.129***
* p < 0.10						
** p < 0.05						
*** p < 0.01						

The Bayesian pooled estimates produced three additional findings of note. First, the negative direct effect of a higher price premium on EV purchase likelihood (H8a) was strongly supported. This result aligns strongly with expectations and removes concerns with the results in Experiments 2 and 3 where the effect was indicated to be not significant. The pooling approach appears to leverage additional statistical power to reveal this expected negative relationship. Second, the direct effects on EV purchase likelihood of several constructs (environmental knowledge, environmental perception, and technology perception) now emerged as positive and

significant, as originally expected. Thus, whereas H3b, H5a, H5b, H7a and H7b had received inconsistent support when data from the three experiments was separately analyzed, Bayesian pooling of the data produced supportive evidence for these hypotheses. Third, the Bayesian pooling approach also revealed a significant positive interaction between EV inconvenience and technology signaling on EV purchase likelihood, thus providing support for H10b.

The findings regarding H7b and H10b merit additional discussion in relation to each other. H7b speaks to the notion that technology signaling value for an EV is seen as undesirable (geeky). The statistically significant negative coefficient obtained from Bayesian pooling indicates that H7b is supported: the greater the perceived technology signaling value associated with EV ownership, the less likely the prospective car buyer will select the EV. Meanwhile, H10b suggests a positive interaction between EV usage inconvenience and the technology signaling value of EV ownership in its impact on EV purchase likelihood. Mathematically similar to the interaction between commitment and knowledge on perceptions (as illustrated in Figure 2.3), the positive interaction effect dominates the negative direct effect, so that the total effect of technology signaling value on EV purchase likelihood is positive. However, unlike the interaction between commitment and knowledge on perception that involves two “positive” concepts, the involvement of the “negative” concept of inconvenience in the interaction with technology signaling value means that the domination of the interaction term does not render moot the observed negative direct effect of technology signaling on EV purchase likelihood. Put another way, the “geek” signaling effect associated with EV ownership never disappears, always tending to depress EV purchase likelihood, but this effect can be overcome if perceived inconveniences of EV ownership are sufficiently high. Car buyers may not want to be seen as geeks, and accordingly may be less inclined to purchase an EV because of the technology

signaling value that EV ownership transmits, but if high inconvenience is also perceived to be associated with EV ownership, it may be the case that the incremental psychic value in making the sacrifices necessary to use an EV outweighs the negative esteem associated with EV ownership.

Although Bayesian pooling did produce greater clarity on the significance of several hypotheses that were advanced in this research, it nevertheless was unable to find support for all expected relationships in the model. Notably, specific knowledge about the implications of EVs on the environment did not significantly affect EV purchase likelihood, thus implying a rejection of H3a. Also, EV price premium did not significantly moderate the effect of EV ownership signaling value on EV purchase likelihood for either the environmental (H9a) or technology pathway (H9b) – even though support for H9a was indicated in the first two experiments.

A summary of the findings relative to the ten pairs of hypotheses is presented below in Table 2.11, indicating substantial support for the conceptual model tested in this research.

Table 2.11: Summary of Hypothesis Testing

Path From	Path To	Hypothesis	Pooled Finding
Env Commitment (EC)	Env Perception (EP)	H1a: positive	Supported
Tech Commitment (TC)	Tech Perception (TP)	H1b: positive	Supported
Familiarity (FA)	Env Knowledge (EK)	H2a: positive	Supported
Familiarity (FA)	Tech Knowledge (TK)	H2b: positive	Supported
Env Knowledge (EK)	EV Purch Likelihood (DV)	H3a: positive	Not Supported
Tech Knowledge (TK)	EV Purch Likelihood (DV)	H3b: positive	Supported
ECxEK	Env Perception (EP)	H4a: positive	Supported
TCxTK	Tech Perception (TP)	H4b: positive	Supported
Env Perception (EP)	EV Purch Likelihood (DV)	H5a: positive	Supported
Tech Perception (TP)	EV Purch Likelihood (DV)	H5b: positive	Supported
Env Perception (EP)	Env Signaling Value (ESV)	H6a: positive	Supported
Tech Perception (TP)	Tech Signaling Value (TSV)	H6b: positive	Supported
Env Signaling Value (ESV)	EV Purch Likelihood (DV)	H7a: positive	Supported
Tech Signaling Value (TSV)	EV Purch Likelihood (DV)	H7b: negative	Supported
Price	EV Purch Likelihood (DV)	H8a: negative	Supported
Inconvenience (IV)	EV Purch Likelihood (DV)	H8b: negative	Supported
PricexESV	EV Purch Likelihood (DV)	H9a: positive	Not Supported
PricexTSV	EV Purch Likelihood (DV)	H9b: positive	Not Supported
IVxESV	EV Purch Likelihood (DV)	H10a: positive	Not Supported
IVxTSV	EV Purch Likelihood (DV)	H10b: positive	Supported

2.8 Implications of Findings

When data from the three experiments is subjected to Bayesian pooling, many aspects of the conceptual model are supported. First, the findings provide evidence that EV purchase likelihood declines as EV price premium increases and as perceived inconveniences associated with EV ownership increase. Although these twin findings are not surprising, their emergence from the pooled data enhances the credibility of the conceptual model being proposed herein.

The hypotheses associated with the upstream portion of the model, including both direct and indirect (i.e., mediated) effects of the antecedents on EV purchase likelihood, are also supported by the statistical analysis. As is intuitively obvious, general familiarity with EVs positively influences specific knowledge about EVs in both environmental and technological contexts. In turn, in both the environmental and technology pathways, specific knowledge interacts positively with the individual's degree of ideological commitment and influences perceptions that EVs are an advancement for that ideological commitment.

Thus, specific knowledge and ideological commitment reinforce each other to form a favorable perception of EVs towards a cause. These perceptions about EV effectiveness then positively influence the signaling value ascribed to EV ownership – again, for both the environmental and technology pathways. This is expected in that if one believes that EVs represent an advancement to a cause, they may see EV ownership as signaling that commitment to others.

Turning to the direct effects on EV ownership, the pooled Bayesian estimates show significant positive relationships associated with both perceptions of EVs as environmentally beneficial and of EVs as advancing the cause of technology. Hence, if a prospective car-buyer

believes that EVs are better for the environment or better for technological advancement, EV purchase likelihood increases (all else being equal).

Further analysis reveals asymmetries between the environmental and technology pathways. As expected, the environmental signaling value attributed to EV ownership positively affects EV purchase likelihood: owning an EV appears to send a signal that the owner is concerned about environmental protection, and further that this signal is viewed favorably by a prospective EV owner. While owning an EV also clearly sends a signal that the owner is committed to technological advancement, this signal (unlike the environmental signal) is negative in its effect on EV purchase likelihood. In short, it's good to be seen as "green" and EV ownership signals greenness, but it's undesirable to be seen as "geeky" and EV ownership signals geekiness.

The positive interaction between perceived inconvenience and technology signaling value on EV purchase likelihood introduces the possibility that the geek signal associated with EV ownership – and its negative effect on EV purchase likelihood – can be surmounted if the prospective car buyer also believes that there is a high degree of inconvenience associated with EV ownership. This would be consistent with a hypothesis that perceived sacrifices (i.e., endurance of significant inconveniences) from owning an EV can provide sufficient psychic value to offset the negative stigma associated with the EV's technology signal. Further focused research on this interpretation is warranted.

Also, although specific knowledge about EVs in the technological domain positively and directly influences EV purchase likelihood, that may not be the case in the environmental domain. All effects of specific knowledge about EVs regarding environmental protection are mediated by perceptions of EV effectiveness in protecting the environment. Thus, an individual

perceives the implications of EV ownership on environmental impact entirely through the lens of how well EVs reduce emissions. In other words, knowing how EVs benefit the environment may not affect EV purchase likelihood, but believing that EVs benefit the environment is by contrast very important. On the other hand, knowledge of an EVs technological implications does translate directly as a positive influence on EV purchase likelihood.

2.9. Directions for Future Research

The findings from this research spawn several potentially fruitful avenues for further investigation. Naturally, the conceptual model presented and tested herein does not include all potential factors that affect EV purchase likelihood. Other cognitive or affective constructs are likely to be relevant in a prospective car-buyer's evaluative process, and there are other exogenous attributes of EV ownership – including positive ones, such as lower maintenance costs – that also could interact with the effect of signaling value on EV ownership. These issues could be examined using more focused models and corresponding experimental designs.

Additional studies could further investigate the effects of technology signaling value on EV purchase likelihood. As noted earlier, Kerner and Pressman (2007) argue that the signal of “coolness” can be an important motivator for buying a novel product, whereas Arbore et al (2014) note that too much coolness may send an undesirable signal. The present findings support the latter perspective, but it would be worth examining whether the relationship observed for technology signaling is actually segmented by both the buyer's own commitment level and the selective audiences to which they may wish to transmit signals through EV ownership.

While identity signaling is mostly directed at others (extrinsic signaling), EV purchases may also serve an intrinsic signaling (i.e., to oneself) purpose (Gal 2015). Richins (1994) notes that “special possessions” both have (1) private meaning to the owner by embodying aspects of

the owner's identity and (2) have public symbolic value by communicating the owner's identity to others. Signaling associated with product ownership is therefore not limited to trying to impress others: buying a product with desired characteristics can lead an individual to feel better about themselves – a boost in self-image that Köszegi (2006) terms “ego utility”. The present data allow a preliminary examination of this issue. Future research could focus more explicitly on both intrinsic and extrinsic signaling value for both the environmental and technology pathways. Recent work by Herziger and Sintov (2023) suggests that the value derived by an individual from private self-signaling about their true identity via EV ownership may have more influence on EV adoption than the value derived from external-signaling.

The findings presented herein relating to specific knowledge about EVs (either pertaining to their environmental effects or their impact on technological advancement) are subject to the caveat that EV knowledge was self-reported. However, Krause et al (2013) found that most car-buyers are poorly informed or misinformed about EVs, which strongly hints at the possibility that self-reported and actual knowledge may even represent separate constructs akin to subjective and objective knowledge (Brucks 1985). These knowledge differences may have both positive and negative effects on EV purchase likelihood and would be interesting to explore further.

The experiments reported here showed no interaction between EV inconvenience and environmental signaling in their effect on EV purchase likelihood. Perhaps such interaction effects would emerge in experiments where long-distance journeys (e.g., road trips) are made more salient when considering EV ownership. Inconveniences associated with EV charging matter minimally if the car is primarily used for local trips, thus allowing overnight recharging at home while the owner sleeps. As St. John (2022) points out, 80% of all EV charging occurs at

home. Additional research on the nuances of contemplating local vs. long-distance journeys when perceiving EV inconvenience would be useful.

Finally, the limitations associated with the participant pool used in these studies should be noted. There is increasing concern that data gathered in online forums are of uncertain quality due to careless survey completion as well as the use of AI devices and web-crawlers (Kennedy et al. 2020) that mimic human respondents. In addition, the possibility of socially desirable responses, particularly for products that incorporate innovative technology also may undermine results conducted with web panel participants (Richman et al. 1999). Accordingly, alternative approaches to gathering good field data relevant for testing the conceptual model would be desirable.

2.10. Research Contributions

The present research contributes to the body of knowledge about how individuals make evaluative assessments of multiple intrinsic and extrinsic factors in assessing whether to buy an electric vehicle or an otherwise-equivalent gasoline vehicle. The research focuses on how these factors are viewed by prospective car buyers who have ideological commitments to both environmental protection and technology advancement. The results show that the two pathways to EV purchase likelihood have significant overlap, but also differ in how they view the signaling value of EV ownership and how they respond to the currently prominent disadvantages of EVs (price premium and usage inconveniences related to charging).

The research contributes to both the academic and practitioner communities. For academic readers, the conceptual model provides an extensive application of TRA to the context of making a purchase decision between a conventional vehicle and an electric vehicle with superior environmental and technological attributes. The process model also extends existing

models of technology acceptance by incorporating constructs such as the signaling value of EV ownership as a factor influencing EV purchase likelihood. Even as the results corroborate the widely tested and applied TRA model, they also show some novel tensions between the values offered by a pro-social innovation and the disadvantages that innovators and early adopters of a technology must trade-off.

For marketing practitioners in the automobile industry, this research may be used to inform positioning and promotional statements for EVs, especially to buyers who are identified as having strong self-identities associated with environmental protection and/or technology advancement. The findings indicate that sales prospects will improve by providing potential early-adopters with compelling information on how EVs facilitate environmental protection and/or technological advancement, so as to explicitly leverage latent commitments to these causes. Moreover, the results suggest that technology enthusiasts may be more likely to select an EV if they can be given compelling evidence that (1) owning an EV will not reveal them to be a “geek” and (2) inconveniences associated with EV recharging are modest and declining.

CHAPTER THREE

Household Electricity Consumption Patterns Resulting From Utility Demand Response Requests

3.1. Introduction

An electricity grid is a shared resource that is relied upon by all communities in the region. In any regional electricity grid, power generation capacity available to produce electricity is fixed in the short-term, while customer demands for electricity vary significantly on a moment-to-moment basis. Within the space of just a few hours during a single summer day, a household's electricity demand can increase by a factor of four (Parker 2002). When aggregated over millions of households, such variation can lead to supply inadequacies that – if unmanaged – could precipitate a region-wide blackout. Under extreme conditions, grid operators resort to reducing regional demand for electricity by invoking “load-shedding” – a form of supply rationing via “rotating blackouts”, in which electricity delivery is interrupted for some duration to specific customer groups. However, a more palatable approach involves utilities alleviating supply stresses during peak demand periods by inducing customers to undertake reductions in electricity consumption. In this way, “demand response” (DR) programs attempt to induce customers to act voluntarily to reduce electricity consumption.

3.1.1. Utility Demand Response Programs

Utility DR programs date back to the early 2000s, a period in the electricity industry when regulatory and market concepts were being dramatically altered (Lotfi et al. 2018). Contemporary DR programs may be placed in two broad categories: price-based and incentive-

based (Albadi and El-Saadany 2007). In price-based DR programs, customers pay for electricity consumption at prices that rise and fall over the course of a day: during most hours of most days, electricity in a price-based DR program is available at a discount relative to standard fixed-rate tariffs, but is priced much higher during selected peak demand periods (Paterakis, Erdinç, and Catalão 2017). Consistent with conventional economic theory, real-world experience with price-based DR programs shows that consumers reduce electricity consumption when electricity prices are sufficiently high to discourage demand (Faruqui and Sergici 2013).

However, some stakeholders remain unenthusiastic about price-based DR programs. Alexander (2010) raises objections to price-based DR based on social equity considerations, arguing that price-based DR programs disadvantage lower-income customers. In addition, price-based DR programs introduce informational, measurement and metering complexities for both the customer and the electric utility (Borges and Heumann 2023). In contrast to price-based DR programs, the second category of DR programs – incentive-based programs – do not involve time-varying electricity prices based on supply and demand conditions. Instead, utilities employing incentive-based DR approaches aim to induce customers to reduce electricity consumption by other means (Chrysikou, Alamaniotis, and Tsoukalas 2015).

Incentive-based DR programs involve the utility sending customers a notification requesting a reduction in electricity consumption during an upcoming time window because the utility anticipates stresses in meeting the region's peak electricity demands. Most incentive-based DR programs also provide customers some compensation (typically a modest credit on their electricity bill) in exchange for tangible customer actions to reduce electricity consumption during the defined time window. As an example of incentive-based DR, California's Flex Alert

program has been invoked by California's grid operator with increasing frequency in recent years (Hiller 2022).

Pro-social DR programs (Pratt and Erickson 2020) represent a particularly interesting emerging DR variant. Like incentive-based DR programs, pro-social DR programs also rely on the utility communicating to customers an impending need for electricity consumption reduction. However, in a pro-social DR program, the utility does not provide any explicit monetary benefit (beyond the savings stemming from reduced electricity purchases) for a customer to reduce electricity consumption. Instead, the utility purely appeals to the customer's willingness to perform what is essentially a favor for the region: reducing electricity consumption so that everyone will be less likely to experience an outage due to inadequate electricity supply. Thus, a customer's response to a pro-social DR program is not explicitly motivated by economic considerations, but instead by a combination of affective and cognitive considerations about electricity consumption, given their overall beliefs and personal circumstances. As Pratt and Erickson (2020) note, pro-social DR programs are a form of nudge (Thaler and Sunstein 2008) that uses a relatively unobtrusive intervention to stimulate socially-desirable consumer behavior. Further, Asensio and Delmas (2015) show that non-price informational interventions (i.e., interventions without economic inducements) can influence electricity consumption.

3.1.2. Need for Increased Implementation of DR Programs

Notwithstanding their intuitive appeal, DR programs remain only a modest factor in the electricity sector. In the U.S., the aggregate reduction in electricity demand available to be initiated by DR programs was recently estimated to be 31 gigawatts (Federal Energy Regulatory Commission 2021) whereas in Europe it is even lower at 20 gigawatts (Srivastava, Van Passel, and Laes 2018). To mitigate climate change, DR likely must become a more significant factor in

electricity markets worldwide: the International Energy Agency concluded that “500 GW of demand response [should be] brought onto the market by 2030, corresponding to a tenfold increase in deployment levels in 2020” to achieve full global decarbonization by 2050 (International Energy Agency 2022b).

The future need for greater DR implementation arises out of the dramatic changes that are occurring on the supply-side of the global electricity industry. Historically, most power generation on regional electricity grids around the world has been based on combustion of fossil fuels: powerplants could be ramped up and down to meet changing demand levels simply by having grid operators modulate the amount of fuel being burned. However, for both economic and environmental reasons, electricity grids in many parts of the world are becoming more reliant on solar and wind energy (Mitchell 2016). Although lower on emissions and increasingly cost-competitive relative to power generation based on fossil fuels, both solar and wind energy are “intermittent”, producing electricity in volumes dependent upon naturally variable inputs, sunlight and wind. Electricity generated by these intermittent resources “introduces significant intra-day variability into the electricity supply, implying that demand be more flexible” (Møller et al. 2019, p. 1057). Hence, DR programs are likely to become an increasingly important tool for grid operators to maintain stable and reliable operations (Paterakis, Erdinç, and Catalão 2017; Good 2019).

3.1.3. Customer Acceptance of DR Programs

Along with the profound supply-side changes, the demand-side of the electricity industry is also evolving in important ways. Households rarely give deliberative thought to electricity consumption, and may not understand key elements of electricity consumption decisions. Using residential electricity consumption data from the 1970’s, Heslop et al (1981) found that a

customer's price consciousness was the only attitudinal variable that predicted consumption levels. Watson, Viney, and Schomaker (2002) state that for many households, "electricity is a low involvement, routine purchase and, as such, one in which inertia and habit play the dominant role in the decision process" (p. 402). Attari et al. (2010) found that consumers systemically overestimate electricity consumption levels of small devices (e.g., light bulbs) and underestimate electricity consumption levels of higher-powered appliances (e.g., air conditioners). In summary, the evidence suggests that residential consumers have little time, interest, or capacity to make energy-related decisions (Nicholls and Strengers 2015).

Nevertheless, consumer engagement related to electricity consumption has been gradually increasing (Gangale, Mengolini, and Onyeji 2013; Ofgem 2023). Increasingly prevalent "smart" home devices (e.g., air conditioning thermostats, kitchen appliances) require households to anticipate when and why they want to control electricity consumption (Abi Ghanem and Mander 2014), even when they are not physically at home. Lithium-ion batteries have contributed to the proliferation of portable electricity-based devices (e.g., cellphones, tablets, laptops, etc.), which in turn has raised the salience of monitoring ongoing energy consumption and opportunities to plug in for recharging (Raymond 2023).

Over the past decade, the emergence of rooftop solar photovoltaics (PV) as an economically-attractive investment in many locations has caused a growing number of homeowners to realize the opportunities for self-generation of electricity ((Leppert and Kennedy 2022; Dutzik et al 2024). Meanwhile, more frequent electricity grid outages (Kim 2023) combined with an increasing reliance on continuous availability of electricity (e.g., for home internet) has raised demand for on-site generators and battery energy storage systems as backup power supplies (Chediak 2023). As electric vehicles (EVs) become more commonplace –

involving battery recharging by plugging-in overnight at home (St. John 2022), and people increasingly utilizing EVs as a backup power supply in the event of outages (Coren 2023) – household electricity consumption behaviors are likely to become more salient. Greater customer engagement with electricity consumption should improve the future effectiveness of DR programs.

The present research aims to contribute to the understanding of factors that influence consumer responsiveness to DR programs. It hopes to contribute knowledge that not only has academic import, but also helps electric utilities and relevant policymakers (e.g., utility regulators, consumer advocates, environmental advocates) to make informed decisions in designing and implementing DR programs that are more effective in reducing demand while minimizing the disutility experienced by consumers when reducing demand.

The remainder of this essay is structured as follows. Section 3.2 reviews the relevant literature on consumer behavior related to electricity consumption decisions. Section 3.3 describes an experimental pro-social DR program conducted by a large electric utility in the Western U.S. that provides the large dataset on household electricity consumption analyzed in this research. Section 3.4 describes the empirical analyses of how households responded to DR notifications, while Section 3.5 discusses the empirical results – especially the marked differences in behavior found between solar households and non-solar households. Section 3.6 illustrates how differences between solar and non-solar households extend beyond DR event days. Section 3.7 describes a planned experimental study to investigate the behavioral differences found between solar and non-solar households from the empirical analyses. Section 3.8 offers concluding suggestions for future research as well as implications of this research for the academic and practitioner communities.

3.2. Literature Review

Household electricity consumption is a complex and multi-faceted topic that has been researched in many academic disciplines (Frederiks, Stenner, and Hobman 2015). For the research presented herein, three relevant strands of literature are reviewed: (1) consumer responses to DR programs, (2) household electricity consumption following installation of a rooftop PV system, and (3) moral licensing effects in electricity consumption behavior.

3.2.1. Customer Responses to DR Notifications

Although there is a sizable body of literature on customer response to DR programs, much of it is focused on price-based DR programs (Faruqui and Sergici 2013), typically examining price elasticities of demand from an economic perspective. In contrast, only a limited amount of scholarly research examines incentive-based DR programs. Pro-social DR programs, a novel offshoot of incentive-based DR programs, have received even less research attention.

Plausibly, pro-social DR programs can be effective in reducing household electricity demand even without offering an explicit economic incentive. In a meta-analysis of 156 studies, Delmas, Fischlein, and Asensio (2013) found that consumers may not require any direct financial benefit to reduce their electricity consumption, if they receive information designed to encourage such reductions. Johnson et al (2017) suggest that games may viably induce household willingness to reduce electricity consumption even without economic incentives, with Pratt and Erickson (2020) finding that a Vermont utility stimulated meaningful reductions in residential electricity consumption by implementing a game that appealed to household willingness to donate to charities.

However, research investigating the causal effects of non-price interventions on household electricity consumption reductions remains relatively sparse. Andor and Fels (2018) are “surprised how little we know” (p. 186). Good (2019) concurred, noting that “a review of [behavioral economics] literature related to modeling of demand-side energy...reveals that the number of studies is quite small” (pp. 108-109). Wilhite et al. (2000) noted that basic research on household electricity demand has historically tended to be “device-centered” rather than based on “social sciences”, and this observation extends into the realm of DR.

Knowledge of the electricity consuming devices within the household is useful in predicting reductions in household electricity consumption via DR (Afzalan and Jazizadeh 2019). Although dishwashers and laundry appliances (washers and dryers) are particularly well-suited for DR-driven discretionary reduction of electricity consumption (Friis and Haunstrup Christensen 2016), most DR-induced reductions tend to be driven by reductions in air conditioning usage (Zhou et al 2016). Yet, research also shows that households lack a good understanding of how appliance usage translates to electricity consumption (Attari et al 2010; Lesic et al 2018). Parnell and Popovic Larsen (2005) concluded that residential energy consumption decisions are made in the three-dimensional context of self-interest, energy knowledge and cognitive deliberation. However, research shows limitations on both energy knowledge and deliberative decision making (Kim and Shcherbakova 2011; Nicholls and Strengers 2015; Lesic et al 2018) Thus, Kim and Shcherbakova (2011)ask: “If consumers are not aware of their usage patterns, how can they be expected to alter them?” (p. 875).

Non-price informational interventions – such as data on the consumer’s consumption levels relative to peers – can induce changes in household electricity consumption (Karlin, Zinger, and Ford 2015; Andor and Fels, 2018). DR programs may also encourage “time-

shifting” electricity consumption (Higginson, Thomson, and Bhamra 2014; Powells et al 2014; Friis and Haunstrup Christensen 2016), reinforcing earlier findings (Sexton, Johnson, and Konakayama 1987) that continuous display monitors of household electricity consumption (along with electricity market prices) encouraged time-shifting. However, time shifting can also raise electricity consumption after peak hours (North American Electric Reliability Council 2011). Observers (Zhou et al 2016; Chen, Yang, and Xu 2019; Hou et al 2023) attribute this “rebound” effect to increased evening usage of air conditioning to compensate for higher indoor air temperatures due to lower afternoon usage – and recall that consumers systemically underestimate electricity consumption for high-power appliances such as air conditioners (Attari et al 2010).

Jain et al (2015) argue that “the role of the DR message is central in influencing the user to participate, and hence in achieving the desired goal of reduction in energy demand” (p. 453). These researchers offered recommendations on both message delivery method and message content, with an emphasis on suggesting tangible actions that a household can take to reduce electricity consumption under then-prevailing conditions. Chatzigeorgiou, Diou, and Andreou (2020) built on this work to suggest that DR program effectiveness can be enhanced if DR notification messages are linked to specific appliances. Vassileva, Wallin, and Dahlquist (2012) further suggest that DR notifications may be more effective if recipient households are involved in designing and developing the messages to be sent on DR event days.

3.2.2. Electricity Consumption Behavior of Solar Households

Residential adoption of solar electricity has grown significantly and may have moved beyond the early adopter to adoption by an early majority (Rogers 2003). Yet, the mechanisms by which solar ownership affects electricity consumption (particularly behavioral ramifications)

are not well understood. Although installing a rooftop PV system may beget further pro-environmental behaviors (Hondo and Baba 2010), evidence also suggests a collateral environmentally-unfriendly outcome: solar households consume more electricity than non-solar households.

A rooftop PV system should have no direct implication on a household's electricity consumption choices (e.g., usage patterns of specific appliances). Although some researchers find the impact to be minimal (Wittenberg and Matthies 2016; Sekitou, Tanaka, and Managi 2018), others find that the mere act of installing a rooftop PV system increases a household's gross electricity consumption by about 7-28% of the PV system's output (Deng and Newton 2017; Qiu, Kahn and Xing 2019; Beppler, Matisoff, and Oliver 2023; Aydın, Brounen, and Ergün 2023)

This increase in electricity consumption is often attributed to economic rationalizations made by the homeowner. For instance, homeowners with PV systems may consider the electricity produced from their rooftop to be "free" – ignoring the sunk costs associated with the system's installation and reasonably assuming the incremental variable cost of PV electricity production to be zero. This may lead the household to consume electricity inside the house less judiciously than it would otherwise (McKenna and Thomson 2014; Palm, Eidenskog, and Luthander 2018). Shimada and Honda (2024) found that solar households that earn financial credit against the monthly utility electricity bill based on the electricity generated by their PV system, an arrangement referred to as "net metering" (National Academies 2023), consume more electricity than solar households that sell electricity produced by their PV system to the utility grid under a revenue contract.

The decision to install rooftop solar also seemingly affects when electricity is consumed. McKenna and Thomson (2014) found that nearly half of homeowners with solar rooftops engage in time-shifting of electricity consumption commonly observed in customer responses to DR programs. They speculated that homeowners take maximum economic advantage of time-varying price differentials on electricity purchased from the utility vs. electricity from the PV system supplied back to the utility – an economic explanation for PV system installation effects on household electricity consumption.

3.2.3. Moral Licensing Effects on Electricity Consumption

As a concept reflecting motivated reasoning, moral licensing (Monin and Miller 2001) has attracted significant research interest (Blanken, van de Ven, and Zeelenberg 2015). Merritt, Effron, and Monin (2010) describe the essence of moral licensing: “past good deeds can liberate individuals to engage in behaviors that...they would otherwise avoid for fear of feeling or appearing immoral” (p. 344). Pro-environmental behaviors represent one of the many contexts in which moral licensing effects are observed. For example, Mazar and Zhong (2010) found that individuals who purchased environment-friendly products were more likely to cheat or steal than those who did not make such purchases. They concluded that “the halo associated with green consumerism has to be taken with reservations...[P]urchasing green products may license indulgence in self-interested and unethical behaviors” (p.497).

When one pro-environmental behavior is followed (or accompanied) by another behavior that is environment-unfriendly, the associated moral licensing effect has been referred to as “negative spillover” (Nash et al. 2017), which sometimes been conflated with the notion of “indirect rebound” (Dütschke et al. 2018). Reimers et al. (2021) distinguish the three interrelated concepts: moral licensing is the “underlying psychological mechanism” causing a

pro-environmental behavior to spawn a subsequent anti-environmental behavior, negative spillover is the “observable behavioral consequence” if environmentally-beneficial changes in one area of consumption lead to environment-unfriendly changes in another consumption area, and indirect rebound captures the quantitative environmental impacts of those changes (p. 9).

Negative spillover from an individual’s moral self-licensing is observed in numerous contexts (Thøgersen and Ölander 2003; Panzone et al 2012; Catlin and Wang 2013; Geng et al 2016; Noblet and McCoy, 2018; McCoy and Lyons, 2017, Seebauer 2018; Gholamzadehmir, Sparks, and Farsides 2019). However, other research indicates the existence of positive spillover effects, such that prior pro-environmental behaviors beget more pro-environmental behaviors, at least in certain contexts (Thøgersen and Noblet 2012; Kaida and Kaida 2015; Steinhorst, Klöckner, and Matthies 2015). Thus, as noted by Dutschke et al (2018), “while psychological theory [often] points to a moral licensing effect, which would increase the rebound when people feel free to engage in ‘immoral’ behavior by increasing their energy consumption, this response may not be universal” (p. 8). Moral licensing effects are more likely when the pro-environmental behavior is low-cost (Gneezy et al 2012) or easy to accomplish (Lanzini and Thøgersen 2014).

Notably, many of the empirically documented moral licensing effects are cross-domain, i.e., an environment-friendly behavior in one domain is followed by an environment-unfriendly behavior in a different domain. However, moral licensing behaviors may also be domain-specific ((Noblet and McCoy 2018; Reimers et al 2021), both for initial (pro-environmental) behaviors and subsequent environment-unfriendly behaviors, although such “within-domain” effects (Catlin and Wang 2013; Noblet and McCoy 2018; Urban, Braun Kohlová, and Bahník 2021) may involve loose definitions of the domain being investigated.

Prior research shows that certain initial pro-environmental behaviors may lead to the indirect rebound of increased electricity consumption. For instance, an individual's electricity consumption was found to increase after decisions to participate in a green electricity program (Jacobsen, Kotchen, and Vandenberg 2012), conserve water consumption (Tiefenbeck et al 2013), and purchase voluntary carbon offsets (Harding and Rapson 2018). However, little research examines moral licensing effects within the electricity consumption domain. Reimers et al. (2021) note that studies reporting “effects that are in line with moral licensing theory and quantify resulting negative consequences of [prior positive] consumer behaviors” often neglected to ‘experimentally operationalize and test the underlying psychological mechanism’ so as to definitively implicate moral licensing as a causal factor (p. 10). McCarthy (2022) tried but failed to find a moral licensing effect in which solar households felt entitled to consume more electricity. As Rabaa, Wilken, and Geisendorf (2024) note, “surprisingly little literature has focused on energy efficiency behavior and potentially resulting moral licensing rebound effects....Evidence for indirect moral licensing rebound effects is even sparser” (p. 3).

3.3. Data from Pro-Social DR Program Field Experiment

This research exploits panel (both time series and cross-sectional) data on household electricity consumption gathered from an experimental pro-social DR program launched and managed by an electric utility. The DR program was launched in 2019, applying to households of a master-planned housing community under development in a suburb of a large metropolitan area in the Western U.S.

3.3.1. Program Details

In the subject DR program, the utility could declare a “DR event” on any weekday (up to 10 days maximum) during the summer months (June 1 through September 30). As a practical

matter, a utility declares a DR event only on days in which ambient weather conditions are expected to be very hot and humid, producing very high levels of regional air conditioning demand in the late afternoon. In this field experiment, to declare a DR event for a certain day, the utility sent a text notification (1) informing recipients that the regional electricity grid will be experiencing strains in meeting anticipated demands in the upcoming afternoon, and (2) asking the recipient – on a purely voluntary basis – to reduce electricity consumption between 4 pm and 8 pm local time (referred to herein as the “DR window”). The notification is sent by the utility via text to customers assigned randomly to the treatment condition (but not to those assigned to the control condition) at 2 pm local time of the DR event day. The text notification does not promise any economic benefits from reducing electricity consumption, but does offer suggestions on how consumption levels could be reduced at minimal disutility to the customer. The exact wording used in the notifications sent during the DR event days are presented in Appendix 3.1.

The utility managed the DR program as a randomized controlled trial (RCT) experiment (Stolberg, Norman, and Trop 2004), consistent with recently recommended research protocols for electric utilities investigating residential electricity consumption behavior (Stewart and Todd 2020). For any given DR event, the utility randomly selects half of the community households to receive a DR notification text (the treatment condition), with the remaining half of the households not receiving any such text (the control condition). Randomization of household selection to the treatment condition occurs independently for each DR event, so that there is zero joint correlation between households, condition assignment, and DR event. This minimizes the likelihood of systemic differences between the control and treatment populations associated with any DR event. Given the RCT design of the DR program and the homogeneity of the households

in this community, endogeneity is unlikely, and statistically significant differences in observed electricity consumption between treatment and control households may be plausibly attributed to the DR notification.

3.3.2. Data Description

The electricity consumption data for this research were continuously collected from the community households by a software vendor contracted to support the utility running the DR program. Electricity consumption data is electronically retrieved at 15-minute intervals from the electricity meter attached to each household. Thus, electricity “consumption” reflects the amount of electricity purchased by the household from the electric utility. (As discussed in Section 3.4.2, the precise definition of electricity consumption matters). For this research, electricity consumption data was used from the period from June 1, 2021 to September 22, 2021. Longitudinally, this 114-day period contains 10,944 consecutive 15-minute intervals.

A separate Excel data file of longitudinal electricity consumption data was provided for each household, named with a unique anonymized identifier (including type of electricity meter) for the house. No information enabling identification of households, such as homeowner name or mailing address, was included in any of the data. Each data record contained two variables: (1) a timestamp associated with the 15-minute time increment, and (2) electricity consumption for the 15-minute time increment expressed as average kilowatts (kW) during the period. Thus, the electricity consumption during a given hour (in kilowatt-hours, kWh) is given by the sum of the four reported 15-minute average kW values. The longitudinal Excel files for each household were then merged to create one panel dataset (containing time series and cross-sectional data). Because the data are proprietary, please contact the author if access to the data is desired.

The raw electricity consumption data in Excel files for each of 1,181 households in this community were provided by the software vendor managing data collection for the utility's DR program. Data from 72 households were excluded due to technical considerations (see Section 3.4.2). In addition, 802 homes with operational electricity meters reported extended durations of zero values for electricity consumption and were inferred to be vacant (e.g., newly-built homes awaiting occupancy) and were also excluded from the dataset. The data used for the analysis were from the remaining 307 households that reported electricity consumption data throughout the focal timespan. Given 10,944 consecutive 15-minute intervals during the timespan, the resulting panel dataset used for analysis totaled 3,359,808 observations (307 x 10,944).

During the timespan of the data, the utility invoked DR events on seven separate days. For each DR event, household assignments to the treatment condition were provided in a separate dataset. The unique anonymized identifier assigned for each household identified the households assigned to treatment condition for each DR and was mapped into the longitudinal electricity consumption dataset as a treatment dummy variable of value 1 (treatment household) or 0 (control household).

STATA was chosen as the statistical package for conducting the panel regression analyses. For all regressions, the dependent variable of interest is household electricity consumption during a given 15-minute time increment, with analysis aiming to identify any significant "DR effect" = the difference in electricity consumption between treatment and control households during the afternoon and evening hours of DR event days. To control for household level variation in electricity consumption (e.g., house size, number of occupants, etc.), all panel regressions included household-specific fixed effects (Kruiniger 2002). To control for intraday variation of household electricity consumption, each of the panel regressions included hourly

dummy variables as independent variables, wherein each hour was comprised of the four successive observations (recorded at 15, 30, 45 and 60 minutes after the top of each hour). This leads to the use of the term “hour-ending” ascribed herein to each hourly dummy variable. Hence, a coefficient estimate for an hourly dummy variable is to be interpreted as the average effect on household electricity consumption during any 15-minute increment of that hour.

3.3.3. Suitability of Data for Research Objectives

Data from this housing community is uncommonly well-suited to quantitative investigation of consumer response to DR programs. The DR program was organized from the outset with RCT principles, thereby producing treatment effects associated only with the subsample of the population randomly assigned to receive DR notification texts. This allows causal inferences from any observed differences in consumption outcomes between households that received the DR notification (treatment group) and those that did not (control group). In addition, households in this community exhibit a high degree of homogeneity. The standardized single-family home designs are marketed to a well-defined segment: young upper-middle class families. Because development of the community began less than 10 years ago, all homeowners have purchased their homes relatively recently, implying that this demographic homogeneity has remained stable. Moreover, all houses are inherently of recent vintage in design and construction, and must comply with a strict building code set by the developers, ensuring that building and appliance performance are similar across houses.

Households in this community are expected to be more responsive to DR notifications than the average residential electricity consumer. When considering home ownership, a prospective buyer receives many cues emphasizing both the technological sophistication and environmental sustainability of the houses and of the community’s lifestyle. The building code

requires that all homes feature technological and environmental elements that substantially exceed U.S. norms, including “solar-ready” rooftops and wiring. Partnering with the local utility, the community has established a formal energy strategy to maximize adoption of renewable energy and energy efficiency, with the declared goal of a carbon-neutral energy supply by 2040. Marketing messages from the community prominently feature that each home has access (via smartphone app) to real-time data on electricity usage and can remotely monitor and control major appliances. Homeowners are also informed that (1) home ownership implies participation in the utility’s voluntary DR program (see Section 3.3.1), and (2) that any electricity consumption reductions will be solely of the homeowner’s (and not the utility’s) choosing. This emphasis on environmental sustainability and “smart home” technologies makes households in this community ideal for participating in a pro-social DR program.

3.4. Empirical Analysis

Empirical analysis began with an exploratory investigation of the data from the seven DR event days (June 10, June 16, July 28, August 9, August 25, September 9 and September 16) in the data sample period in the summer of 2021. This “model-free” analysis revealed data characteristics that guided subsequent analyses.

3.4.1. Treatment Effects on DR Event Days

An initial analysis examined hourly differences in electricity consumption on DR event days between households assigned to the treatment and control conditions respectively. Using data sets for each of the seven DR days, panel regressions with fixed effects for each household (Kruiniger 2002) were employed to estimate household electricity consumption. The following regression equation was used for each of the seven DR days:

$$E_{it} = \beta_h h_h + \gamma_h h_h T_i + \xi_i H_i + \varepsilon_{it} \quad (1)$$

where:

E_{it} = energy consumption for household i in 15-minute time increment t

h_h = hourly dummy variable for hour-ending h (for all h from 1, 2, ..., 13, 15, ...24)

T_i = treatment condition dummy variable for household i , with $T_i=1$ if assigned to treatment condition on DR day and $T_i=0$ otherwise

H_i = fixed effect for household i in hour-ending 14

ε_{it} = error term for household i in time increment t

β_h = coefficient for average household electricity consumption in hour-ending h

γ_h = coefficient for incremental average treatment household electricity consumption in hour-ending h

ξ_i = coefficient for incremental average hourly electricity consumption for household i

Note that estimating equation (1) involves specifying 23 hourly dummy variables (h_h), omitting one hourly dummy variable (selected as hour-ending 14, i.e., 2 pm, that coincides with the DR notification, 2 hours prior to the beginning of the DR event window). When performing panel regressions with fixed effects in STATA, results are presented with a single intercept term that equals the average value of the household fixed effects (i.e., $\frac{1}{n} \sum_{i=1}^n \xi$). Thus, Equation 1 is estimated in STATA via the following equation:

$$E_{it} = \alpha + \beta_h h_h + \gamma_h h_h T_i + \varepsilon_{it} \quad (2)$$

where $\alpha = \frac{1}{n} \sum_{i=1}^n \xi$

The final term in equation (2) represents 23 hourly-treatment dummy variables ($h_h T_i$), which are crucial to this investigation: the expected DR effect on a DR event day would be indicated if the estimated coefficients (γ_h) for the hourly-treatment dummy variables associated with the DR

event window (hour-ending 17 through hour-ending 20, running from 4 pm to 8 pm) were negative and statistically significant.

In these initial analyses, no evidence was found in support of DR effects in the expected direction. Two aspects of the results were particularly surprising. First, when the hourly-treatment effect coefficients were statistically significant, many of the coefficients were positive rather than negative, suggesting that the DR notification actually resulted in higher electricity consumption. Second, the hourly-treatment effect coefficients were often statistically significant for time periods *before* the DR event window (i.e., before the treatment effect should have taken effect). One example of this anomalous set of results (for the first of seven DR event days, June 10, 2021) is presented below:

Table 3.1: Estimated Hourly Treatment Coefficients for June 10, 2021

energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
treathoure1	.079165	.0260742	3.04	0.002	.0280583	.1302717
treathoure2	.1003666	.0260797	3.85	0.000	.0492492	.1514839
treathoure3	.0864928	.026062	3.32	0.001	.03541	.1375756
treathoure4	.0724912	.0260956	2.78	0.005	.0213427	.1236398
treathoure5	.0672546	.0260452	2.58	0.010	.0162048	.1183044
treathoure6	.0544435	.0260847	2.09	0.037	.0033163	.1055707
treathoure7	.076269	.0260859	2.92	0.003	.0251394	.1273985
treathoure8	.0445165	.0260805	1.71	0.088	-.0066025	.0956355
treathoure9	.0397078	.0260859	1.52	0.128	-.0114218	.0908374
treathoure10	.0361743	.0260745	1.39	0.165	-.0149329	.0872815
treathoure11	.0393034	.0260842	1.51	0.132	-.0118227	.0904296
treathoure12	.0269804	.0260319	1.04	0.300	-.0240434	.0780042
treathoure13	-.0079264	.0260211	-0.30	0.761	-.0589288	.0430761
treathoure15	.0056459	.0260323	0.22	0.828	-.0453786	.0566703
treathoure16	.0486823	.0260395	1.87	0.062	-.0023563	.0997209
treathoure17	.0934702	.0260661	3.59	0.000	.0423794	.144561
treathoure18	.1161847	.0260772	4.46	0.000	.0650722	.1672971
treathoure19	.0778998	.0260935	2.99	0.003	.0267553	.1290443
treathoure20	.0702793	.0261103	2.69	0.007	.019102	.1214567
treathoure21	.0758355	.0260562	2.91	0.004	.0247642	.1269068
treathoure22	.0721424	.0260577	2.77	0.006	.0210682	.1232166
treathoure23	.1293906	.0260907	4.96	0.000	.0782517	.1805295
treathoure24	.1246839	.0261122	4.77	0.000	.0735029	.175865

An analysis pooling the data from all seven DR event days for a single regression analysis provided no additional clarification of the anomaly that emerged above. Even with the pooled data, only a few statistically significant hourly treatment effects emerged. Where they did emerge – in the evening at and after the end of the DR window, hour-ending 18 through hour-ending 22 – the statistically significant effects were positive rather than negative. Taken at face value, these results imply that households receiving the DR notifications were actually increasing (rather than reducing) electricity consumption during the event time window. These pooled results (see Table 3.2) provoked a closer scrutiny of the raw data to identify other factors that may have contributed to these puzzling results.

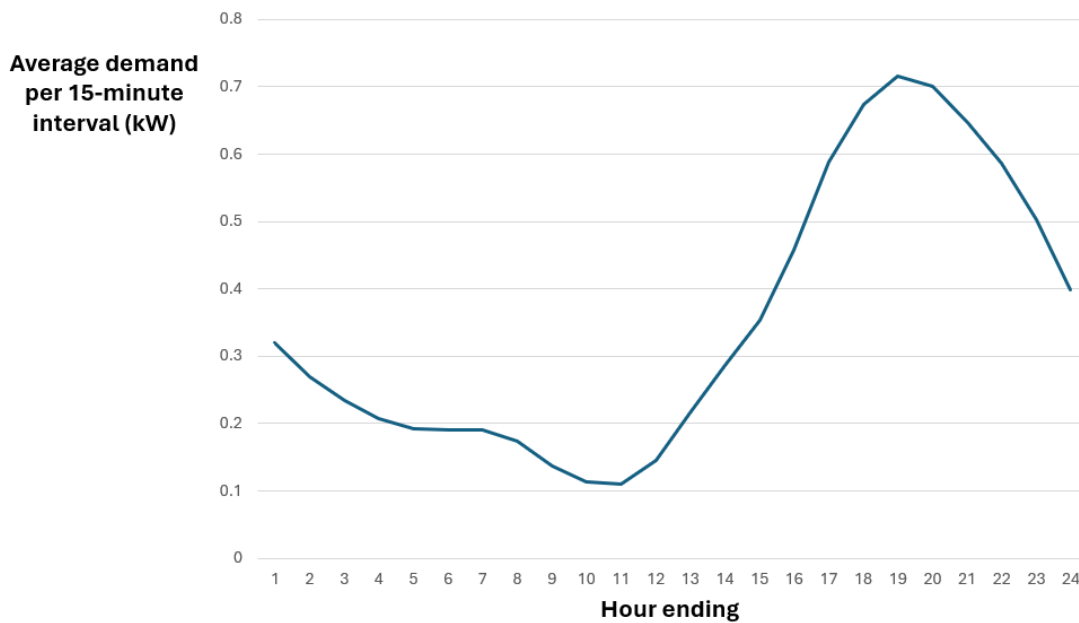
Table 3.2: Estimated Hourly Treatment Coefficients for Pooled 7 DR Days

energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
treathoure1	.0061908	.0073324	0.84	0.398	-.0081805	.0205621
treathoure2	.0060641	.0073333	0.83	0.408	-.0083084	.0204366
treathoure3	.0063179	.0073208	0.86	0.388	-.0080307	.0206664
treathoure4	.0088028	.0073226	1.20	0.229	-.0055493	.0231549
treathoure5	.0029161	.0073223	0.40	0.690	-.0114355	.0172677
treathoure6	-.0022834	.0073306	-0.31	0.755	-.0166513	.0120844
treathoure7	.0021325	.0073339	0.29	0.771	-.0122416	.0165067
treathoure8	-.0014736	.0073333	-0.20	0.841	-.0158462	.012899
treathoure9	-.0058208	.0073338	-0.79	0.427	-.0201948	.0085532
treathoure10	-.0005647	.0073359	-0.08	0.939	-.0149429	.0138135
treathoure11	.0000103	.0073403	0.00	0.999	-.0143765	.0143971
treathoure12	.0020337	.0073433	0.28	0.782	-.012359	.0164263
treathoure13	-.0134844	.007323	-1.84	0.066	-.0278373	.0008685
treathoure15	-.0098655	.0073522	-1.34	0.180	-.0242756	.0045446
treathoure16	.0035454	.0073442	0.48	0.629	-.010849	.0179398
treathoure17	.0039825	.0073435	0.54	0.588	-.0104105	.0183756
treathoure18	.0162534	.0073438	2.21	0.027	.0018596	.0306472
treathoure19	.0187086	.0073331	2.55	0.011	.0043359	.0330814
treathoure20	.0133469	.0073406	1.82	0.069	-.0010405	.0277343
treathoure21	.0152948	.0073346	2.09	0.037	.0009191	.0296705
treathoure22	.0121934	.0073368	1.66	0.097	-.0021866	.0265735
treathoure23	-.0069567	.007347	-0.95	0.344	-.0213567	.0074433
treathoure24	-.0081093	.0073442	-1.10	0.270	-.0225038	.0062852

3.4.2. Distinguishing Solar Households from Non-Solar Households

Upon closer scrutiny of the puzzling findings presented above, it became apparent that some unobserved factor was affecting the results in important ways. Hence, analysis was undertaken of the electricity consumption levels on an hour-by-hour basis. Note that the coefficients of the hourly dummy variables (along with the intercept term) enable direct calculation of average recorded household electricity consumption values for all households in the control condition (i.e., those not receiving DR notification) on an hour-by-hour basis. Figure 3.1 presents average 15-minute (kW) electricity consumption levels for each hour for all control households during the seven DR event days of summer 2021.

**Figure 3.1: Daily Electricity Consumption Pattern
for All Control Households on All DR Days**



Visual inspection of Figure 3.1 reveals that average household electricity consumption during late morning hours on DR event days fell substantially below consumption levels from overnight hours. This unusual pattern of recorded electricity consumption hinted at some other

factor exerting strong effects on the data. A major clue to explaining this unusual consumption pattern emerged under further scrutiny. For a substantial number of households, electricity consumption was reported as negative over several time intervals. The sole plausible explanation for these negative values is that, during those hours, the household was not receiving electricity from the grid but instead was sending electricity to the grid. In other words, such a household could safely be assumed to have a power generation device that was producing electricity in excess of the amount being consumed at the household, with the surplus electricity being transferred to the grid.

It was further inferred that any household power generation was supplied by solar photovoltaic (PV) modules mounted on the rooftop. Although on-site electricity production at a household could theoretically be provided by a backup (natural gas or diesel operated) generator, this possibility was ruled out for two reasons: (1) backup generators only operate when there is a grid outage, but the community's electricity consumption data recorded no outages, and (2) negative electricity consumption values were seen during late morning and early afternoon hours (i.e., when the sun is high in the sky and solar energy availability is therefore high) and never at night (when solar energy availability is zero). Moreover, the community actively promotes itself to be environmentally-conscientious – recall that all homes are required to be “solar-ready” – and likely discourages backup generators that are typically considered environment-unfriendly (Friedman 2020). Discussions with the software vendor managing the electricity consumption data, as well as review of Google Maps aerial photography of the community, confirmed that a substantial fraction of homes are equipped with rooftop solar installations.

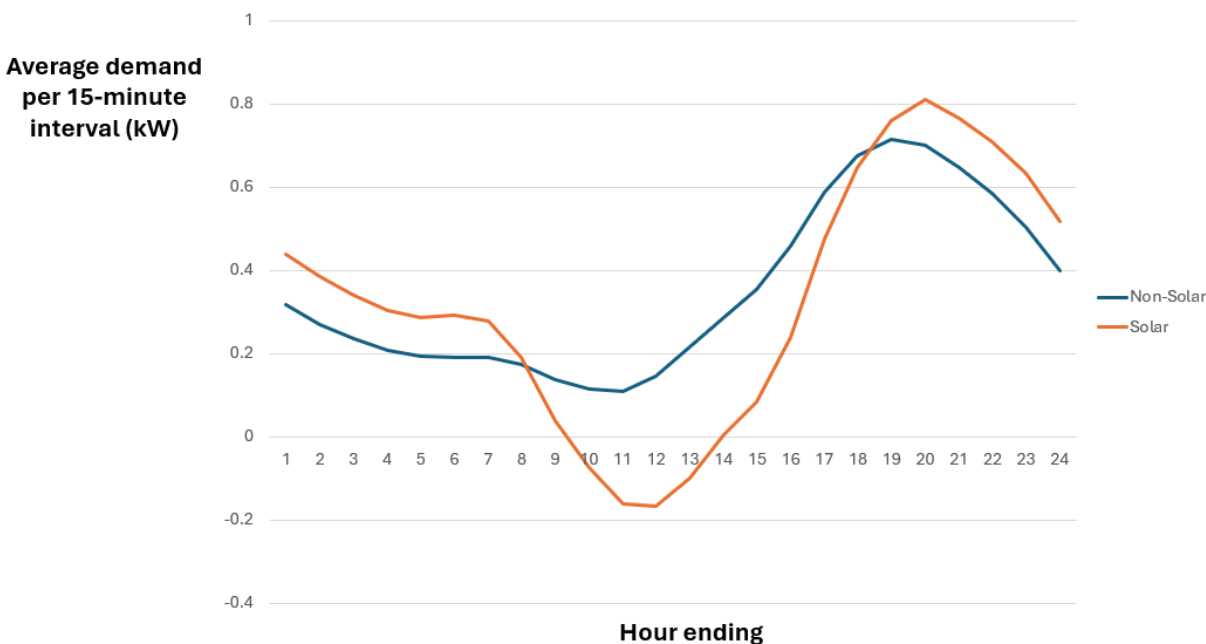
Household rooftop solar adoption is rapidly increasing worldwide and is common in many locations (International Energy Agency 2022a). Grid operators recognize that, after

adopting rooftop solar, a residential electricity customer becomes a “prosumer” (Parag and Sovacool 2016): sometimes producing electricity for the grid, at other times consuming electricity from the grid. The transfer of electricity to the grid from a house’s solar rooftop reverses the direction of operation of the house’s electricity meter. The corresponding lowering of the household’s electricity bill is termed “net metering” and is increasingly accommodated by many electric utilities around the world (National Academies 2023). Because of net metering, the observations in the dataset more precisely reflect “household electricity purchases from the utility” rather than “household electricity consumption”. As a result, some fraction of a solar household’s electricity consumption (during sunny hours) is not recorded in the data, as it is being supplied by output from the house’s rooftop solar installation rather than the grid.

Although the raw data provided by the software vendor did not include definitive identification of households with solar rooftops, solar households can be reasonably distinguished from non-solar households by interpretation of the electricity consumption data itself: any observation with a negative recorded value is an unambiguous signal of that household being equipped with a solar rooftop. This criterion is believed to be a good discriminator of homes with (versus without) solar rooftops because instances of a solar household never contributing any electricity back to the grid during an entire summer are highly unlikely. Thus, a solar dummy variable with a value of 1 was applied to households that had at least one observation of negative value.

Having distinguished solar vs. non-solar households, the significantly different daily electricity consumption pattern for the average solar household vs. the average non-solar household (across all seven DR event days) is shown in Figure 3.2.

**Figure 3.2: Daily Electricity Consumption Pattern on DR Days
for Solar vs. Non-Solar Households**



As Figure 3.2 reveals, the hourly differences in electricity consumption between solar and non-solar households are large, dwarfing any underlying DR treatment effect. Between solar households and non-solar households, the daily electricity consumption pattern begins diverging in the early morning hours (hour-ending 7) as the sun rises, and eventually reconverges in the early evening hours (hour-ending 20) as the sun sets. Note the negative electricity consumption values among solar households in the late morning and early afternoon hours. During these hours, when the sun is high in the sky, rooftop PV system output is near or at maximum rated capacity and (on average) exceeds internal household electricity demands. The surplus volume of electricity is sent back to the grid in a reverse flow such that electricity purchases from the utility are negative. Because daily electricity consumption patterns are so profoundly different between solar and non-solar households, the sample of solar and non-solar households cannot be

deemed as homogenous, and all subsequent analyses discussed below evaluate DR effects separately for solar and non-solar households.

During classification of solar and non-solar houses, the data also revealed 71 households with many successive mid-day electricity consumption readings of zero, but with substantially positive electricity consumption during overnight hours. Discussions with the software vendor operating the DR program confirmed that these households were equipped with a particular model of electricity meter (“meter type 14”) that did not record negative values, but only values of zero when the grid was not supplying the house with electricity. Anticipating potential complications in analyses, data from these 71 households were excluded from the analyses. Data from one other household was excluded because the recorded electricity consumption signaled a defective meter. The final panel dataset used in the analyses included a total of 307 households, of which 124 were inferred to be solar households and the remaining 183 deemed as non-solar households.

3.4.3. Treatment Effects for Solar and Non-Solar Households on DR Event Days

Panel regression methods were again employed to estimate household electricity consumption for each time increment among the four categories of households (2: control vs. treatment x 2: solar vs. non-solar). To estimate contrasts between solar households and non-solar households, regression equation (2) was expanded to also include solar x hourly dummy variables and solar x treatment x hourly dummy variables, resulting in the following regression equation:

$$E_{it} = \alpha + \beta_h h_h + \gamma_h h_h T_i + \delta_h h_h S_i + \rho_h h_h S_i T_i + \varepsilon_{it} \quad (3)$$

where:

S_i = solar dummy variable for household i ($S_i=1$ if solar household and $S_i=0$ otherwise)

δ_h = coefficient for incremental average solar household electricity consumption in hour-ending h

ρ_h = coefficient for incremental average solar treatment household electricity consumption in hour-ending h

In regression equation (3), the (β_h) coefficients estimate hourly variations in electricity consumption, the (γ_h) coefficients reflect the average hourly impact on energy consumption for a non-solar household in the treatment condition, the (δ_h) coefficients identify the average hourly impact on electricity consumption for a solar household, and the (ρ_h) coefficients estimate the average hourly impact on electricity consumption of a solar household assigned to the treatment condition. The analysis included household fixed effects as before, with the average effect for a non-solar control household reflected in the coefficient α . The dataset pooled electricity consumption for all seven DR days, providing additional statistical power for the analysis conducted to estimate equation 3.

Table 3.3 compares the estimated treatment effect coefficients (and their statistical significance levels) for non-solar and for solar households. As the right-hand panel shows, the solar households show a DR effect in which electricity consumption for treatment households declines after receiving a DR notification, as indicated by the negative and statistically-significant coefficient estimates for timespan from hour-ending 13 through hour-ending 17.

**Table 3.3: Estimated Hourly Treatment Coefficients for
Non-Solar and Solar Households for all 7 DR Days**

Hourly Treatment Coefficients: Non-Solar Households						Hourly Treatment Coefficients: Solar Households							
energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]	energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]		
treathoure1	-.0040198	.008702	-0.46	0.644	-.0210756	.0130359	solartreathoure1	.015263	.0136155	1.12	0.262	-.011423	.041949
treathoure2	-.0025785	.0087082	-0.31	0.758	-.0197465	.0143894	solartreathoure2	.0111599	.0136132	0.82	0.412	-.0155216	.0378415
treathoure3	-.0042254	.0086867	-0.49	0.627	-.0212511	.0128003	solartreathoure3	.0161426	.0135955	1.19	0.235	-.0105041	.0427894
treathoure4	-.0037813	.0086883	-0.44	0.663	-.0208102	.0132476	solartreathoure4	.0228179	.0135986	1.68	0.093	-.003835	.0494709
treathoure5	-.0057173	.0086888	-0.66	0.511	-.0227472	.0113125	solartreathoure5	.0130388	.0135977	0.96	0.338	-.0136124	.03969
treathoure6	-.0071726	.0086954	-0.82	0.409	-.0242155	.0098703	solartreathoure6	.0032354	.0136154	0.24	0.812	-.0234505	.0299213
treathoure7	-.0008436	.0087098	-0.10	0.923	-.0179147	.0162275	solartreathoure7	-.0008871	.0136142	-0.07	0.948	-.0275705	.0257964
treathoure8	-.0037639	.0087053	-0.43	0.665	-.020826	.0132983	solartreathoure8	.0022872	.0136152	0.17	0.867	-.0243982	.0289726
treathoure9	-.0114245	.0086916	-1.31	0.189	-.0284598	.0056107	solartreathoure9	.0186217	.0136277	1.37	0.172	-.0080882	.0453316
treathoure10	.0028298	.008698	0.33	0.745	-.0142181	.0198776	solartreathoure10	.0013164	.0136277	0.10	0.923	-.0253935	.0280263
treathoure11	.011734	.0087106	1.35	0.178	-.0053385	.0288065	solartreathoure11	-.0159435	.01363	-1.17	0.242	-.0426579	.010771
treathoure12	.0172445	.0087014	1.98	0.048	-.00019	.034299	solartreathoure12	-.0217909	.0136449	-1.60	0.110	-.0485346	.0049527
treathoure13	.0142268	.0086822	1.64	0.101	-.0027902	.0312437	solartreathoure13	-.0485438	.0136044	-3.57	0.000	-.0752081	-.0218794
treathoure15	.0137865	.0087301	1.58	0.114	-.0033243	.0308973	solartreathoure14	-.0317633	.010487	-3.03	0.002	-.0523175	-.0112091
treathoure16	.0255863	.0087214	2.93	0.003	.0084927	.04268	solartreathoure15	-.0473356	.0136478	-3.47	0.001	-.074085	-.0205862
treathoure17	.0164755	.0087198	1.89	0.059	-.0006152	.0335661	solartreathoure16	-.04322176	.013633	-3.17	0.002	-.069938	-.0164971
treathoure18	.0246439	.0087274	2.82	0.005	.0075383	.0417494	solartreathoure17	-.0250054	.0136326	-1.83	0.067	-.051725	.0017142
treathoure19	.0074402	.0087141	0.85	0.393	-.0096393	.0245197	solartreathoure18	-.020648	.0136285	-1.52	0.130	-.0473596	.0060635
treathoure20	.0114161	.0087247	1.31	0.191	-.005684	.0285162	solartreathoure19	.0217932	.0136097	1.60	0.109	-.0048813	.0484678
treathoure21	.0031964	.0087088	0.37	0.714	-.0138727	.0202654	solartreathoure20	-.0044054	.0136217	-0.32	0.746	-.0311037	.0222928
treathoure22	.0109232	.0087196	1.25	0.210	-.006167	.0280135	solartreathoure21	.0182693	.0136174	1.34	0.180	-.0084205	.044959
treathoure23	.0042082	.0087368	0.48	0.630	-.0129156	.0213321	solartreathoure22	-.0099814	.0136167	-0.73	0.464	-.0366698	.0167069
treathoure24	.0023507	.008727	0.27	0.788	-.0147541	.0194555	solartreathoure23	-.040061	.0136318	-2.94	0.003	-.0667789	-.013343
							solartreathoure24	-.0365638	.0136304	-2.68	0.007	-.0632791	-.0098485

Meanwhile, the left-hand panel suggests that non-solar households show the opposite DR effect: non-solar treatment households increase electricity consumption after receiving the DR notification, evidenced by the positive and significant coefficient estimates for timespan from hour-ending 16 through 18. In other words, among non-solar households, the DR notification may have had the unintended effect of increasing electricity consumption rather than decreasing it.

For solar households, the results were more aligned with what is expected from a DR effect. For these households, the solar x treatment x hourly coefficients indicate a significant reduction in electricity consumption among treatment households in the afternoon (hour ending 13 through hour ending 17). However, the desired DR effect did not occur during the evening hours of the DR window. Interestingly, the solar households also show a significant DR effect for several hours in the late evening (hour-ending 23 and hour-ending 24) well after the end of the DR window.

At this point, an as-yet unexplained anomaly in the results should be noted: the data show evidence of statistically-significant treatment effects before the 2 pm (hour-ending 14) issuance of the DR notification to treatment households. For instance, in the results presented in Table 3.3, significant treatment effects are shown in hour-ending 12 for non-solar households and hour-ending 13 for solar households. Although the software vendor responsible for managing the data and delivering the DR text notifications confirms that the text messages on DR event days were sent at 2 pm local time (hour-ending 14), it is difficult to explain findings regarding the existence of DR effects before the 2 pm DR notification (hour ending 14) text message was sent. Since there is no logical way in which randomly-assigned treatment (control) households could have systemically guessed that a DR event would (would not) be forthcoming

before the DR text notification was issued, it is currently suspected that a separate communication pathway – for instance, a signal to the house’s electricity meter indicating impending assignment to the treatment condition, subsequently spawning adjustments by the smart thermostat inside the house – may have been actuated before the official DR notification was issued. This possibility is under investigation and remains a caveat in interpreting the results of the above and the following analyses.

3.4.4. Treatment Effects Using Data From Entire Summer of 2021

To bring even more statistical power to this assessment (e.g., through better estimation of household fixed effects), the panel dataset was expanded beyond the seven DR days to include household electricity consumption data from all 114 days between June 1 and September 22. Accordingly, the panel regression equation was modified with additional dummy variables created to control for non-DR weekdays and for weekend days and holidays. The resulting regression equation took the following form:

$$E_{it} = \alpha + \beta_h h_h + \eta_h h_h DR_j + \delta_h h_h S_i + \rho_h h_h S_i T_i + \theta_h h_h NS_i T_i + \lambda_h h_h w_j + \varepsilon_{it} \quad (4)$$

where:

NS_i = non-solar dummy variable for household i, with $S_i=1$ if non-solar household and $S_i=0$ otherwise

DR_j = DR dummy variable for day j, with $DR_j=1$ if DR event day and $DR_j=0$ otherwise

w_j = weekend/holiday dummy variable for day j, with $DR_j=1$ if weekend day or holiday and $DR_j=0$ otherwise

Equation (4) includes both solar x treatment dummy variables and non-solar x treatment dummy variables. If the data used in the regression reflected only the energy consumption values from DR event days, the regression would not be estimable due to singularity issues.

However, since the expanded dataset includes non-DR days, the singularity issue is eliminated because the treatment dummy is zero for all households (no treatment is administered on non-DR days), hence making the regression estimable. The regression specification of equation (4) also enables use of the estimated coefficients to directly calculate the DR treatment effects via contrasts of the average household energy consumption for the treatment group versus that for the control group. The coefficients (λ_h) related to the weekend/holiday dummy are not of focal interest and are included only to account for the substantial variance in household energy consumption introduced when including weekdays and holidays in the analysis.

In summary, the coefficients in equation 4 may be used as follows to infer the average hourly electricity consumption for both solar and non-solar households in the treatment and control conditions:

- a) $\alpha + \beta_h + \eta_h$ = hourly average consumption for all non-solar control households
- b) $\alpha + \beta_h + \eta_h + \delta_h$ = hourly average consumption for all solar control households.
- c) $\alpha + \beta_h + \eta_h + \theta_h$ = hourly average consumption for all non-solar treatment households
- d) $\alpha + \beta_h + \eta_h + \delta_h + \rho_h$ = hourly average consumption for all solar treatment households.

Contrasts can be drawn between all four (2 x 2: solar vs. non-solar, treatment vs. control) household types of interest. Subtracting (a) from (c) reveals the estimated magnitude of the average treatment effect (θ_h) for each hour of a DR event day for non-solar households, while subtracting (b) from (d) reveals the estimated magnitude of the average treatment effect (ρ_h) for each hour of a DR event day for solar households. In turn, subtracting these two treatment effects from each other (i.e., a difference-in-difference calculation) shows how the treatment effect for solar households differs from that for non-solar households. The results from the single panel regression on equation (4), using data from all 114 days, are presented in Table 3.4.

**Table 3.4: Estimated Hourly Treatment Coefficients for
Non-Solar and Solar Households Using Summer 2021 Data**

Hourly Treatment Coefficients: Non-Solar Households				Hourly Treatment Coefficients: Solar Households									
energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]	energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]		
nonsolartreatmenthour1	.001672	.0077803	0.21	0.830	-.013577	.0169211	solartreatmenthour1	.0136322	.0087325	1.56	0.119	-.0034831	.0307476
nonsolartreatmenthour2	.0013523	.0077865	0.17	0.862	-.0139089	.0166135	solartreatmenthour2	.0134041	.0087226	1.54	0.124	-.0036918	.0305
nonsolartreatmenthour3	.0026429	.0077684	0.34	0.734	-.0125828	.0178687	solartreatmenthour3	.0122967	.008713	1.41	0.158	-.0047805	.0293738
nonsolartreatmenthour4	.0069821	.0077654	0.90	0.369	-.0082378	.022202	solartreatmenthour4	.013562	.0087186	1.56	0.120	-.0035262	.0306591
nonsolartreatmenthour5	.0046625	.007766	0.60	0.548	-.0105587	.0198837	solartreatmenthour5	.0027588	.0087158	0.32	0.752	-.0143239	.0198415
nonsolartreatmenthour6	-.0023917	.0077738	-0.31	0.758	-.0176281	.0128448	solartreatmenthour6	.0003249	.0087288	0.04	0.970	-.0167832	.017433
nonsolartreatmenthour7	-.0008482	.0077859	-0.11	0.913	-.0161082	.0144119	solartreatmenthour7	.0092497	.0087236	1.06	0.289	-.0078483	.0263478
nonsolartreatmenthour8	-.0001559	.007782	-0.02	0.984	-.0154083	.0150965	solartreatmenthour8	.0040254	.0087246	0.46	0.645	-.0130746	.0211254
nonsolartreatmenthour9	.0082286	.0077758	1.06	0.290	-.0070117	.023469	solartreatmenthour9	-.0114263	.0087345	-1.31	0.191	-.0285457	.0056931
nonsolartreatmenthour10	.01766	.0077755	2.27	0.023	.0024202	.0328998	solartreatmenthour10	-.0068418	.0087447	-0.78	0.434	-.0239812	.0102976
nonsolartreatmenthour11	.0252473	.0077793	3.25	0.001	.0100002	.0404945	solartreatmenthour11	-.0136475	.0087449	-1.56	0.119	-.0307872	.0034922
nonsolartreatmenthour12	.0305338	.0077717	3.93	0.000	.0153016	.045766	solartreatmenthour12	-.0140149	.00876	-1.60	0.110	-.0311841	.0031544
nonsolartreatmenthour13	.0169098	.0077764	2.18	0.029	.0016926	.0321269	solartreatmenthour13	-.0279585	.0087238	-3.20	0.001	-.0450568	-.0108601
nonsolartreatmenthour14	.008096	.0077666	1.04	0.297	-.0071264	.0233183	solartreatmenthour14	-.0242508	.0087485	-2.77	0.006	-.0413976	-.007104
nonsolartreatmenthour15	.0340127	.0077893	4.37	0.000	.0187459	.0492795	solartreatmenthour15	-.0532001	.0087617	-6.07	0.000	-.0703726	-.0360275
nonsolartreatmenthour16	.0526661	.0077882	6.76	0.000	.0374014	.0679307	solartreatmenthour16	-.0472584	.0087391	-5.41	0.000	-.0643867	-.0301301
nonsolartreatmenthour17	.0342336	.0077909	4.39	0.000	.0189638	.0495035	solartreatmenthour17	-.0247464	.0087365	-2.83	0.005	-.0418696	-.0076232
nonsolartreatmenthour18	.0399471	.0077962	5.12	0.000	.0246668	.0552273	solartreatmenthour18	-.008205	.0087282	-0.94	0.347	-.025312	.0089019
nonsolartreatmenthour19	.0232293	.0077896	2.98	0.003	.007962	.0384966	solartreatmenthour19	.0162978	.0087125	1.87	0.061	-.0007784	.033374
nonsolartreatmenthour20	.0076072	.0077935	0.98	0.329	-.0076678	.0228822	solartreatmenthour20	.0236433	.0087249	2.71	0.007	.0065429	.0407437
nonsolartreatmenthour21	.0077694	.0077905	1.00	0.319	-.0074997	.0230386	solartreatmenthour21	.0248652	.0087262	2.85	0.004	.0077621	.0419683
nonsolartreatmenthour22	.0143232	.0078017	1.84	0.066	-.0009679	.0296143	solartreatmenthour22	.0068371	.0087123	0.78	0.433	-.0102386	.0239129
nonsolartreatmenthour23	.0031073	.0078129	0.40	0.691	-.0122057	.0184203	solartreatmenthour23	-.0240692	.0087216	-2.76	0.006	-.0411633	-.0069752
nonsolartreatmenthour24	.0039853	.0078027	0.51	0.610	-.0113076	.0192783	solartreatmenthour24	-.025828	.0087281	-2.96	0.003	-.0429348	-.0087212

The above analysis further clarifies the findings from equation (3) that only evaluated DR days. The data for all 114 days in summer 2021 reveals statistically significant DR effects (i.e., differences in electricity consumption between treatment households and control households on DR event days) – and notably, the DR effects differed substantially between solar and non-solar households. Solar households provide evidence of a DR effect in which electricity consumption among treatment households declines beginning in hour-ending 13 (12 pm to 1 pm), whereas non-solar households evidence an “inverse” DR effect beginning as early as hour-ending 10 (9 am to 10 am) in which treatment households increase electricity consumption (contrary to the electricity consumption decrease desired by the utility). The difference in DR effects between solar and non-solar households is clearly evident in Figure 3.3.

Figure 3.3: DR Effects for Solar and Non-Solar Households



Table 3.5 presents a side-by-side comparison of the hourly numerical estimates of the hourly DR treatment effects for solar and non-solar households. There is a robust difference in

how households in this community respond to the utility’s DR notification requesting conservation of electricity. Households without solar rooftops increase electricity consumption on DR event days, when the utility wants them to reduce electricity consumption. For households equipped with solar rooftops, the utility appears to be able to elicit a modest reduction in electricity consumption for at least a few hours in the afternoon, although this desired negative effect on electricity consumption reverses to an increase in electricity consumption during the evening hours of the DR event window.

**Table 3.5: Hourly Treatment Coefficients and Significance Levels
For Solar and Non-Solar Households**

Hour-ending	Non-solar treatment dummies		Solar treatment dummies	
	Coefficient	p-value	Coefficient	p-value
1	0.0017	0.830	0.0136	0.119
2	0.0014	0.862	0.0134	0.124
3	0.0026	0.734	0.0123	0.158
4	0.0070	0.369	0.0136	0.120
5	0.0047	0.548	0.0028	0.752
6	-0.0024	0.758	0.0003	0.970
7	-0.0008	0.913	0.0092	0.289
8	-0.0002	0.984	0.0040	0.645
9	0.0082	0.290	-0.0114	0.191
10	0.0177	0.023	-0.0068	0.434
11	0.0252	0.001	-0.0136	0.119
12	0.0305	0.000	-0.0140	0.110
13	0.0169	0.029	-0.0280	0.001
14	0.0081	0.297	-0.0243	0.006
15	0.0340	0.000	-0.0532	0.000
16	0.0527	0.000	-0.0473	0.000
17	0.0342	0.000	-0.0247	0.005
18	0.0399	0.000	-0.0082	0.347
19	0.0232	0.003	0.0163	0.061
20	0.0076	0.329	0.0236	0.007
21	0.0078	0.319	0.0249	0.004
22	0.0143	0.066	0.0068	0.433
23	0.0031	0.691	-0.0241	0.006
24	0.0040	0.610	-0.0258	0.003

Recall the caveat provided earlier about the timing of the effects relative to that of the formal DR notification text: it is speculated that households assigned to the treatment condition

somehow were able to discern an impending DR event before the official 2 pm text notification was sent to homeowners. As noted previously, this issue is being investigated further.

3.5 Discussion of Findings

The findings reported in Section 3.4 raise the question of why otherwise similar households within the same community seem to make electricity consumption decisions differently depending upon whether or not the home is equipped with a rooftop PV system. The data from this experimental DR program for the 114 days of the summer of 2021 suggest that solar households generally respond favorably to notifications on DR event days by reducing electricity consumption (in most hours). However, non-solar households respond unfavorably to DR notifications and increase rather than decrease their electricity consumption. For both solar and non-solar households, these DR effects begin emerging late morning to noon-time and persist through the afternoon.

Why do the DR effects operate in the intended direction (i.e., reduce electricity consumption) for solar households but in the opposite direction (i.e., increase consumption increase) for non-solar households? The dataset lacks demographic or attitudinal information that may reveal motivational differences between solar and non-solar households. However, the results suggest that solar and non-solar households display different responses to the same DR message. One conjecture is that solar households read the message as a call to take prosocial action (reducing electricity consumption) and comply, whereas non-solar households disregard the utility's DR request to reduce consumption and instead respond by "pre-cooling" the house to mitigate the potential discomfort of a hot and humid afternoon (increasing electricity consumption). Given that the air conditioning system is one of the most energy-intensive

appliances in a household, its usage patterns are the major driver of intra-day variation in household electricity consumption in the summer.

Upon delivery of the DR text notification at 2 pm local time (hour-ending 14), there is evidence that the message has some degree of the intended effect of reducing electricity consumption among both solar and non-solar households that receive the DR message (i.e., the treatment households). For solar households, the *negative* coefficient associated with the solar x treatment x hour dummy variables for hour-ending 15 and hour-ending 16 becomes larger, whereas for non-solar households, the *positive* coefficient for hour-ending 14 (i.e., from 1 pm to 2 pm) becomes not significant. These indicators suggest a conjecture that the DR notification two hours before the DR event window does have a negative electricity consumption as intended, even if for a brief period.

By the evening hours (hour-ending 19 for solar households, hour-ending 20 for non-solar households), the DR effect is no longer significant. For both solar and non-solar households, there is no difference in energy consumption between treatment and control households. In fact, among solar-households between 8 pm and 10 pm (during hour-ending 21 and hour-ending 22), the DR effect reverses direction such that (as with non-solar households) electricity consumption is higher for treatment households. Although not definitive, these results appear consistent with prior findings by Zhou et al (2016) that households that initially reduce (even for a few hours) electricity consumption in response to a DR event end up later in the day consuming more electricity than their counterparts who did not initially reduce consumption. As these researchers note, households participating in DR programs initially reduce their air conditioning usage to lower electricity consumption as requested by the utility. However, as the home temperature

becomes uncomfortable some hours later, “customer air conditioning loads typical overshoot [sic] normal load baseline level” in a “rebound effect” (p. 5).

The results show that from 10 p.m. to midnight (hour-ending 23 and hour-ending 24), hours after the end of the DR event window, solar households in the treatment condition revert to consuming less electricity than solar households in the control condition. These statistically significant effects suggest a possibility the DR event triggers temporal adjustments in consumption behavior for solar households, but not for non-solar households.

3.6. Solar/Non-Solar Differences in Consumption Unrelated to DR

Initial analyses of the data (see Section 3.4.2) also revealed significant differences in electricity consumption between solar and non-solar households in hours well outside the relatively narrow DR event windows. In other words, solar households consumed significantly more electricity than non-solar households most hours of the day (see Table 3.6).

**Table 3.6: Estimated Coefficients for
Solar Hourly Dummy Variables Using Summer 2021 Data**

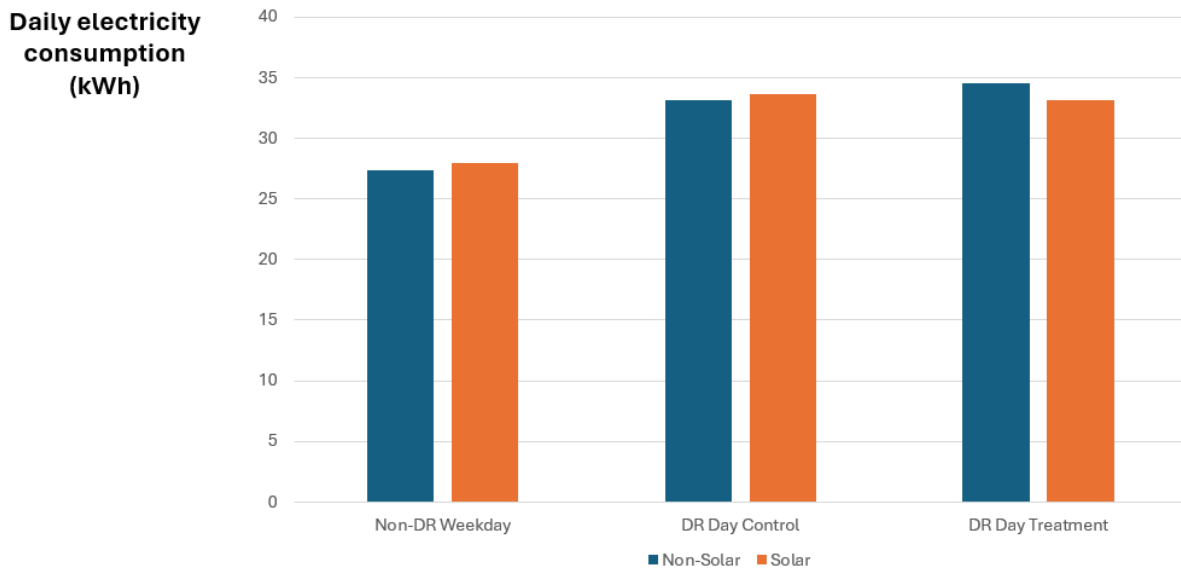
energy	Coefficient	Std. err.	t	P> t	[95% conf. interval]
solarhoure1	.2384315	.0026315	90.61	0.000	.2332738 .2435891
solarhoure2	.2279672	.0026311	86.64	0.000	.2228103 .2331241
solarhoure3	.2186324	.0026309	83.10	0.000	.2134759 .2237888
solarhoure4	.2100525	.0026309	79.84	0.000	.2048961 .2152089
solarhoure5	.2096767	.0026307	79.70	0.000	.2045206 .2148327
solarhoure6	.2109256	.0026308	80.17	0.000	.2057693 .216082
solarhoure7	.1781619	.0026306	67.73	0.000	.1730059 .1833179
solarhoure8	.0693614	.0026307	26.37	0.000	.0642052 .0745175
solarhoure9	-.0945331	.0026307	-35.93	0.000	-.0996891 -.089377
solarhoure10	-.2542293	.0026316	-96.61	0.000	-.2593871 -.2490715
solarhoure11	-.3886141	.0026315	-147.68	0.000	-.3937717 -.3834564
solarhoure12	-.4551803	.0026321	-172.94	0.000	-.460339 -.4500215
solarhoure13	-.4683185	.0026323	-177.92	0.000	-.4734776 -.4631594
solarhoure14	-.421458	.0026321	-160.12	0.000	-.4266169 -.4162991
solarhoure15	-.3569932	.0026319	-135.64	0.000	-.3621516 -.3518347
solarhoure16	-.2540274	.0026317	-96.53	0.000	-.2591854 -.2488693
solarhoure17	-.1110744	.0026315	-42.21	0.000	-.116232 -.1059169
solarhoure18	.0301655	.0026314	11.46	0.000	.025008 .035323
solarhoure19	.1346128	.0026314	51.16	0.000	.1294554 .1397701
solarhoure20	.2105387	.002631	80.02	0.000	.2053821 .2156953
solarhoure21	.2331336	.0026309	88.61	0.000	.227977 .2382901
solarhoure22	.2483442	.0026311	94.39	0.000	.2431873 .253501
solarhoure23	.26847	.0026313	102.03	0.000	.2633127 .2736273
solarhoure24	.2541372	.0026312	96.59	0.000	.2489801 .2592943

These differences in electricity consumption patterns (see Figure 3.3 and the statistically significant coefficients reported in Table 3.6) are prominent between sunset and sunrise, when electricity generation at solar households definitively is zero. During overnight hours, when there is no sunlight to enable a PV system to produce any output, the solar households in this community consistently consume twice as much electricity (about 0.2 kW more per 15-minute increment) than non-solar households. Alas, this difference in appliance consumption levels between solar and non-solar households cannot be estimated accurately without household level data on the generating capacity of the rooftop PV system for each solar household – which unfortunately is not available. As McKenna et al (2019) note, this is a common problem confronting researchers investigating solar PV usage. Hence, it is not possible to confirm whether, during daylight hours, solar households continue to use more appliances (or use them more intensively) than non-solar households. The conjecture is that if solar households consume more electricity than non-solar households during overnight hours, this pattern would likely persist during daytime hours as well.

Given the high degree of household homogeneity within the community, the initial expectation was that all households (solar and non-solar) would consume similar amounts of electricity on average. Instead, the data suggest that solar households consume much more electricity (i.e., use more appliances and/or use them more intensively). Although unexpected for this community, the finding echoes prior results (Deng and Newton 2017; Qiu, Kahn, and Xing 2019); Beppler, Matisoff, and Oliver 2023; Aydın, Brounen, and Ergün 2023) that gross household electricity consumption tends to be higher for households with installed rooftop PV systems. Figure 3.4 illustrates the aggregate daily electricity consumption of solar and non-solar

households on both non-DR weekdays and DR event days – and within DR event days, for treatment and control households.

**Figure 3.4: Average Daily Electricity Consumption
Among Solar and Non-Solar Households**



As Figure 3.4 shows, except for treatment households on DR event days, solar and non-solar households purchase about the same daily amount of electricity from the utility. This implies that the average volume of electricity produced by the PV system at a solar household is almost the same as the extra electricity used by the average solar household (when compared to the average non-solar household). Put another way, the electricity that solar households purchase from the utility is approximately similar to the volumes purchased by their non-solar peers. The data thus suggest a conjecture that solar households ascribe a portion of their electricity consumption to what they themselves produce.

Further research on electricity pricing in this community would be required to confirm where or not (1) there is time-variation (e.g., time-of-use, peak/off-peak) in electricity prices, and (2) electricity prices between the utility and the consumer are the same regardless of who is the

buyer or seller. If solar households consume more electricity (i.e., have higher appliance usage) than non-solar households, but pay about the same amount each month to the utility, solar households may perceive their effective electricity price (\$/kWh) to be lower than that paid by non-solar households. This would imply that solar households consider their investment in solar to be a sunk cost and ignore it (or consider it less) in determining their post-installation electricity consumption. Thus, this lower perceived price may influence of marginal behaviors on appliance usage. Note that Ito (2014) found that households tend to make electricity consumption decisions based on average prices over the billing cycle versus marginal prices that may vary by hour of the day. Perhaps solar households evaluate their monthly electricity bill against total appliance utilization versus just the amount of electricity sourced from the utility grid.

3.7. Planned Experimental Research: Solar vs. Non-Solar Households

Although the panel dataset used in this research is cross-sectionally extensive and temporally granular, it essentially contains only one variable: electricity purchased from the utility. Thus, while it provides insight into average household electricity consumption patterns across the hours of the day, it is silent about the psychological reasons or processes used by individual households in making electricity consumption decisions that underlie the findings. In particular, the differences in electricity consumption patterns between solar and non-solar households beg meaningful explanations. Accordingly, future research is planned to examine the mental mechanism that may drive the observed differences.

3.7.1. Conjectures to Investigate

Three conjectures of interest are provided below as explanations for the differences in electricity consumption patterns between solar and non-solar households. First, if solar

households view their incremental electricity consumption to be free (i.e., they ignore the sunk costs of their PV installations), they may experience a moral license to consume electricity more freely during most hours of the day. Such a license may stem from their investment in a solar rooftop – a justification that is not available to non-solar homeowners.

Second, solar households may respond more favorably to DR requests from the utility because they are both more environmentally-committed and more cognizant of the impact of their electricity consumption than non-solar households. The fact that they have made an investment to install rooftop solar is testimonial to their environmental commitment. Even if this commitment is not salient at all times, it may be activated by the DR request. Non-solar households may lack such a commitment and may instead be more self-oriented and invested in their own comfort. Hence, on average, non-solar households may be less responsive to the DR notification issued by the utility.

A final testable conjecture is that while a solar household's latent commitment to environment-friendly behaviors would be triggered by the DR notification, there may be an unintended effect on non-solar households. As suggested earlier, non-solar households may interpret the utility's DR notification not as a call to conserve, but as a signal that a hot and humid day is in the offing. This may then trigger increased electricity consumption because they turn up their air conditioning (i.e., turn down their thermostat) to maximize comfort in the face of rising summer afternoon temperatures.

In order to obtain deeper insights into the validity of these conjectures and causal understanding of the processes underlying the various electricity consumption differences evidenced above between solar and non-solar households, a set of experiments is proposed. These experiments are guided by the psychology and behavioral economics literatures on

memory and attention, as well as the motivational processes that may drive moral licensing to influence the electricity consumption patterns described earlier. The human subjects research protocol outlined below is being prepared for submission to the Virginia Tech Institutional Review Board. Along with the empirical results described previously, the results of the proposed experimental research are expected to validate the above three conjectures distinguishing the mental processes that guide the electricity consumption behaviors of solar and non-solar households.

3.7.2. Research Design and Participant Recruitment

The proposed experiment features a between-subjects design that enables comparison of responses from participants that already have solar PV systems installed on their house to those who do not have a PV system. The plan is to recruit a usable sample of 200 respondents (100 from solar homes and 100 from non-solar homes). Respondents will be drawn from a web platform (e.g., Prolific) and the recruiting process for this quota sample will use screening procedures to account for the fact that only about 10% of U.S. households own solar PV systems.

3.7.3. Planned Survey Instrument

After the introductory informed consent formalities, participants will be provided orienting instructions to the study. Immediately thereafter, all participants will be asked to consider a text message purportedly sent to them by their local utility at mid-day on a hot summer afternoon asking for reduced electricity consumption later in the afternoon. The wording of the text message will mimic the DR text messages sent out in the field study: “Please do your part by reducing energy use from 4 to 8 PM. A tip to conserve during this critical period is to turn up the thermostat on your air conditioner until after 8 PM.”

Participants will then be asked to indicate on 7-point Likert scale their disagreement-agreement with the following statements (presented in random order) regarding the utility's reasons for sending the text message: (1) the upcoming afternoon will be hot and uncomfortable, (2) electricity demand will be very high and the utility needs to manage demand levels, (3) the utility is testing customer responsiveness to text notifications, and (4) the government requires the utility to send messages of this type.

Next, participants will be asked to indicate their likelihood of taking the following actions (7 point Likert scales indicating unlikely-likely) in response to the DR message: (1) "turn the thermostat down by about 5 degrees, so that the house will be comfortably cool", (2) "turn the thermostat up by about 5 degrees, so that the house will become uncomfortably warm", and (3) "make no change in the thermostat setting". The options will be presented randomly.

Respondents will then answer five randomly-presented questions regarding their underlying motivation for their thermostat setting behavior. Their answers will be collected on 7 point Likert scales (disagree – agree) for the following five items: (1) to comply with the utility's request, (2) to keep the house comfortable on a hot day, (3) to lower the probability of electricity outages in the community, (4) to manage their monthly electricity bill, and (5) to conserve energy as a good citizen.

The next set of questions will address electricity consumption volumes. Respondents will be asked to indicate how much they try to minimize their electricity consumption on a (7-point Likert scale: 1 – a little, 7 – a lot). A related question will ask whether respondents own (or plan to own) an EV, recognizing that EV ownership may be at cross purposes with reducing overall electricity consumption. As Sharda et al (2024) hypothesized, being more

environmentally-committed, solar households are more likely to own an EV, which may increase their overall electricity consumption (especially during overnight hours).

The questionnaire will then present three panels of 7-point Likert scale items asking respondents the degree to which they agree (1 – disagree, 7 – agree) with a set of statements. The first panel will feature three statements regarding their degree of environmental commitment: (1) “I care a lot about minimizing my impact on the environment”, (2) “I am very concerned about climate change”, and (3) “I often think about things I can do to reduce my carbon footprint”. The second panel will include two statements indicating their degree of affluence: (1) “Our household is financially comfortable” and (2) “Our household is not very price sensitive”. The third panel will consist of three statements indicating their propensity to engage in moral licensing reasoning about environmental domain because of prior pro-environmental actions or behaviors: (1) “My pro-environmental actions entitle me to some slack in my energy consumption choices”, (2) “I sometimes indulge myself because I contribute more than my fair share to environmental protection”, and (3) “I do not feel guilty when I take an occasional break from being less vigilant in my behaviors to protect the environment”.

It is hypothesized that solar households will be more environmentally committed, more affluent, and more subject to moral licensing than non-solar households. Responses to the above items will allow assessments of the extent of support for the three conjectures framed earlier.

Finally, the survey will conclude with a series of standard socio-demographic questions. Among these, average values associated with household income among solar households and non-solar households are of particular interest.

3.8. Concluding Remarks

The research presented herein examined how household electricity consumption behavior responds to an experimental pro-social DR program, in which the local electric utility asked homeowners to voluntarily reduce electricity consumption on hot summer afternoons. The empirical analysis leveraged hourly data during the summer of 2021 from 307 households in a large residential community. The analysis notably found that (1) non-solar households tend to respond to utility DR requests by increasing (versus decreasing) electricity consumption, and (2) solar households are more responsive to DR requests but yet consume more electricity during other hours. These key findings will be examined further with planned experimental studies of the underlying behavioral mechanisms. This concluding section discusses the planned and potential future refinements of this work, as well as the contributions of this research to the academic and practitioner communities.

3.8.1. Potential Refinements of Empirical Research

Additional refinements may allow further use of the rich cross-sectional and temporally granular dataset on household electricity consumption. The sample of households were from an atypically homogeneous community with an ethos that is particularly conducive to examining environment-friendly behaviors. First, more data can be added to the empirical analysis. The 802 households that were excluded (see Section 3.2) were vacant in 2021 and reported zero electricity consumption during many of the time increments. Additional data screening may identify when true occupancy begins, enabling inclusion of these households in the data panel.

Also, the 15-minute interval data on household electricity consumption extends beyond the summer of 2021. The present findings here may be cross-validated on data from DR days during ensuing summers. The COVID pandemic was still significantly influencing society when

the data used in this analysis was collected, and increased work-from-home activity at the time (Bick, Blandin, and Mertens 2023) may have affected household electricity consumption patterns. Validation of the DR effects found in this research with more recent data may provide new insights.

Obtaining and merging relevant weather data (e.g., sunlight, temperature, cooling degree days) into the dataset and using them as covariates or causal drivers in the panel regressions should also add value. Many aspects of electricity consumption are explicitly weather-driven (e.g., customer demands for lighting, heating, cooling), so weather data may capture some of the unexplained variation, improving the quality of estimates and adding robustness to findings. Moreover, the DR program implemented in 2021 did not facilitate investigation of “learning” or “fatigue” effects (Kim and Shcherbakova 2011) at the household level over the course of successive DR events. No two DR events were chronologically closer than six days apart, implying minimal opportunity for recency effects. Additional observation and more explanatory variables (e.g., weather data) may allow detection of inter-event behavioral effects that may have been masked in the present analysis by statistical noise.

The planned experimental study described in Section 3.7 may provide insights on whether the causal effects of solar ownership on DR responsiveness are mediated through attention to electricity consumption that may have created the two puzzling phenomena described earlier. Thus, solar ownership may induce moral licensing that reduces attention to electricity consumption. However, overconsumption can also stimulate moral “cleansing” (Gholamzadehmir, Sparks, and Farsides 2019) in which a prior less-than-ideal deed promotes a good deed to be undertaken as penance.

Experimental research can also test other conjectures about why solar households are more responsive to DR notifications. For instance, solar households may be more inclined to reduce electricity consumption on hot afternoons because they are more attentive to a day's solar conditions and may modulate their electricity consumption based on the weather. Non-solar households may lack such an imperative. Also, solar households may be more inclined to adopt technological advancements, and consequently may have stronger remote capability or practices to modulate mid-day electricity consumption when a DR event is invoked by the utility when the homeowner is away from home. Such explanations may be examined in the lab and in field experiments

Some of the hour-by-hour behaviors warrant further study. For instance, while DR notifications initially cause a decline in consumption (as expected) among solar households, they eventually lead to an increase in consumption (relative to households that were not sent a DR notification) by the early evening hours. This “rebound” effect has been observed before in the field (Zhou et al 2016). More puzzling, after the rebound effect, during the period 10 pm to midnight (hour-ending 23 and hour-ending 24), solar households that received DR notifications reduced electricity consumption relative to households that did not receive notifications. This effect occurred even though the DR notification – received by the household fully eight hours earlier – did not ask customers to reduce electricity consumption beyond 8 pm. Moreover, the effect appeared only for solar households: non-solar households that received DR notifications never consumed less than the non-solar households that did not receive the DR notification. Meaningful hypotheses that purport to explain such effects warrant further investigation.

An alternative explanation for higher electricity consumption among solar households may be rooted in economics. The positive relationship between ownership of a rooftop PV

system and higher gross electricity consumption may not be causal, and a household's affluence level may drive both solar ownership and higher gross electricity consumption (Pearl and Mackenzie 2018). Naturally, wealthier households are more able to afford and spend money on a solar rooftop, and they usually live in larger homes with more space to cool/heat and own more electricity-consuming devices. Thus, solar ownership and higher gross electricity consumption may be positively correlated but not causally related. Although such endogeneity concerns may be mitigated somewhat by attributing rooftop solar installations to street addresses via visual inspection of satellite photographs (e.g., Google Maps) and then matching these to real estate transactions data (as indicators of affluence), the procedure does not eliminate the possibility of endogeneity. Nevertheless, this may be a fruitful exercise in addition to experimental and longitudinal panel data methods.

A speculation rooted in behavioral economics is that solar households exhibit higher gross electricity consumption than non-solar households because their prior investment in solar may have created an "endowment" that support the daily consumption of more electricity in perpetuity for decades (subject to maintenance and other related costs). As noted in Section 3.6, the net amount of electricity bought daily from the utility grid by households in this community was about the same between solar and non-solar households. Thus, electricity generation from rooftop solar was very close to the difference between gross electricity consumption (i.e., total appliance usage) and net electricity consumption at solar households. Under residential electricity pricing regimes and net metering policies in most U.S. locations, the finding implies that both solar and non-solar households pay approximately similar monthly utility bills. In other words, the greater gross electricity consumption at solar households is effectively supported financially by the ongoing output from the sunk costs of PV system installation. New

research could explore whether such mental accounting (Thaler 1985; Prelec and Loewenstein 1998) may occur among owners of homes with solar rooftops.

3.8.2. Contributions of This Research

The main empirical finding that solar households and non-solar households consume electricity differently needs additional research examining the underlying behavioral economics. Why does installing a solar rooftop – an admittedly-sizable investment decision with a significant pro-environmental patina – produce an enduring pattern of daily decisions that have negative environmental consequences (higher electricity consumption) and only occasional positive consequences (greater willingness to reduce electricity consumption upon request on DR event days)?

The finding that non-solar households in the treatment condition deliberately increase electricity consumption when asked by their local electric utility to do exactly the opposite also raises interesting behavioral questions. Is this behavior explained by the attentional response of a group with lower environmental commitment to an alert suggesting that a hot and humid afternoon is coming up? Does the DR notification trigger self-interested (versus pro-social) behavior. Or – given that an electric utility may be perceived as an exploitative big business that uses its resources to lobby against environmentalism and the public interest – is this phenomenon a manifestation of reactance (Brehm 1966) wherein the recipient of the DR notification responds in a manner to explicitly counteract the message sender's interest?

For the practitioner community engaged with utilities and the utility industry, the findings presented herein may be provocative. The empirical results suggest that pro-social DR programs may not be merely ineffective in producing the intended ameliorative reductions in household electricity consumption on high demand days, but in fact may exacerbate regional electricity

supply challenges by increasing consumption among non-solar households (the vast majority of homes) at exactly the time when the grid operator faces difficulties in meeting regional demand. The findings should inform both utility practitioners and regulators about the importance of proper framing of their customer communications, taking account of not only the economic but also the psychological drivers of electricity consumption, both generally and in response to DR notifications. Professionals specializing in the field of DR program design and implementation are likely to find these results both informative and challenging.

APPENDICES

APPENDIX 2.1:
EXPERIMENT 1, FEBRUARY 2023

**EXPERIMENT 1
FEBRUARY 2023**

SURVEY INSTRUMENT

Thank you for participating in this consumer opinion study about electric vehicles (EVs). There are no right or wrong answers to the questions that will be asked. We are seeking your honest opinions. Your responses will remain anonymous and will be published only in aggregate fashion. Your participation is voluntary (you may choose to stop at any time), and consent is implied by submission of the survey. Should you have any questions or concerns about the study, you may contact researchers Dr. Dipankar Chakravarti at dchakra1@vt.edu or Richard Stuebi at richardts@vt.edu. If you have questions or concerns about your rights as a research participant, you can call the Virginia Tech Institutional Research Board (IRB) at 540-231-3732 or email irb@vt.edu. Please record the IRB number 21-928 and the researchers' contact information before continuing.

When responding to this survey, it is important to pay close attention to the questions. At a few points during the survey, we will ask certain questions whose answers will indicate whether you are in fact being attentive. If your answers to these questions indicate inadequate attention being paid, we reserve the right to excuse you from the remainder of the survey without being compensated. We appreciate your understanding. Now, let's begin.

Which of the following is the most important issue facing Americans today?

1. Inflation and the economy
2. War in Ukraine
3. Crime and policing
4. Immigration
5. Voting security

Which of the following performers would you most like to see in person?

1. Taylor Swift
2. Elton John
3. Beyonce
4. Keith Urban
5. Drake

Which of the following Hollywood actors do you like the most? We want to make sure you're reading carefully: please select the third option.

1. Tom Hanks
2. Bradley Cooper
3. Al Pacino
4. Denzel Washington
5. Christian Bale

(If something other than #3 selected in prior question.) We appreciate your interest in participating in this study. Based on your answers to the questions above, we are excusing you from the remainder of this survey. Thank you for your time.

For the following screens, please indicate your level of agreement with the statements that are presented.

Preserving the environment is important to me because I enjoy nature.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that environmental quality is enhanced since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I care strongly about protecting the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to environmental causes.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Trying out new technologies is important to me because I enjoy playing with innovative devices.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that technological progress is supported since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I care strongly about technological innovation.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to the cause of technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I know more about EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have spent considerable time reading about EVs.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have talked at length with EV owners.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have more experience riding in EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Now, please imagine that you are in the market to buy a new car. Your options are to buy a conventional gasoline-powered car or an EV. You have budgeted \$38,000 for this purchase. After research and test-drives, you have chosen a particular vehicle model, and are now choosing between two versions: a conventional model powered by a gasoline engine, or an EV powered solely by batteries. From a functionality standpoint, other than the way it is powered, the EV and the conventional vehicle are identical in all aspects: appearance, type, size, comfort, performance, acceleration, range, appeal, safety, etc. You are also aware that EV ownership involves (1) paying a higher initial price, and (2) allowing for fewer public recharging stations and longer battery recharging times.

Based on the text from the prior screen, which of the following is not part of the scenario you are being asked to imagine?

1. \$38,000 budget for purchasing a new car
2. Choosing between an EV and an equivalent gasoline-powered vehicle

3. Higher initial price for EVs
4. Fewer public recharging station for EVs
5. Deciding whether to purchase extended warranty

(If the prior answer was #5.) Your answer was incorrect. The scenario presented to you involves buying a new car within a \$38,000 budget and choosing between an EV and an equivalent gasoline-powered vehicle, while recognizing that buying the EV would imply paying a higher initial price and facing fewer public recharging stations. In the scenario, we are not asking you to consider whether to purchase an extended warranty for the vehicle. Please proceed.

(Low price condition assignment.) For the vehicle model you are considering, note that the EV costs \$1,000 more to purchase than the equivalent gasoline-powered variant.

(High price condition assignment.) For the vehicle model you are considering, note that the EV costs \$5,000 more to purchase than the equivalent gasoline-powered variant.

Please select the amount by which the EV is more expensive than the gasoline-powered vehicle.

1. \$500
2. \$1,000
3. \$2,500
4. \$5,000

(If respondent in low price condition and responded with something other than #2 in prior question.) Your answer was incorrect. The scenario presented to you involves considering an EV with an initial price that is \$1,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

(If respondent in high price condition and responded with something other than #4 in prior question.) Your answer was incorrect. The scenario presented to you involves considering an EV with an initial price that is \$5,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

How likely is it that you would choose to purchase the battery-powered EV over the gasoline-powered version?

1. Unlikely
- 2.
- 3.
- 4.
- 5.
- 6.
7. Likely

For the following screens, please indicate your level of agreement with the statements that are presented.

Wider EV adoption will spur other environmental trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs do not burn fossil fuels but instead are powered by electricity.

1. Disagree
- 2.
- 3.
- 4.

- 5.
- 6.
7. Agree

EVs are a major advancement in pollution control.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Further adoption of EVs will accelerate the rate of improvement in environmental quality.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Wider EV adoption will spur other technology trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are not powered by a gasoline engine but rather use advanced battery technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are a major advancement in transportation technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Further adoption of EVs will accelerate the rate of broader technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.

7. Agree

EVs are good for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs pollute less than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with an environmentally sustainable society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs have a smaller carbon footprint than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are good for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs perform better than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with a high-tech digitized society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are more innovative than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for the environment to myself.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my personal views about the environment, regardless of others' views.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about the environment.

1. Disagree

- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for technology advancement to myself.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my personal views about technology advancement, regardless of others' views.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about technology advancement.

1. Disagree
- 2.
- 3.

- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for technological progress.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

If you were to purchase an EV, please indicate on the scale below how you would intend to use it:

1. Primarily for local trips
- 2.
- 3.
- 4.
- 5.
- 6.
7. Primarily for long-distance trips

Now, imagine owning an EV, and using it daily for short local trips (e.g., commuting, shopping, errands). Please indicate your level of agreement with the following statements:

I would spend a considerable amount of time at public stations recharging my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I would worry about running out of charge before finding a place to recharge my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be a hassle to pre-plan recharging stops.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be inconvenient to recharge my EV overnight where I live.

1. Disagree
- 2.

- 3.
- 4.
- 5.
- 6.
7. Agree

Again, imagine owning an EV, but now planning to use it on a 10-day long-distance road trip. Please indicate your level of agreement with the following statements:

I would spend a considerable amount of time at public stations recharging my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I would worry about running out of charge before finding a place to recharge my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be a hassle to pre-plan recharging stops.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be inconvenient to recharge my EV overnight where I am staying.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

According to the scenario presented to you earlier, please select the amount by which the EV is more expensive than the equivalent gasoline-powered vehicle.

1. \$500
2. \$1,000
3. \$2,500
4. \$5,000

Lastly, a few demographic questions about you:

What is your age (in years)?

What is your gender?

1. Male
2. Female
3. Other

Are you married?

1. Yes
2. No

How many children or dependents reside in your household?

1. None
2. 1
3. 2 or 3
4. 4 or more

In what state is your primary residence located?

What is the annual income for your household?

1. Less than \$50,000
2. \$50,001 to \$75,000
3. \$75,001 to \$100,000
4. \$100,001 to \$150,000
5. More than \$150,000

My stance on economic issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.
- 6.
7. Conservative

My stance on social issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.
- 6.
7. Conservative

Which of the following best describes you?

1. Asian or Pacific Islander
2. Black or African-American
3. Hispanic or Latino
4. Native American or Alaskan Native
5. White or Caucasian
6. Multiracial or Biracial
7. A race/ethnicity not listed here

What is your Prolific ID?

Thanks again for participating in our survey. Your response has been recorded.

To receive your payment, please copy and paste the code 1BE942D3 into the box at the page you left open in

Prolific.

**EXPERIMENT 1
FEBRUARY 2023**

CONSTRUCTS

ENVIRONMENTAL COMMITMENT (EC)

- Preserving the environment is important to me because I enjoy nature.
- It is important to me that environmental quality is enhanced since it makes the world a better place.
- I care strongly about protecting the environment.
- I am committed to environmental causes.

Mean: 5.52
Standard Deviation: 1.26
Cronbach Alpha: 0.92

TECHNOLOGY COMMITMENT (TC)

- Trying out new technologies is important to me because I enjoy playing with innovative devices.
- It is important to me that technological progress is supported since it makes the world a better place.
- I care strongly about technological innovation.
- I am committed to the cause of technology advancement.

Mean: 5.06
Standard Deviation: 1.32
Cronbach Alpha: 0.90

EV FAMILIARITY (FA)

- I know more about EVs than the average person.
- I have spent considerable time reading about EVs.
- I have talked at length with EV owners.
- I have more experience riding in EVs than the average person.

Mean: 2.55
Standard Deviation: 1.34
Cronbach Alpha: 0.85

KNOWLEDGE OF EV IMPACT ON ENVIRONMENT (EK)

- Wider EV adoption will spur other environmental trends with impacts of their own.
- EVs do not burn fossil fuels but instead are powered by electricity.
- EVs are a major advancement in pollution control.
- Further adoption of EVs will accelerate the rate of improvement in environmental quality.

Mean: 5.51
Standard Deviation: 1.10
Cronbach Alpha: 0.77

KNOWLEDGE OF EV IMPACT ON TECHNOLOGY (TK)

- Wider EV adoption will spur other technology trends with impacts of their own.
- EVs are not powered by a gasoline engine but rather use advanced battery technology.
- EVs are a major advancement in transportation technology.

- Further adoption of EVs will accelerate the rate of broader technology advancement.

Mean: 5.72
 Standard Deviation: 0.94
 Cronbach Alpha: 0.71

PERCEPTION OF EVs AS ENVIRONMENTAL ADVANCEMENT (EP)

- EVs are good for the environment.
- EVs pollute less than gasoline vehicles.
- EV use is more consistent with an environmentally sustainable society.
- EVs have a smaller carbon footprint than gasoline vehicles.

Mean: 5.48
 Standard Deviation: 1.34
 Cronbach Alpha: 0.91

PERCEPTION OF EVs AS TECHNOLOGICAL ADVANCEMENT (TP)

- EVs are good for technology advancement.
- EVs perform better than gasoline vehicles.
- EV use is more consistent with a high-tech digitized society.
- EVs are more innovative than gasoline vehicles.

Mean: 5.29
 Standard Deviation: 1.03
 Cronbach Alpha: 0.80

ENVIRONMENTAL SIGNALING VALUE (ESV)

- Purchasing an EV affirms my concern for the environment to myself.
- Owning an EV is consistent with my concern for the environment.
- Buying an EV reinforces my personal views about the environment, regardless of others' views.
- Using an EV signals to other people my concern for the environment.
- Driving an EV shows the world I care about the environment.
- Having an EV would make others recognize my concern for the environment.

Mean: 4.67
 Standard Deviation: 1.54
 Cronbach Alpha: 0.95

TECHNOLOGY SIGNALING VALUE (TSV)

- Purchasing an EV affirms my concern for technology advancement to myself.
- Owning an EV is consistent with my concern for technology advancement.
- Buying an EV reinforces my personal views about technology advancement, regardless of others' views.
- Using an EV signals to other people my concern for technology advancement.
- Driving an EV shows the world I care about technology advancement.
- Having an EV would make others recognize my concern for technological progress.

Mean: 4.48
 Standard Deviation: 1.48
 Cronbach Alpha: 0.94

EV INCONVENIENCE WEIGHTING FACTOR (IVWEIGHT)

- If you were to purchase an EV, please indicate on the scale below how you would intend to use it.

Mean: 2.66

Standard Deviation: 1.37

LOCAL EV INCONVENIENCE (IVLOCAL)

- I would spend a considerable amount of time at public stations recharging my EV.
- I would worry about running out of charge before finding a place to recharge my EV.
- It would be a hassle to pre-plan recharging stops.
- It would be inconvenient to recharge my EV overnight where I live.

Mean: 3.97

Standard Deviation: 1.62

Cronbach Alpha: 0.80

LONG-DISTANCE EV INCONVENIENCE (IVLD)

- I would spend a considerable amount of time at public stations recharging my EV.
- I would worry about running out of charge before finding a place to recharge my EV.
- It would be a hassle to pre-plan recharging stops.
- It would be inconvenient to recharge my EV overnight where I am staying.

Mean: 5.47

Standard Deviation: 1.42

Cronbach Alpha: 0.88

EV INCONVENIENCE (IV)

Calculated as weighted average of:

- IVLOCAL
- IVLD

Using IVWEIGHT as a weighting factor:

- 100% weighted to IVLOCAL if IVWEIGHT=1
- 100% weighted to IVLD if IVWEIGHT = 7
- Proportionally weighted to IVLOCAL and IVLD if $1 < \text{IVWEIGHT} < 7$

Mean: 4.30

Standard Deviation: 1.52

APPENDIX 2.2:
EXPERIMENT 2, AUGUST 2023

**EXPERIMENT 2
AUGUST 2023**

SURVEY INSTRUMENT

Thank you for participating in this consumer opinion study about electric vehicles (EVs). Please read the questions carefully and provide your honest opinions. Your responses will remain anonymous and will be published only in aggregate fashion. Your participation is voluntary (you may choose to stop at any time), and consent is implied by submission of the survey. Should you have any questions or concerns about the study, you may contact researchers Dr. Dipankar Chakravarti at dchakra1@vt.edu or Richard Stuebi at richardts@vt.edu. If you have questions or concerns about your rights as a research participant, you can call the Virginia Tech Institutional Research Board (IRB) at 540-231-3732 or email irb@vt.edu. Please record the IRB number 21-928 and the researchers' contact information before continuing.

When responding to this survey, it is important to pay close attention to the questions. At a few points during the survey, we will ask certain questions whose answers will indicate whether you are in fact being attentive. If your answers to these questions indicate inadequate attention being paid, we reserve the right to excuse you from the remainder of the survey without being compensated. We appreciate your understanding. Now, let's begin.

Which of the following is the most important issue facing Americans today?

1. Inflation and the economy
2. War in Ukraine
3. Crime and policing
4. Immigration
5. Voting security

Which of the following Hollywood actors do you like most? We want to make sure you are reading carefully: please select the third option.

1. Tom Hanks
2. Bradley Cooper
3. Al Pacino
4. Denzel Washington
5. Christian Bale

(If something other than #3 selected in prior question.) We appreciate your interest in participating in this study. Based on your answers to the questions above, we are excusing you from the remainder of this survey. Thank you for your time.

For the following screens, please indicate your level of agreement with the statements that are presented.

Preserving the environment is important to me because I enjoy nature.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that environmental quality is enhanced since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.

- 5.
- 6.
7. Agree

I care strongly about protecting the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to environmental causes.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Trying out new technologies is important to me because I enjoy playing with innovative devices.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that technological progress is supported since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I care strongly about technological innovation.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to the cause of technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.

7. Agree

I know more about EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have spent considerable time reading about EVs.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have talked at length with EV owners.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have more experience riding in EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Now, please imagine that you are in the market to buy a new car. Your options are to buy a conventional gasoline-powered car or an electric vehicle (EV). You have budgeted \$50,000 for this purchase. After research and test-drives, you have chosen a particular vehicle model, and are now choosing between two versions: a conventional model powered by a gasoline engine, or an EV powered solely by batteries. Other than the way it is powered, the EV and the conventional vehicle are identical in all aspects: they both have a range of about 250 miles before needing refueling/recharging, and they both have the same appearance, size, comfort, performance, acceleration, appeal, safety, etc. You are also aware that EV ownership involves (1) paying a higher initial price, and (2) incurring inconveniences associated with finding public recharging stations and wait-times for battery recharging when travelling away from home.

Based on the text from the prior screen, which of the following items is not part of the scenario you are being asked to imagine? Check all that apply.

1. Choosing between an EV and an equivalent gasoline powered vehicle
2. A new car purchase budget of \$50,000
3. Both car options have a range of about 300 miles
4. Higher initial price for EVs
5. Inconvenience of finding public charging stations
6. Inconvenience of recharging wait times

7. Deciding whether to purchase extended warranty

(If something other than items #3 and #7 were not selected in the prior question.) Your answer was incorrect. The scenario presented to you involves purchasing a vehicle within a budget of \$50,000 and needing to choose between an EV and an equivalent gasoline-powered vehicle. Both cars have an operating range of about 250 miles. Buying the EV would imply paying a higher initial price and incurring inconveniences associated with finding public recharging stations and wait-times for battery recharging. Extended warranty purchase was not part of the scenario. Please proceed.

Price difference between the EV and the conventional gasoline vehicle:

(Low price condition assignment.) For the vehicle model you are considering, note that after all rebates and subsidies are included, the EV costs a modest \$2,000 more to purchase than the equivalent gasoline-powered vehicle.

(High price condition assignment.) For the vehicle model you are considering, note that after all rebates and subsidies are included, the EV costs a significant \$10,000 more to purchase than the equivalent gasoline-powered vehicle.

Please select the amount by which the EV is more expensive than the gasoline-powered vehicle.

1. \$500
2. \$2,000
3. \$5,000
4. \$10,000

(If assigned to low price condition and answer to previous question was other than #2.) Your answer was incorrect. In the scenario presented, the EV's initial price (net of rebates and subsidies) is \$2,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

(If assigned to high price condition and answer to previous question was other than #4.) Your answer was incorrect. In the scenario presented, the EV's initial price (net of rebates and subsidies) is \$10,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

Inconveniences associated with recharging an EV:

(Low inconvenience condition assignment.) EV owners can recharge their vehicles at home while sleeping. If recharging is required away from home, EV owners will need to use public charging stations. This recharging will take longer than refueling a gasoline-powered vehicle and may involve locating an appropriate charging station. However, unless the EV owner is travelling more than 250 miles in a given day, wait times and availability of public charging stations are modest inconveniences. Continuing technology improvements will further reduce these inconveniences in the near future.

(High inconvenience condition assignment.) Recharging EV batteries takes far longer than refueling a gasoline-powered vehicle. If recharging is required away from home, EV owners will need to locate a public charging station, which are much less easy to find than service stations for gasoline-powered vehicles. When taking long trips requiring EV recharging, wait times for battery charging and limited availability of public charging stations are significant inconveniences. Even with expected improvements in technology, these issues may persist for some time into the future.

How likely is it that you would choose to purchase the battery-powered EV over the gasoline-powered version?

1. Unlikely
- 2.
- 3.
- 4.
- 5.
- 6.
7. Likely

How sizable do you perceive the difference in purchase price between the EV and the otherwise-comparable gasoline vehicle?

1. Small
- 2.
- 3.
- 4.
- 5.
- 6.
7. Large

How sizable do you perceive the inconveniences associated with recharging an EV relative to refueling a conventional gasoline vehicle?

1. Small
- 2.
- 3.
- 4.
- 5.
- 6.
7. Large

For the following screens, please indicate your level of agreement with the statements that are presented.

Wider adoption will spur other environmental trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs do not burn fossil fuels but instead are powered by electricity.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are a major advancement in pollution control.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Further adoption of EVs will accelerate the rate of improvement in environmental quality.

1. Disagree
- 2.
- 3.
- 4.
- 5.

- 6.
7. Agree

Wider EV adoption will spur other technology trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are not powered by a gasoline engine but rather use advanced battery technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are a major advancement in transportation technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Further research on EVs will accelerate the rate of broader technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are good for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs pollute less than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with an environmentally sustainable society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs have a smaller carbon footprint than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are good for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs perform better than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with a high-tech digitized society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are more innovative than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for the environment to myself.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my own personal views about the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for technology advancement to myself.

1. Disagree
- 2.

- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my own personal views about technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for technological progress.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I frequently take long road trips in my car.

1. Disagree
- 2.
- 3.
- 4.

- 5.
- 6.
7. Agree

I often drive more than 200 miles in a day.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Sometimes I take long drives that are not pre-planned.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I drive more miles per year than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Public EV charging stations are easy to find.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV charging is available at my workplace.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have a dedicated place to recharge an EV at home at night.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.

7. Agree

Charging an EV is not likely to pose any problems for me.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

According to the scenario presented to you earlier, please select the amount by which the EV is more expensive than the equivalent gasoline-powered vehicle.

1. \$500
2. \$2,000
3. \$5,000
4. \$10,000

Lastly, a few questions about you:

What is your age (in years)?

What is your gender?

1. Male
2. Female
3. Other

Are you married?

1. Yes
2. No

How many children or dependents reside in your household?

1. None
2. 1
3. 2 or 3
4. 4 or more

In what state is your primary residence located?

1. Alabama
2. Alaska
3. Arizona
4. Arkansas
5. California
6. Colorado
7. Connecticut
8. Delaware
9. Florida
10. Georgia
11. Hawaii
12. Idaho
13. Illinois
14. Indiana
15. Iowa
16. Kansas
17. Kentucky
18. Louisiana

19. Maine
20. Maryland
21. Massachusetts
22. Michigan
23. Minnesota
24. Mississippi
25. Missouri
26. Montana
27. Nebraska
28. Nevada
29. New Hampshire
30. New Jersey
31. New Mexico
32. New York
33. North Carolina
34. North Dakota
35. Ohio
36. Oklahoma
37. Oregon
38. Pennsylvania
39. Rhode Island
40. South Carolina
41. South Dakota
42. Tennessee
43. Texas
44. Utah
45. Vermont
46. Virginia
47. Washington
48. West Virginia
49. Wisconsin
50. Wyoming
51. District of Columbia

What is the annual income for your household?

1. Less than \$50,000
2. \$50,001 to \$75,000
3. \$75,001 to \$100,000
4. \$100,001 to \$150,000
5. More than \$150,000

My stance on economic issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.
- 6.
7. Conservative

My stance on social issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.

- 6.
7. Conservative

How likely is it that you will be in the market to buy a new car within the next 2 years?

1. Unlikely
- 2.
- 3.
- 4.
- 5.
- 6.
7. Likely

Please indicate how much you agree or disagree with the following four statements.

Waiting a long time for EV battery charging is a significant inconvenience.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Limited availability of public EV charging stations is a significant inconvenience.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I often use my automobile for long distance road trips.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

My automobile usage is mostly for short distance commuting.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Which of the following best describes you?

1. Asian or Pacific Islander
2. Black or African-American
3. Hispanic or Latino
4. Native American or Alaskan Native
5. White or Caucasian

6. Multiracial or Biracial
7. A race/ethnicity not listed here

What is your Prolific ID?

Thanks again for participating in our survey. Your response has been recorded.

To receive your payment, please copy and paste the code 1BE942D3 into the box at the page you left open in Prolific.

**EXPERIMENT 2
AUGUST 2023**

CONSTRUCTS

ENVIRONMENTAL COMMITMENT (EC)

- Preserving the environment is important to me because I enjoy nature.
- It is important to me that environmental quality is enhanced since it makes the world a better place.
- I care strongly about protecting the environment.
- I am committed to environmental causes.

Mean: 5.23
Standard Deviation: 1.36
Cronbach Alpha: 0.92

TECHNOLOGY COMMITMENT (TC)

- Trying out new technologies is important to me because I enjoy playing with innovative devices.
- It is important to me that technological progress is supported since it makes the world a better place.
- I care strongly about technological innovation.
- I am committed to the cause of technology advancement.

Mean: 4.81
Standard Deviation: 1.33
Cronbach Alpha: 0.92

EV FAMILIARITY (FA)

- I know more about EVs than the average person.
- I have spent considerable time reading about EVs.
- I have talked at length with EV owners.
- I have more experience riding in EVs than the average person.

Mean: 2.24
Standard Deviation: 1.25
Cronbach Alpha: 0.87

KNOWLEDGE OF EV IMPLICATIONS ON ENVIRONMENT (EK)

- Wider adoption will spur other environmental trends with impacts of their own.
- EVs do not burn fossil fuels but instead are powered by electricity.
- EVs are a major advancement in pollution control.
- Further adoption of EVs will accelerate the rate of improvement in environmental quality.

Mean: 5.47
Standard Deviation: 1.12
Cronbach Alpha: 0.74

KNOWLEDGE OF EV IMPLICATIONS ON TECHNOLOGY (TK)

- Wider EV adoption will spur other technology trends with impacts of their own.
- EVs are not powered by a gasoline engine but rather use advanced battery technology.

- EVs are a major advancement in transportation technology.
- Further research on EVs will accelerate the rate of broader technology advancement.

Mean: 5.75
 Standard Deviation: 0.94
 Cronbach Alpha: 0.71

PERCEPTIONS OF EVs AS ENVIRONMENTAL ADVANCEMENT (EP)

- EVs are good for the environment.
- EVs pollute less than gasoline vehicles.
- EV use is more consistent with an environmentally sustainable society.
- EVs have a smaller carbon footprint than gasoline vehicles.

Mean: 5.45
 Standard Deviation: 1.42
 Cronbach Alpha: 0.92

PERCEPTIONS OF EVs AS TECHNOLOGY ADVANCEMENT (TP)

- EVs are good for technology advancement.
- EVs perform better than gasoline vehicles.
- EV use is more consistent with a high-tech digitized society.
- EVs are more innovative than gasoline vehicles.

Mean: 5.06
 Standard Deviation: 1.12
 Cronbach Alpha: 0.80

ENVIRONMENTAL SIGNALING VALUE (ESV)

- Purchasing an EV affirms my concern for the environment to myself.
- Owning an EV is consistent with my concern for the environment.
- Buying an EV reinforces my own personal views about the environment.
- Using an EV signals to other people my concern for the environment.
- Driving an EV shows the world I care about the environment.
- Having an EV would make others recognize my concern for the environment.

Mean: 4.43
 Standard Deviation: 1.62
 Cronbach Alpha: 0.96

TECHNOLOGY SIGNALING VALUE (TSV)

- Purchasing an EV affirms my concern for technology advancement to myself.
- Owning an EV is consistent with my concern for technology advancement.
- Buying an EV reinforces my own personal views about technology advancement.
- Using an EV signals to other people my concern for technology advancement.
- Driving an EV shows the world I care about technology advancement.
- Having an EV would make others recognize my concern for technological progress.

Mean: 4.19
 Standard Deviation: 1.53
 Cronbach Alpha: 0.95

EV INCONVENIENCE (IV)

- How sizable do you perceive the inconveniences associated with recharging an EV relative to refueling a conventional gasoline vehicle?
- Waiting a long time for EV battery charging is a significant inconvenience.
- Limited availability of public EV charging stations is a significant inconvenience.

Mean: 5.35

Standard Deviation: 1.41

Cronbach Alpha: 0.86

APPENDIX 2.3:
EXPERIMENT 3, OCTOBER 2023

**EXPERIMENT 3
OCTOBER 2023**

SURVEY INSTRUMENT

Thank you for participating in this consumer opinion study about electric vehicles (EVs). Please read the questions carefully and provide your honest opinions. Your responses will remain anonymous and will be published only in aggregate fashion. Your participation is voluntary (you may choose to stop at any time), and consent is implied by submission of the survey. Should you have any questions or concerns about the study, you may contact researchers Dr. Dipankar Chakravarti at dchakra1@vt.edu or Richard Stuebi at richardts@vt.edu. If you have questions or concerns about your rights as a research participant, you can call the Virginia Tech Institutional Research Board (IRB) at 540-231-3732 or email irb@vt.edu. Please record the IRB number 21-928 and the researchers' contact information before continuing.

When responding to this survey, it is important to pay close attention to the questions. At a few points during the survey, we will ask certain questions whose answers will indicate whether you are in fact being attentive. If your answers to these questions indicate inadequate attention being paid, we reserve the right to excuse you from the remainder of the survey without being compensated. We appreciate your understanding. Now, let's begin.

Which of the following is the most important issue facing Americans today?

1. Inflation and the economy
2. War in Ukraine
3. Crime and policing
4. Immigration
5. Voting security

Which of the following Hollywood actors do you like most? We want to make sure you are reading carefully: please select the third option.

1. Tom Hanks
2. Bradley Cooper
3. Al Pacino
4. Denzel Washington
5. Christian Bale

(If an answer other than #3 is provided in the prior question.) We appreciate your interest in participating in this study. Based on your answers to the questions above, we are excusing you from the remainder of this survey. Thank you for your time.

For the following screens, please indicate your level of agreement with the statements that are presented.

Preserving the environment is important to me because I enjoy nature.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that environmental quality is enhanced since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.
- 5.

- 6.
7. Agree

I care strongly about protecting the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to environmental causes.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Trying out new technologies is important to me because I enjoy playing with innovative devices.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It is important to me that technological progress is supported since it makes the world a better place.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I care strongly about technological innovation.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I am committed to the cause of technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I know more about EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have spent considerable time reading about EVs.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have talked at length with EV owners.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I have more experience riding in EVs than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Now, please imagine that you are in the market to buy a new car. Your options are to buy a conventional gasoline-powered car or an electric vehicle (EV). You have budgeted \$50,000 for this purchase. After research and test-drives, you have chosen a particular vehicle model, and are now choosing between two versions: a conventional model powered by a gasoline engine, or an EV powered solely by batteries. Other than the way it is powered, the EV and the conventional vehicle are identical in all aspects: they both have a range of about 250 miles before needing refueling/recharging, and they both have the same appearance, size, comfort, performance, acceleration, appeal, safety, etc. You are also aware that EV ownership involves (1) paying a higher initial price, and (2) incurring inconveniences associated with finding public recharging stations and wait-times for battery recharging when traveling away from home.

Based on the text from the prior screen, which of the following items is not part of the scenario you are being asked to imagine? Check all that apply.

1. Choosing between an EV and an equivalent gasoline powered vehicle
2. A new car purchase budget of \$50,000
3. Both car options have a range of about 300 miles
4. Higher initial price for EVs
5. Inconvenience of finding public charging stations
6. Inconvenience of recharging wait times
7. Deciding whether to purchase extended warranty

(If the answer to the prior question was something other than #3 and #7.) Your answer was incorrect. The scenario presented to you involves purchasing a vehicle within a budget of \$50,000 and needing to choose between an EV and an equivalent gasoline-powered vehicle. Both cars have an operating range of about 250 miles. Buying the EV would imply paying a higher initial price and incurring inconveniences associated with finding public recharging stations and wait-times for battery recharging. Extended warranty purchase was not part of the scenario. Please proceed.

Consider the price difference between the EV and the conventional gasoline vehicle:

(Low price condition assignment.) For the vehicle model you are considering, note that after all rebates and subsidies are included, the EV costs a modest \$2,000 more to purchase than the equivalent gasoline-powered vehicle.

(High price condition assignment.) For the vehicle model you are considering, note that after all rebates and subsidies are included, the EV costs a significant \$10,000 more to purchase than the equivalent gasoline-powered vehicle.

Please select the amount by which the EV is more expensive than the gasoline-powered vehicle.

1. \$500
2. \$2,000
3. \$5,000
4. \$10,000

(If participant assigned to low price condition and answer to prior question was not #2.) Your answer was incorrect. In the scenario presented, the EV's initial price (net of rebates and subsidies) is \$2,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

(If participant assigned to high price condition and answer to prior question was not #4.) Your answer was incorrect. In the scenario presented, the EV's initial price (net of rebates and subsidies) is \$10,000 higher than the equivalent gasoline-powered vehicle. Please proceed.

Now, consider the inconveniences associated with recharging an EV:

(Low inconvenience condition assignment.) According to Jason Foster, an authority on new automotive technologies, in a recent issue of *Automotive Today*: "EV owners can recharge their vehicles at home while sleeping. If recharging is required away from home, EV owners will need to use public charging stations. This recharging will take longer than refueling a gasoline-powered vehicle and may involve locating an appropriate charging station. However, unless the EV owner is traveling more than 250 miles in a given day, wait times and availability of public charging stations are modest inconveniences [emphasis added]. Continuing technology improvements will further reduce these inconveniences in the near future."

(High inconvenience condition assignment.) According to Rusty Sampson, an authority on the auto industry, in a recent issue of *Automotive Today*: "Recharging EV batteries takes far longer than refueling a gasoline-powered vehicle. If recharging is required away from home, EV owners will need to locate a public charging station, which are much less easy to find than service stations for gasoline-powered vehicles. When taking long trips requiring EV recharging, wait times for battery charging and limited availability of public charging stations are significant inconveniences [emphasis added]. Even with expected improvements in technology, these issues may persist for some time into the future."

From the article passage you just read, please select the degree of inconveniences that the author attributed to EV battery recharging.

1. Few inconveniences
2. Modest inconveniences
3. Some inconveniences
4. Significant inconveniences

(If participant assigned to low inconvenience condition and answer to prior question was not #2.) Your answer was incorrect. The article's author indicated that, "unless the EV owner is traveling more than 250 miles in a given day, wait times and availability of public charging stations are modest inconveniences." Please proceed.

(If participant assigned to high inconvenience condition and answer to prior question was not #4.) Your answer was incorrect. The article's author indicated that, "when taking long trips requiring EV recharging, wait times for battery charging and limited availability of public charging stations are significant inconveniences." Please proceed.

What is your general impression of how inconvenient it is to own an EV and be required to consider its battery recharging needs (1 - very inconvenient, 7 - not inconvenient)

1. Very inconvenient
- 2.
- 3.
- 4.
- 5.
- 6.
7. Not inconvenient

Returning to the decision on which car to buy, how likely is it that you would choose to purchase the battery-powered EV over the gasoline-powered version?

1. Unlikely
- 2.
- 3.
- 4.
- 5.
- 6.
7. Likely

For the following screens, please indicate your level of agreement with the statements that are presented.

Wider adoption will spur other environmental trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs do not burn fossil fuels but instead are powered by electricity.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are a major advancement in pollution control.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.

7. Agree

Further adoption of EVs will accelerate the rate of improvement in environmental quality.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Wider EV adoption will spur other technology trends with impacts of their own.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are not powered by a gasoline engine but rather use advanced battery technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are a major advancement in transportation technology.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Further research on EVs will accelerate the rate of broader technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are good for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs pollute less than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with an environmentally sustainable society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs have a smaller carbon footprint than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are good for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs perform better than gasoline vehicles.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EV use is more consistent with a high-tech digitized society.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

EVs are more innovative than gasoline vehicles.

1. Disagree

- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for the environment to myself.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my own personal views about the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about the environment.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for the environment.

1. Disagree
- 2.
- 3.

- 4.
- 5.
- 6.
7. Agree

Purchasing an EV affirms my concern for technology advancement to myself.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Owning an EV is consistent with my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Buying an EV reinforces my own personal views about technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Using an EV signals to other people my concern for technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Driving an EV shows the world I care about technology advancement.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Having an EV would make others recognize my concern for technological progress.

1. Disagree
- 2.
- 3.
- 4.
- 5.

- 6.
7. Agree

Now, imagine owning an EV. Please indicate your level of agreement with the following statements:

Owning an EV would be more inconvenient than owning a gasoline-powered vehicle.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be inconvenient to recharge my EV overnight where I live.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

It would be a bother to think about where I would charge my EV overnight on trips away from home.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I would spend a lot of time at public stations recharging my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I would worry about running out of charge before finding a place to recharge my EV.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I would worry that a charger would not be available to use when I got to an EV charging station.

1. Disagree
- 2.
- 3.
- 4.
- 5.

- 6.
7. Agree

Please think about how you currently use your vehicle, and indicate your level of agreement with the following statements:

I frequently take long road trips in my car.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I often drive more than 200 miles in a day.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

Sometimes I take long drives that are not pre-planned.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

I drive more miles per year than the average person.

1. Disagree
- 2.
- 3.
- 4.
- 5.
- 6.
7. Agree

According to the scenario presented to you earlier, please select the amount by which the EV is more expensive than the equivalent gasoline-powered vehicle.

1. \$500
2. \$2,000
3. \$5,000
4. \$10,000

Lastly, a few questions about you:

What is your age (in years)?

What is your gender?

1. Male
2. Female

3. Other

Are you married?

1. Yes
2. No

How many children or dependents reside in your household?

1. None
2. 1
3. 2 or 3
4. 4 or more

In what state is your primary residence located?

1. Alabama
2. Alaska
3. Arizona
4. Arkansas
5. California
6. Colorado
7. Connecticut
8. Delaware
9. Florida
10. Georgia
11. Hawaii
12. Idaho
13. Illinois
14. Indiana
15. Iowa
16. Kansas
17. Kentucky
18. Louisiana
19. Maine
20. Maryland
21. Massachusetts
22. Michigan
23. Minnesota
24. Mississippi
25. Missouri
26. Montana
27. Nebraska
28. Nevada
29. New Hampshire
30. New Jersey
31. New Mexico
32. New York
33. North Carolina
34. North Dakota
35. Ohio
36. Oklahoma
37. Oregon
38. Pennsylvania
39. Rhode Island
40. South Carolina
41. South Dakota
42. Tennessee
43. Texas

44. Utah
45. Vermont
46. Virginia
47. Washington
48. West Virginia
49. Wisconsin
50. Wyoming
51. District of Columbia

What is the annual income for your household?

1. Less than \$50,000
2. \$50,001 to \$75,000
3. \$75,001 to \$100,000
4. \$100,001 to \$150,000
5. More than \$150,000

My stance on economic issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.
- 6.
7. Conservative

My stance on social issues tends to be:

1. Liberal
- 2.
- 3.
- 4.
- 5.
- 6.
7. Conservative

How likely is it that you will be in the market to buy a new car within the next 2 years?

1. Unlikely
- 2.
- 3.
- 4.
- 5.
- 6.
7. Likely

Which of the following best describes you?

1. Asian or Pacific Islander
2. Black or African-American
3. Hispanic or Latino
4. Native American or Alaskan Native
5. White or Caucasian
6. Multiracial or Biracial
7. A race/ethnicity not listed here

What is your Prolific ID?

Thanks again for participating in our survey. Your response has been recorded.

To receive your payment, please copy and paste the code 1BE942D3 into the box at the page you left open in Prolific.

**EXPERIMENT 3
OCTOBER 2023**

CONSTRUCTS

ENVIRONMENTAL COMMITMENT (EC)

- Preserving the environment is important to me because I enjoy nature.
- It is important to me that environmental quality is enhanced since it makes the world a better place.
- I care strongly about protecting the environment.
- I am committed to environmental causes.

Mean: 5.28
Standard Deviation: 1.28
Cronbach Alpha: 0.91

TECHNOLOGY COMMITMENT (TC)

- Trying out new technologies is important to me because I enjoy playing with innovative devices.
- It is important to me that technological progress is supported since it makes the world a better place.
- I care strongly about technological innovation.
- I am committed to the cause of technology advancement.

Mean: 4.92
Standard Deviation: 1.34
Cronbach Alpha: 0.91

EV FAMILIARITY (FA)

- I know more about EVs than the average person.
- I have spent considerable time reading about EVs.
- I have talked at length with EV owners.
- I have more experience riding in EVs than the average person.

Mean: 2.49
Standard Deviation: 1.33
Cronbach Alpha: 0.86

KNOWLEDGE OF EV IMPACTS ON ENVIRONMENT (EK)

- Wider adoption will spur other environmental trends with impacts of their own.
- EVs do not burn fossil fuels but instead are powered by electricity.
- EVs are a major advancement in pollution control.
- Further adoption of EVs will accelerate the rate of improvement in environmental quality.

Mean: 5.50
Standard Deviation: 1.05
Cronbach Alpha: 0.73

KNOWLEDGE OF EV IMPACTS ON TECHNOLOGY (TK)

- Wider EV adoption will spur other technology trends with impacts of their own.
- EVs are not powered by a gasoline engine but rather use advanced battery technology.

- EVs are a major advancement in transportation technology.
- Further research on EVs will accelerate the rate of broader technology advancement.

Mean: 5.84
 Standard Deviation: 0.87
 Cronbach Alpha: 0.73

PERCEPTION OF EVs AS ENVIRONMENTAL ADVANCEMENT (EP)

- EVs are good for the environment.
- EVs pollute less than gasoline vehicles.
- EV use is more consistent with an environmentally sustainable society.
- EVs have a smaller carbon footprint than gasoline vehicles.

Mean: 5.44
 Standard Deviation: 1.30
 Cronbach Alpha: 0.90

PERCEPTION OF EVs AS TECHNOLOGY ADVANCEMENT (TP)

- EVs are good for technology advancement.
- EVs perform better than gasoline vehicles.
- EV use is more consistent with a high-tech digitized society.
- EVs are more innovative than gasoline vehicles.

Mean: 5.02
 Standard Deviation: 1.13
 Cronbach Alpha: 0.81

ENVIRONMENTAL SIGNALING VALUE (ESV)

- Purchasing an EV affirms my concern for the environment to myself.
- Owning an EV is consistent with my concern for the environment.
- Buying an EV reinforces my own personal views about the environment.
- Using an EV signals to other people my concern for the environment.
- Driving an EV shows the world I care about the environment.
- Having an EV would make others recognize my concern for the environment.

Mean: 4.60
 Standard Deviation: 1.57
 Cronbach Alpha: 0.95

TECHNOLOGY SIGNALING VALUE (TSV)

- Purchasing an EV affirms my concern for technology advancement to myself.
- Owning an EV is consistent with my concern for technology advancement.
- Buying an EV reinforces my own personal views about technology advancement.
- Using an EV signals to other people my concern for technology advancement.
- Driving an EV shows the world I care about technology advancement.
- Having an EV would make others recognize my concern for technological progress.

Mean: 4.34
 Standard Deviation: 1.52
 Cronbach Alpha: 0.95

EV INCONVENIENCE (IV)

- Owning an EV would be more inconvenient than owning a gasoline-powered vehicle.
- It would be inconvenient to recharge my EV overnight where I live.
- It would be a bother to think about where I would charge my EV overnight on trips away from home.
- I would spend a lot of time at public stations recharging my EV.
- I would worry about running out of charge before finding a place to recharge my EV.
- I would worry that a charger would not be available to use when I got to an EV charging station.

Mean: 5.20

Standard Deviation: 1.29

Cronbach Alpha: 0.84

APPENDIX 3.1:
TEXT NOTIFICATIONS FROM SUMMER 2021 DR EVENTS

DR Event Date	DR Notification Text
6/10/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to postpone using major appliances until after 8PM.
6/16/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to use a ceiling fan to circulate already-cooled air in your home.
7/28/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to postpone using major appliances until after 8PM.
8/9/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to use a ceiling fan to circulate already-cooled air in your home.
8/25/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to use a ceiling fan to circulate already-cooled air in your home.
9/9/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to use a ceiling fan to circulate already-cooled air in your home.
9/16/2021	Please do your part by reducing energy use from 4 to 8PM. A tip to conserve during this critical period is to turn off any lights when not needed.

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