

IMPACT OF CONSUMER DEMOGRAPHIC CHARACTERISTICS ON ADOPTION
RATE OF ELECTRIC TRANSPORTATION

Presented in Partial Fulfillment of the Requirements for
The Master of Education Degree in the
College of Education and Human Service Professions

By

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Dedication

This thesis is dedicated to my family, friends and co-workers who supported me through the learning, research and writing. Especially, my Aunt who has relentlessly and tirelessly reminded me that I need to finish it!

Abstract

This study sought to contribute additional research to advancing electric transportation through identifying correlations between demographic characteristics and a consumer's interest in adopting electric transportation. While the electric vehicle (EV) market is relatively small, it has steadily expanded since 2010 and is forecasted for exponential growth in the coming decades if the United States follows suit behind other developed countries. This paper utilized customer survey results from a mid-sized electric utility in Northeastern Minnesota. Quantitative analysis was used to explore the relationship between demographic characteristics and interest in ownership of an EV. Results did not show a statistical significance between any of the demographic variables and interest in electric vehicles, but demonstrate a need for further research on this topic and the ways that the U.S. has been able to incentivize adoption of EVs.

Keywords – plug-in electric vehicles; beneficial electrification, transportation electrification.

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Chapter One

Introduction

In 2017, the transportation sector made history by making its way to the top of the list for the United States' highest contributor of greenhouse gas (GHG) emissions (United States Environmental Protection Agency, 2019). Its predecessor, electricity generation, previously held the lead position. That makes it hard to imagine that refueling an entire industry to be powered off of the formerly leading GHG contributor would be a move in the right direction, but that appears to be the case. When considering the future, “all-in” emissions and overall efficiency, there are many forms of environmentally Beneficial Electrification (Dennis, 2015). As energy generated and sent onto the grid gets cleaner due to mounting pressures from policy makers and climate change, we “are changing the environmental value of using electric appliances to produce heat and hot water in buildings, requiring a more systems-based approach to energy efficiency tools and revisions to the methodology for calculating ‘source’ energy metrics (Dennis, 2015, p. 100)”.

This essentially means that energy efficiency policy and the experts creating it are considering a look at the entire picture of carbon footprint of a fuel and possible end-use applications. There is growing conversation and policy development around electrification of transportation which is a prime example of this methodology not only increasing energy efficiency, but also reducing environmental impacts (Malone et al., 2018). A growing Transportation Electrification effort represents enormous opportunity, but comes with significant challenges. Since 2010, the United States Electric Vehicle (EV) market has been steadily growing (Loveday, 2018). Wide-ranging benefits for the country range from reducing GHG to improving the nation's energy independence (Department of Energy). At a consumer level,

individuals can expect to have a safer (O’Malley, 2015), cheaper to fuel and maintain (Department of Energy), and more environmentally-friendly vehicle. As shown below, fuel-mix of the regional electricity generation has an impact on GHG emissions equivalence. Regardless, with an efficient EV “99 percent of the country is in a region where electricity emissions would be lower than a 50 MPG gasoline vehicle” (Reichmuth, 2018, More efficient EVs now available too section, para. 1). So, while all of this data and reasoning is compelling to make the change, it has been a slow uptake overall. This study seeks to understand which consumers may be more likely to switch from a gas-powered Internal Combustion Engine (ICE) vehicle to an electric vehicle. Also, which segments might not be interested and their reasoning.

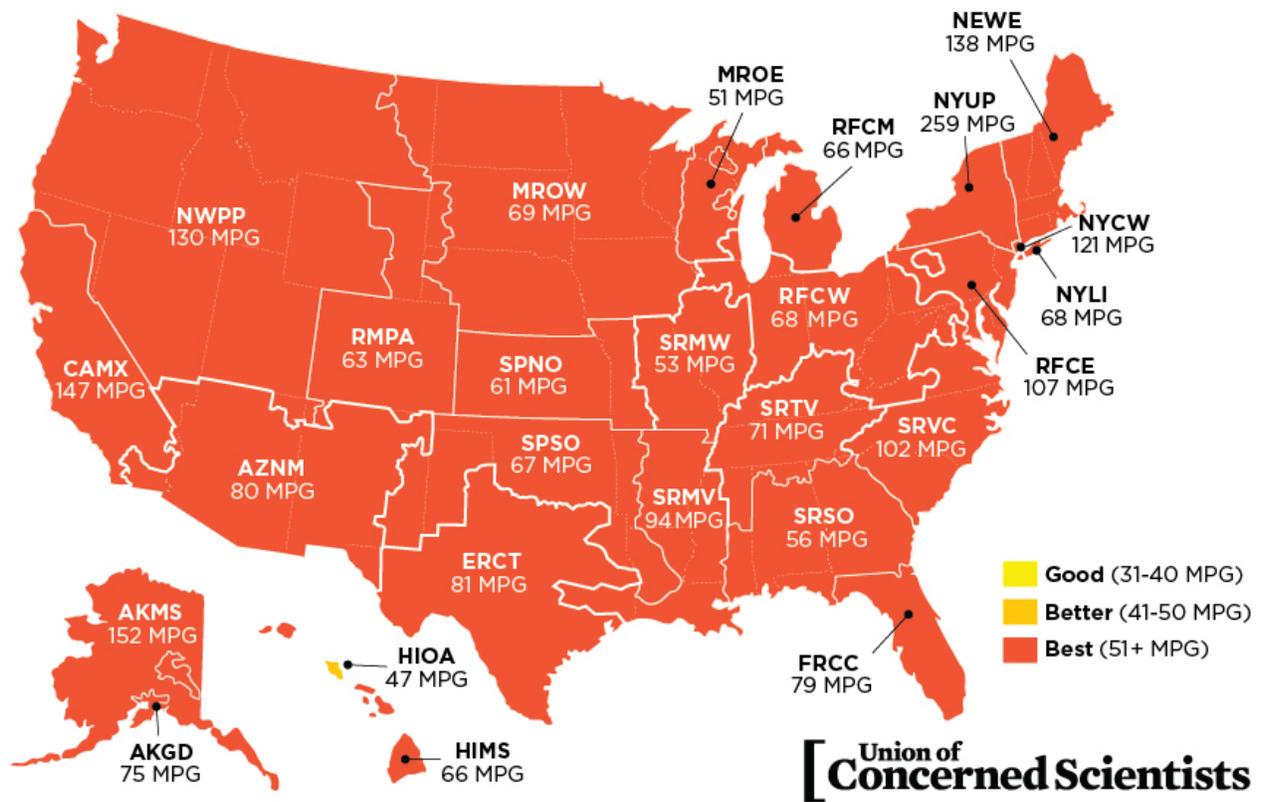


Figure 1. A map of the United States showing electricity for an EV total emissions equivalent to an internal combustion engine (ICE) vehicle's emissions miles per gallons (MPG) based on generation mix and driving an efficient EV model (Hyundai Ioniq BEV, Prius Prime, and Tesla Model 3)

Purpose of the Study

The purpose of this study was to compare interest in electric transportation against demographic characteristics in order to add resources to available research used by policy makers, auto manufacturers and other interested stakeholders trying to grow the adoption of electric transportation. The study used responses from an online survey conducted by *Company A*.

As with most emerging technologies, there are “growing pains” as adoption increases and the market comes to scale. A significant challenge of breaking into the next consumer segment of the five groups (shown below in *Figure 2*) of technology adopters will be appealing to broader demographics.

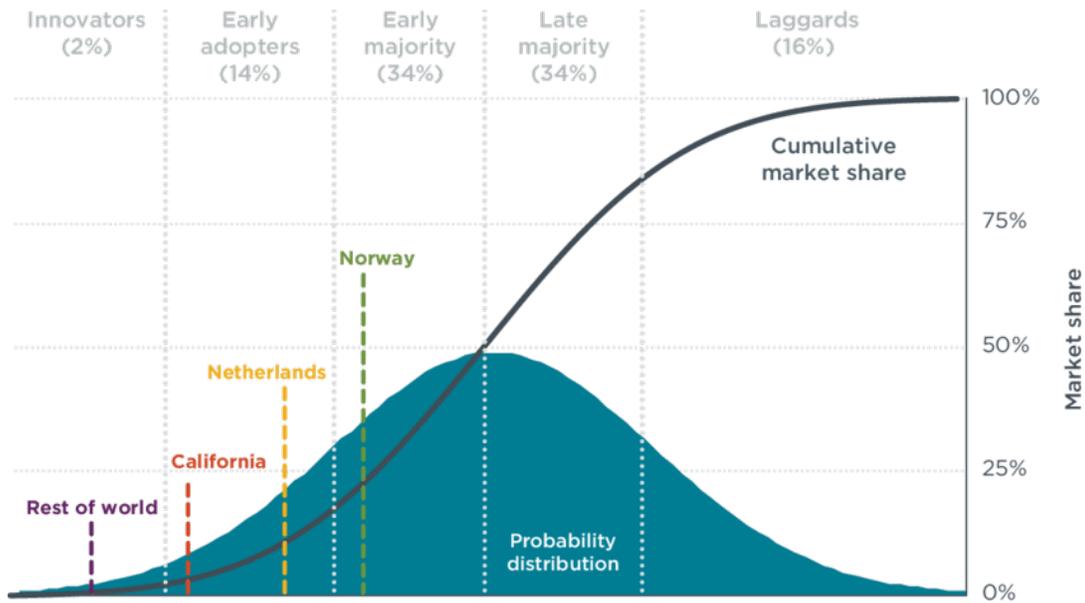


Figure 2. EV technology adoption curve including select EV markets (Slowik, 2016)

Background and Significance of the Study

In October 2018 the United Nations’ Intergovernmental Panel on Climate Changes (IPCC) shared some disappointing information (Rogelj); "Transport accounted for 28 percent of

global final-energy demand and 23 percent of global energy-related CO2 emissions in 2014," according to the second chapter of the report. "Emissions increased by 2.5 percent annually between 2010 and 2015, and over the past half century the sector has witnessed faster emissions growth than any other" (Joselow, 2018, THE CLIMATE REPORT SECTION

. section, para.3). The study maps out various scenarios of the world’s climate future under different decarbonization of electricity and other fuels, and electrification of energy end use. The study makes it clear that to minimize the impacts of climate change, the world needs to rapidly do both of those things.

Only a month before the IPCC report, it had been announced that electric vehicle sales in the United States finally reached one million units sold (Kane, 2018). While this might seem like cause to celebrate, this record-setting sales month for EVs was only 0.03% of the vehicles sold that month (MarkLines, 2018).

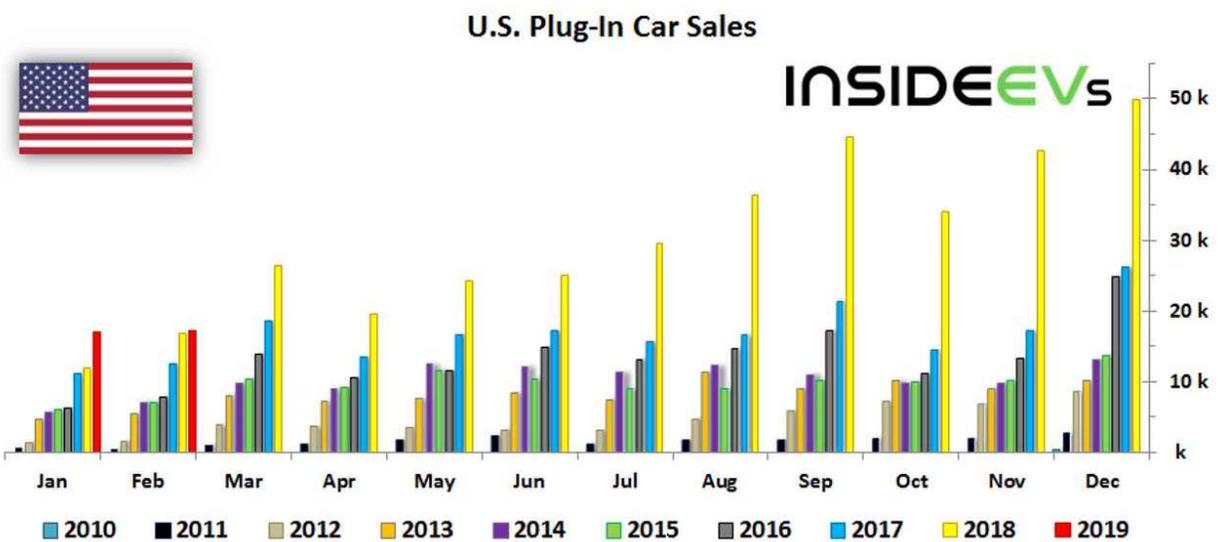


Figure 3. insideEVs.com monthly chart for U.S. plug-in EV sales from January 2010 – February 2019

If the United States and other countries around the world are going to rapidly decarbonize the transportation sector, understanding the barriers to entry will be key to unlocking market

potential for the broader population to adopt EVs. Furthermore, it will be important to recognize that characteristics like gender identity, income and home-ownership factor into different barriers of entry and ultimately the likelihood of adoption. In turn, understanding how these indicators might currently prevent a consumer from considering an EV may inform future strategies on awareness efforts, education, outreach and marketing to targeted demographic segments.

Setting

This study focused on customers of an electric utility in Northeastern Minnesota. The utility marketed the survey online through their website, social media channels and email interest lists. Customers that chose to take the survey did so on their own personal devices, but were required to provide confirmation that they were an actual customer of the utility.

Assumptions

The primary researcher was an employee of the electric utility for several years, working on initiatives related to EVs prior to the study. With several years of experience working directly with customers of the utility, the researcher had an inherent bias while developing the survey as to the questions asked in the instrument.

Scope and Limitations of the Study

The survey conducted was only made available to the customers from *Company A*, based in Northeastern Minnesota. Marketing of the survey was done almost completely online through email marketing and social media. Therefore, some bias should be assumed as customers who only opt to receive physical communications would not have had the option to participate. Additionally, a majority of the customers that responded already participate in *Company A*'s program offerings related to emerging electric technologies.

Definitions

Beneficial Electrification – changing the fuel from one source like petroleum, natural gas, etc. to electricity to achieve more efficient use of energy and/or reduction in environmentally harmful emissions.

Decarbonization – removing carbon-emitting fuels from various sectors like transportation and electricity generation.

Electric Vehicle – a vehicle powered by a battery that is charged from electricity.

Summary

The purpose of this study was to see if any correlations could be drawn between demographic characteristics and interest in adopting electric transportation.

Chapter Two

Literature Review

There were three predominant themes in the literature on electric vehicles. First, the technology of electric transportation and its supporting infrastructure. Then, the benefits associated with transitioning to this technology. Finally, a limited body of research on consumer demographics influencing interest in electrification of transportation.

Electric Transportation Technology

The Department of Energy developed a comprehensive overview on the *History of Electric Car* in 2014. Electric Vehicles were first available for purchase in the United States in 1889. They were very popular in cities for their quiet, clean and easy to drive qualities in comparison to a steam or gasoline-powered car. Women especially enjoyed them and were targeted with ads for EVs as shown below.

Roadways in the country had not yet developed, so short and slow speed trips (early models had a top speed of around 14 miles per hour) around town were what most people had a need for. EVs held approximately a third of the vehicle market in the late 1800s, equally shared by steam powered and internal combustion engine vehicles.

With the discovery of cheap domestic crude oil, development of the highway system and improvements in the gasoline-powered vehicle technology in the early 1900s, the EV market began

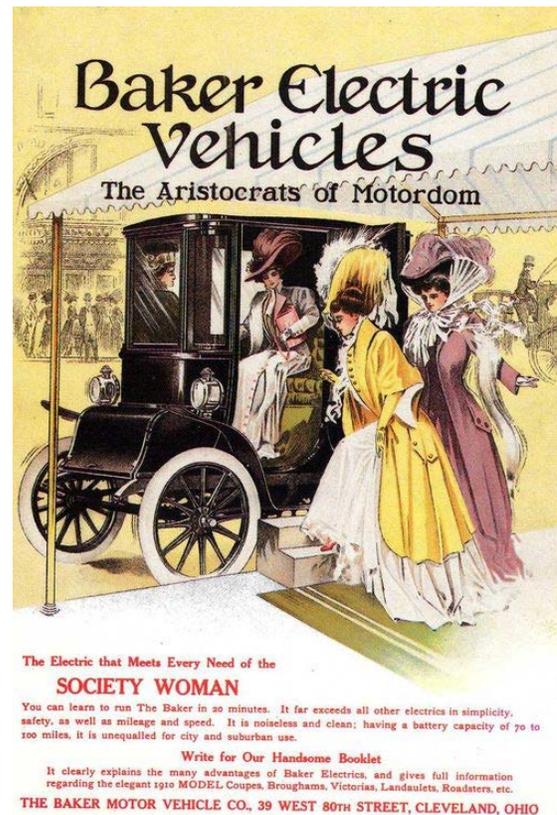


Figure 4: An Electric Vehicle advertisement from the late 1800s targeting women.

its decline. It wasn't until the late 1960s when gasoline prices skyrocketed that the country began thinking about how to transition some of all of the transportation sector back to electricity to reduce its reliance on foreign oil. Congress followed along and later passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 appropriating funds for research and development of electric and hybrid vehicle technology. Gas prices returned to a somewhat "normal" state and so did society's sense of urgency over the matter. EVs developed in the 70s had a high price and less-than-desirable performance when comparing range and speed with ICE vehicles.

Fast forward to the 1990s and early 2000s. Environmental policy and regulation entered a new era, setting new mandates for vehicle efficiency standards. This, along with the introduction of hybrid vehicles to the U.S. market in 1999, rekindled auto-manufacturer's intrigue with plug-in electric vehicle technology. In 2006, a Silicon Valley startup called Tesla Motors announced their first model. This marked the beginning of a U.S. EV market renaissance.

Barriers Associated with Electrifying Transportation

"The plug-in electric vehicle (PEV) holds much promise today—from reducing dependency on imported petroleum to decreasing greenhouse gas emissions to improving urban air quality (National Academy of Sciences, 2015, Abstract, para.1)". In spite of that opportunity, 93% of transportation is fueled by petroleum (EEL, 2014). There are many perceived and real barriers standing in the way of making this benefit (and many others) a reality.

Charging infrastructure. Charging an EV can happen anywhere a standard outlet exists, but there are different levels of voltage determining the speed rate of the how the charging. 95% of charging happens at home and work, where charging is generally funded by the homeowner or business (Transport & Environment, 2018). The other 5% is made up of public charging which

has variable coverage across the United States as shown below. The lack of charging is a major cause of concern for consumer, causing range anxiety or a feeling of limitation on their ability to travel freely like they can with an ICE.

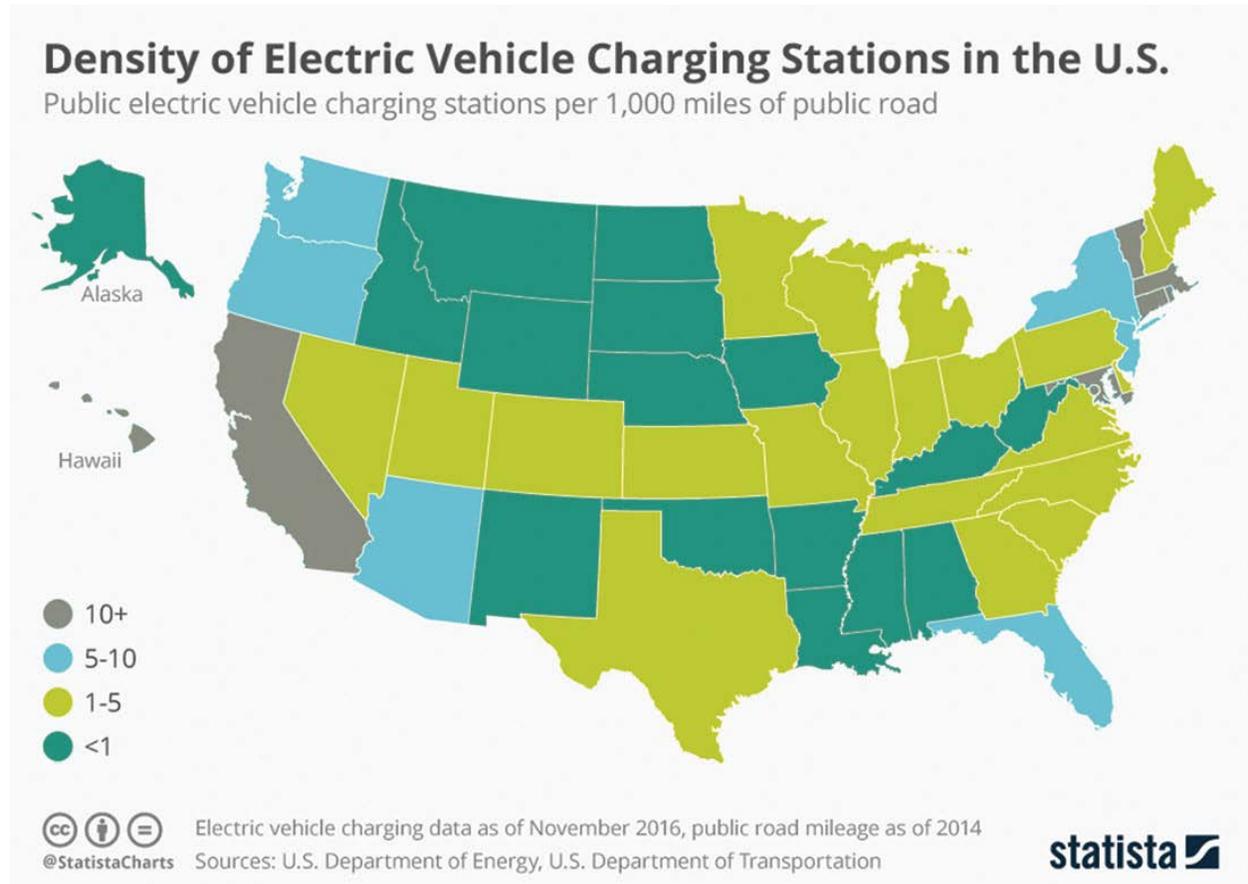


Figure 5. EV charger density by state based on amount of public roads

EV charging technology. Speed of charging, Charging an EV can happen anywhere a standard 110 volt electric outlet exists, but this type of charging (Level 1) is slow, adding about three to five miles of range per hour. While 95% of charging happens at home and work (Transport & Environment, 2018), consumers will generally get hung up on those 5% scenarios where they will rely on public charging to travel outside the range their home or workplace charging would allow. It generally takes less than ten minutes to full a conventional gasoline-

powered car or ICE, but charging an EV can from empty to full can range from 30 minutes to several days (in the extreme cases of using 110 AC outlets to recharge EVs with a larger kWh batteries) (Menser). Until the convenience of fueling ICE vehicles can be matched by EVs, adoption will continue to be slower.

Perceptions on ownership. Until a consumer experiences an EV for themselves they tend to be skeptical of EV technology (Bühler, 2014). Common fears include limitation of their range, flammability of batteries, performance and higher costs. The promising results of the field study reference above showed that consumer attitudes towards EVs dramatically changed when they drove the vehicles, making this limitation easier to overcome.

Consumer Demographics Influencing Interest in EVs

There was limited research available on how consumer demographics correlate to the early adopters of EVs or current consumers' interest in transitioning to an EV. Some studies had been done on socio-economic indicators. The most prevalently researched topic was the impact of incentives on adoption.

Socio-economic factors. Sierzchula conducted a detailed study across 30 countries to try and identify correlations between incentives, local charging, socio-demographic variables and electric vehicle adoption. The study concluded that locality to EV production facility and available public charging were the strong indicators of adoption. The broader socio-demographic variables such as income, education level, and environmentalism were not good predictors of adoption levels. This could be because national EV markets were so small, relative to overall automobile sales.

Incentives. The same 2014 study found a statistical significance in financial purchase incentives driving adoption of EVs. The results vary widely and below is a chart of the country's financial incentives compared against the rate of EV adoption.

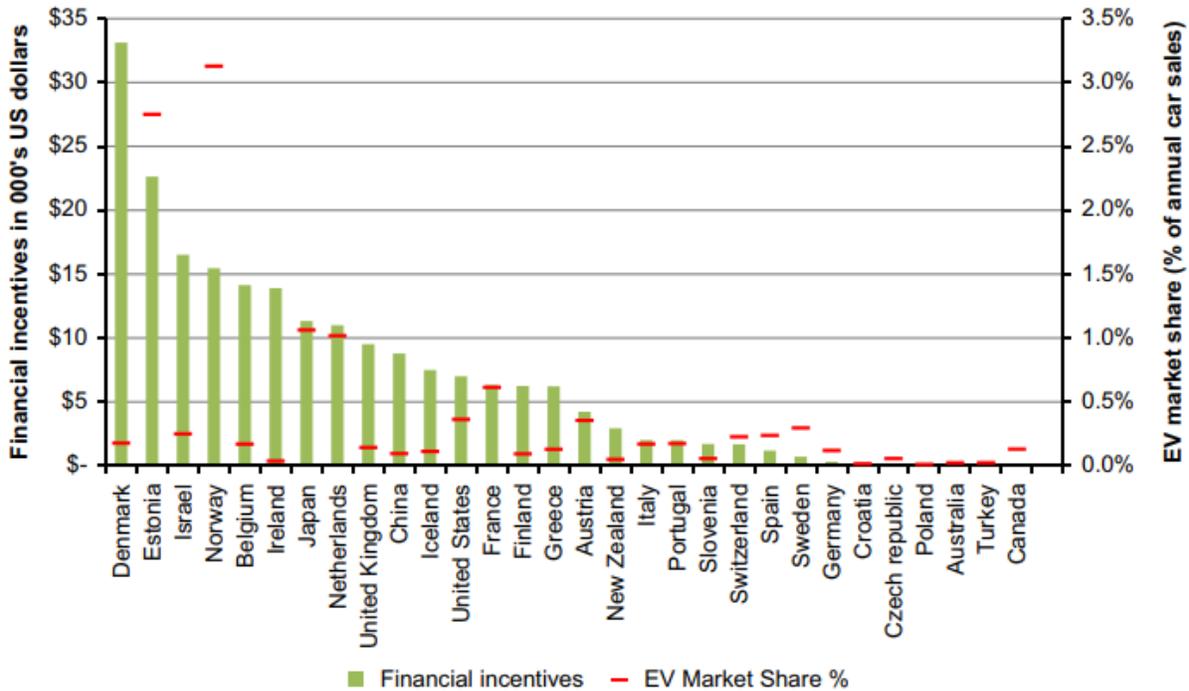


Figure 6. 2014 EV purchase incentive comparison by country compared to EV adoption rate.

Another study from 2015 suggested that vehicle range was still the leading factor for U.S. consumers in making the decision to drive electric (Helveston).

Summary

Converting the United States transportation sector from carbon-based fueled cars to increasingly-renewable powered electric vehicles will take significant effort and a lot of time. With consumer skepticism, lack of available public charging, and relatively low gasoline prices, policy-makers will have to decide what measures to take regarding extending or expanding the federal tax rebate incentive. Additionally, in-person experiences are thought to be very impactful of changing consumer perception of EVs. Car dealerships, electric utilities, EV charging

companies and public organizations should partner together to arrange these experiences for consumers. Finally, a higher tax on gasoline would likely drive consumers to seek alternatives. Until then, more research is needed on to specify which populations or consumer groups will be the easiest to convert and target the efforts there.

Chapter Three

Methodology

The purpose of this quantitative study was to determine if there are correlations between demographic characteristics and interest level in purchasing an electric vehicle. If patterns can be identified between certain demographics that are more or less likely to be interested in an electric vehicle, automotive dealerships, policy makers and other members of the electric transportation industry may be able to take a more strategic approach when promoting this form of Beneficial Electrification. This chapter will explain the setting and survey participants, how the study was developed, and the procedures used to gather and analyze data.

Research Design

The research methods deployed for this study were quantitative descriptive and correlational. The quantitative descriptive method was used because there were research questions that involved a relationship between two variables. A correlational method was also used because there were research questions that had multiple variables being studied within the same group of survey participants.

Setting and Participants

The participants of this study included 229 customers of *Company A*, an electric utility in Northeastern Minnesota. Customers were solicited to respond to this survey via the company's social media channels, website and email marketing lists. As shown below in Table 1, this resulted in 229 verified customers of *Company A* responding to the survey. 124 of the respondents identified as female, 96 as male, and 9 preferred not to identify with a gender. Almost 46% of the respondents indicated that they have an annual income in excess of \$75,000. The majority of survey participants identified as working, as well as having children in the home (though these

were not mutually exclusive). The highest participating age range of respondents was ages 35-54, representing 42% of the sample.

Table 1
Participant Characteristics (n=229)

Variable	Frequency	Percent	Variable	Frequency	Percent
Own/Rent			Kids at Home		
Own	214	93.4	No	154	67.2
Rent	15	6.6	Yes	75	32.8
Age Range			Income Range		
18 - 34	39	17.0	Less than \$35,000	15	6.6
35 - 54	97	42.4	\$35,000 – \$75,000	84	36.7
55 - 65	58	25.3	\$75,000+	105	45.9
65+	33	14.4	Prefer not to answer	25	10.9
Prefer not to answer	2	0.9	Gender Identity		
Employment Status			Female	124	54.1
Working	184	80.3	Male	96	41.9
Not working	4	1.7	Prefer not to answer	9	3.9
Retired	37	16.2			
Prefer not to answer	4	1.7			

Measures

The written survey questionnaire was developed by the researcher, an employee of *Company A*. The survey contained multiple choice (matrix, single-answer and multiple-answer) and demographic questions.

Data Gathering and Analysis

The survey was available and marketed online for four weeks. Upon closure of the survey, the researcher downloaded the results into an Excel spreadsheet file. After obtaining the raw data, *Company A* removed all Personally Identifiable Information from the responses and released the information for public use to the researcher. This information was then entered into SPSS. IBM SPSS Statistics Software version 25 (2017). Descriptive (means, standard deviations, and percentages) and inferential statistics (correlations) were used.

Summary

Two hundred twenty nine customers of an electric utility based out of Northeastern Minnesota participated in the survey. An online survey questionnaire was developed to determine a correlation between demographic characteristics (age, income, gender identity) and interest level in electric vehicle ownership at a point in time measurement.

Chapter Four

Results and Discussion

First, this chapter will report participant interest in a plug-in electric vehicle by their demographic characteristics. Then the associations between the interest and environmental awareness are described.

Participant Interest in a Plug-in Electric Vehicle by Demographic Characteristics

Table 2 shows the results on the participant interests in a plug-in electric vehicle analyzed by their demographic characteristics.

Interest by the residence type. As you can see in both *Table 1* and the second variable line of *Table 2*, 93.4 percent of (or 214 of 229) respondents are home-owners – not representative of the broader customer base (United States Census Bureau, 2017). About half of the people who owned their current home responded that they were *Interested* (43.9%) with a similar response rate of 41.6% for *Not Interested* in a plug-in electric vehicle, which was seemingly higher than the renter group (26.7% *Interested*, with a response rate of 66.7% for *Not Interested*). No respondents with a renting status already own an EV. However, the group difference in the interest rates were by the own/rent- a home status was not statistically significant, Chi-square = 3.90, $p = .27$. A prominent barrier to EV ownership is the logistical difficulty of getting an at-home charger installed. This is further complicated when you don't own your residence as you have to work through a landlord or building manager.

Interest by age range. There appears to be a relationship between age and interest in plug-in electric vehicles. Specifically, the younger the participant the more they were interested. The 35-54 age group had the highest volume of responses (45) interested (this age group was 97 total out of the 229 respondents). This is shown in the *Table 2* results: 18-34 age group (51.3%),

35-54 age group (46.4%), 55-65 age group (41.4%), and 65 or older group (24.2%). However, the age group differences in the interest rates were not statistically significant, Chi-square = 12.17, $p = .43$.

Interest by employment status. The highest response group by employment status was the working group that selected *Interested* (n=83 or 45.1%). In the not working/retired group (which was smaller than the working group), the most popular response (41.5%) indicated they were *Not Interested* in plug-in electric vehicle ownership, Chi-square = 7.33, $p = 0.06$.

Interest by the kids-at-home status. Over two-thirds of the customers that responded indicated that they did not have kids still living at home. Of those, the results between *Interested* and *No Interest* were quite similar, 45.1% and 43.5% respectively. For participants with no kids at home, the highest response percentage (48%) has *No interest* in owning an EV. Chi-square = 1.11, $p = 0.78$.

Interest by the income range. Participants with the lowest annual income range (<\$35,000) had the highest percentage of responses in the *No interest* category at 60%. The other ranges of income categories (\$35,000 - \$75,000 and >\$75,000) had their highest portion of responses in the *Interested* category. The highest rate of respondents that indicated they *Already own* an EV were in the highest income category. Chi-square = 10.31, $p = 0.11$.

Interest by the gender identity. For customers identifying with the female gender, there was no responses in the *Already own* category and highest selection was *No interest* at 49.2%. 10.4% of the male-identifying respondents *Already own* and 43.8% were *Interested*. Chi-square = 21.4, $p = 0.01$.

Table 2

Participants Interest in a Plug-in Electric Vehicle by Demographic Characteristics

Variable	Already				Chi-square	p
	own	Interested	No interest	Don't know		
Entire Group (n=229)	11 (%) (4.8)	98 (42.8)	99 (43.2)	21 (9.2)		
Own/Rent					3.9	0.27
Own (n=214)	11 (%) (5.1)	94 (43.9)	89 (41.6)	20 (9.3)		
Rent (n=15)	0 (%) (0.0)	4 (26.7)	10 (66.7)	1 (6.7)		
Age Range*					12.17	0.43
18 - 34 (n=39)	2 (%) (5.1)	20 (51.3)	16 (41.0)	1 (2.6)		
35 - 54 (n=97)	5 (%) (5.2)	45 (46.4)	41 (42.3)	6 (6.2)		
55 - 65 (n=58)	2 (%) (3.4)	24 (41.4)	23 (39.7)	9 (15.5)		
65+ (n=33)	2 (%) (6.1)	8 (24.2)	18 (54.5)	5 (15.2)		
Employment Status					7.33	0.06
Working (n=184)	9 (%) (4.9)	83 (45.1)	80 (43.5)	12 (6.5)		
Not working+Retired (n=41)	2 (%) (4.9)	14 (34.1)	17 (41.5)	8 (19.5)		
Kids at Home					1.11	0.78
No (n=154)	8 (%) (5.2)	68 (44.2)	63 (40.9)	15 (9.7)		
Yes (n=75)	3 (%) (4.0)	30 (40.0)	36 (48.0)	6 (8.0)		
Income Range*					10.31	0.11
Less than \$35,000 (n=15)	0 (%) (0.0)	3 (20.0)	9 (60.0)	3 (20.0)		
\$35,000 – \$75,000 (n=84)	2 (%) (2.4)	38 (45.2)	35 (41.7)	9 (10.7)		
\$75,000+	8 (%) (7.6)	51 (48.6)	39 (37.1)	7 (6.7)		
Gender Identity*					21.4	0.01**
Female (n=124)	0 (%) (0.0)	49 (39.5)	61 (49.2)	14 (11.3)		
Male (n=96)	10 (%) (10.4)	42 (43.8)	37 (38.5)	7 (7.3)		

Note . * Those who responded with Prefer Not to Answer (n=2) were removed from the analysis' ** significant at $p < .01$.

Associations between Interest in a Plug-in Electric Vehicle and Environmental Awareness

Table 3 presents the results on the associations between the interest in an electric vehicle and environmental awareness. The *Interested* response rates for those who have taken steps to lower their electric bill using less electricity on a *Daily* basis (41.6%) and *Often* (44.6%) were very similar to the groups answered *Sometimes* (42.0% and *Never* (40.0%), Chi-square = 2.17, $p = .99$. Correlation between engagement in energy efficiency and interest in EV adoption was lacking.

Of customers responding they have “No interest” (n=99), the top identifying statement they agreed with was “I want to save money” (n=90 or 90.9%), followed by “to help protect our environment by reducing my energy use” (n=73 or 73.7%). About half of the “No interest” group, responded that they wanted “to help our environment by using renewable resources such as wind or solar instead of carbon-emitting resources” (n=45 or 45.5%). Less than half of the “No interest” group, responded that they wanted “a consistent bill, one that does not change a lot from month to month or season to season” (n=39 or 39.4%).

Of customers responding they have “No interest” the top identifying statement they agreed with was “I want to save money”. Electric vehicles were very expensive when they first were introduced and this perception still carries on today. This is despite the fact that today an efficient EV will save owners money on energy costs (vs. fuel), and receive financial incentives upon purchase and have less ongoing maintenance costs (Reichmuth, 2017).

Table 3

Association with Interest in a Plug-in Electric Vehicle and Environmental Awareness Questions

Variable	Interest in a Plug-in Electric Vehicle				Chi-square	p
	Already own	Interested	No interest	Don't know		
Have you taken steps to lower your electric bill by using less electricity? (n=229)					2.17	0.99
Daily (n=77)	4	32	33	8		
(%)	(5.2)	(41.6)	(42.9)	(10.4)		
Often (n=92)	4	41	41	6		
(%)	(4.3)	(44.6)	(44.6)	(6.5)		
Sometimes (n=50)	2	21	21	6		
(%)	(4.0)	(42.0)	(42.0)	(12.0)		
Never (n=10)	1	4	4	1		
(%)	(10.0)	(40.0)	(40.0)	(10.0)		
Participants who answered "I have no interest in buying a plug-in electric vehicle" (n=99)						
I want.....			Yes (n)	Yes (%)		
to save money			90	90.9		
to help protect our environment by reducing my energy use			73	73.7		
to help protect our environment by using renewable resources such as wind or solar instead of carbon-emitting resources			45	45.5		
a consistent bill, one that does not change a lot from month to month or season to season			39	39.4		

Summary

The results generally aligned with the limited research available. No statistical significance could be drawn between consumer demographics and interest in purchasing EVs. However, there does appear to be a higher portion of interest and ownership within the populations that own their homes and have annual incomes above \$35,000.

Chapter Five

Summary and Conclusions

Electric vehicles still represent a very small portion of vehicles on the road today. Until adoption increases it will be difficult to have a statistically representative population to determine if demographic characteristics are a leading indicator of likelihood to convert to this re-emerging and technology. Other research suggests that financial incentives play a strong role and recommend that the United States continue to offer financial incentives to consumers until adoption rates increase. Availability of public charging infrastructure is also a key theme across the majority of any research done related to EVs and often referred to as the biggest challenge with this massive change ahead.

More research should be done across a broader geographical area with a larger sample size. If further studies also lack a statistical significance, policy-makers could make more well-informed decisions on how to target consumers through the other correlating indicators. Focus should then shift to expanding EV charging infrastructure, financial incentives and general education and outreach to the uninformed population.

Significant Findings

While statistically insignificant, there were varying levels of interest across the demographic characteristics. Consumers that rent vs. owned showed a lower level of interest in owning an EV. This is likely due to the fact that there are logistical challenges of establishing “home charging” facilities when you don’t own the property, or have a way to properly compensate the landlord for the additional energy used. This is not a well-researched topic and will be especially important as popularity of condominiums has been on the rise in recent years.

Interest by age groups steadily declined as the age group increases. Younger consumers are more likely to take interest in new technology and be open to new experience so this is no surprise. Additionally, males and higher income (\$75,000+) were the most interested in their respective demographic categories. The income results are typical and expected as EVs have historically had a higher upfront cost and therefore purchased by consumers with a higher income.

Implications

Electrifying transportation will yield significant benefits in the United States and continuously improve as the country takes further steps to decarbonize electricity generation. How far and how fast is dependent on the combination of federal and state policy makers, public and private research, and the automobile industry. Advancing adoption will require education and outreach to a broad population, different strategies for different segments and an improvement in the cost/benefit ratio. This could come in the way of increased gas prices (naturally or through taxation), lowering the purchase price and ownership costs of EVs (naturally or through tax breaks).

These benefits will be realized when adoption rates increase, gasoline consumption declines and the nation utilizes the electric grid more efficiently. Results of this study reveal a small, but noticeable difference in a limited set of participants that indicate different approaches may be needed. Depending if financial incentives continue, urban areas are targeted first with public charging stations, or home-owners are found to be the priority, may results in different results and inform future plans to increase adoption. This transition will not happen fast and is likely to need a multi-faceted approach.

Limitations and Recommendations

This study was limited to a small pool of participants in a somewhat rural area of the Midwest. These results are not statistically representative of the U.S., or even the region. Additionally, the researcher had an inherent bias as an employee of *Company A*, an electric utility in Northeastern Minnesota. The survey was only conducted online and solicited to a relatively small subset of customers that have different technology habits and interests when compared with the entire population.

More quantitative studies should be done on consumers interest in EVs as it relates to their interest or disinterest in owning an EV. As it related to actionable items to advance adoptions of electric vehicles, the United States should invest in public EV charging infrastructure and continue to incentivize the purchase of the cars themselves. While there was limited confirmation that demographic characteristics necessarily play a role in adoption, both of those strategies seem well-researched to support further funding.

Conclusion

They say it took over 50 years for the United States to majorly transition from horse and carriage to automobiles. At that time, three technologies had an almost equal market share: electric, steam, and internal combustion vehicles. While gasoline has reigned supreme for the last century there is a growing movement that suggests the quiet, clean, and efficient ride of an electric vehicle will make its way back to the top in due time. It's now the leading opportunity for the United States to reduce its greenhouse gas emissions and limit their contribution to the future impacts of climate change.

As with all emerging technologies, the “early adopter” population is small. Close attention will have to be paid to breaking down the barriers of adoption, potentially segment by

segment. Until then, broad measures like incentives and investments in public charging should be increased and the corresponding impacts on adoption examined. After all, technology solutions for the largest contributors to climate change are currently one of the few positive outlooks on the horizon for our climate future.

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Appendices

Appendix I

IRB Approval Letter

UNIVERSITY OF MINNESOTA

Twin Cities Campus

*Human Research Protection Program
Office of the Vice President for Research*

*Room 350-2
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EXEMPTION DETERMINATION

February 25, 2019

Insoon Han

218-726-8682
hanxx093@umn.edu

Dear Insoon Han:

On 2/25/2019, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Impact of Consumer Demographic Characteristics on Adoption Rate of Electric Transportation
Investigator:	Insoon Han
IRB ID:	STUDY00005819
Sponsored Funding:	None
Grant ID/Con Number:	None
Internal UMN Funding:	None
Fund Management Outside University:	None
IND, IDE, or HDE:	None
Documents Reviewed with this Submission:	<ul style="list-style-type: none"> • HRP-595 - Data or Specimen Only Protocol_AppendixA added Ver2.2.docx, Category: IRB Protocol; • MP Letter of Support - EV Thesis - 1 17 2019.pdf, Category: Letters of Support / Approvals (Location);

The IRB determined that this study meets the criteria for exemption from IRB review. To arrive at this determination, the IRB used "WORKSHEET: Exemption (HRP-312)." If you have any questions about this determination, please review that Worksheet in the [HRPP Toolkit Library](#) and contact the IRB office if needed.

Driven to DiscoverSM

This study met the following category for exemption:

• (4) Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met: (i) The identifiable private information or identifiable biospecimens are publicly available; (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects; (iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or (iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Ongoing IRB review and approval for this study is not required; however, this determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit a Modification to the IRB for a determination.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the [HRPP Toolkit Library](#) on the IRB website.

For grant certification purposes, you will need these dates and the Assurance of Compliance number which is FWA00000312 (Fairview Health Systems Research FWA00000325, Gillette Children's Specialty Healthcare FWA00004003).

Sincerely,

Bri Warner
IRB Analyst

We value feedback from the research community and would like to hear about your experience. The link below will take you to a brief survey that will take a minute or two to complete. The questions are basic, but your responses will help us better understand

what we are doing well and areas that may require improvement. Thank you in advance for completing the survey.

Even if you have provided feedback in the past, we want and welcome your evaluation.

https://umn.qualtrics.com/SE/?SID=SV_5BiYrqPNMJRQSBn

Appendix II

1. What is the address of your primary residence?
2. Do you own or rent your current residence? [IF "RENT", ASK] Do you pay your own electric utility bills?
 - Own
 - Rent/Yes
 - Rent/No
3. Which of the following ranges contains your age?
 - 18 – 34
 - 35 – 54
 - 55 – 65
 - 65+
 - Prefer not to answer
4. Are you currently working, not working or retired?
 - Working
 - Not Working
 - Retired
5. Do you have pre-school or school-aged children living at home?
 - Yes
 - No
6. Which of the following categories contains your total household income for last year?
 - Less than \$35,000
 - \$35,000 - \$75,000
 - \$75,000+
7. Gender
 - Male
 - Female
 - Prefer not to answer
8. Which of the following statements best describes your interest in a Plug-In Electric Vehicle?
 - A. I already own a Plug-In Electric Vehicle
 - B. I expect my next car to be a Plug-In Electric Vehicle
 - C. I plan to at least look into buying a Plug-In Electric Vehicle
 - D. I've thought about buying a Plug-In Electric Vehicle
 - E. I have no interest in buying a Plug-In Electric Vehicle
 - F. Don't know

IF ANSWER E

- What is the primary reason why you are not interested in an Electric Vehicle? [select all that apply]
 - i. Cost of purchasing the car
 - ii. Cost of charging
 - iii. Cost of maintaining the car (battery repair)
 - iv. Leery about the technology
 - v. Concern about the car's performance in winter/on hills
 - vi. Lack of public charging in our region
 - vii. Hassle of charging
 - viii. Waiting for the kinks to get worked out with the technology

YOUR BILL

9. Which of the following statements most closely describes how you handle your monthly electric bill. (check only one)
 - I look at the total and pay it
 - I glance at the different charges before paying the bill
 - I have auto pay and rarely look at the bill
 - I thoroughly review my bill to understand changes in my energy use
 - I use MyAccount to monitor my real-time usage and use that as an estimate to gauge what my next bill will be

10. Please select all statements that apply to you
 - I want to save money
 - I want to help protect our environment by reducing my energy use
 - I want to help protect our environment by using renewable resources such as wind or solar instead of carbon-emitting resources
 - I want a stable bill; one that does not change a lot from month to month or season to season
 - I want to reduce stress on the electric system by reducing usage during peak times
 - I don't think about my bill or how much electricity I'm using

11. Regarding how your electricity usage impacts the amount you pay on your bill, would you say that you:
 - Understand Fairly Well
 - Are Somewhat Confused - and would like more information
 - Are Somewhat Confused - and would NOT like more information
 - Don't Know

12. What do you think is the average amount of your electric bill each month?
 - Between \$0--40
 - Between \$41-80
 - Between \$81-120
 - Between \$121-160
 - Between \$161-200

- Over \$200
- Don't Know

13. When you think about the amount of electricity you use every month, do you believe you are using:

- Similar amounts as others on average
- A little more than others on average
- A lot more than others on average
- A little less than others on average
- A lot less than others on average

14. In the past 12 months, how often did you receive an electric bill that was higher than you expected?

- Never
- Rarely (1-2 bills)
- Sometimes (3-4 bills)
- Often (5+)

15. In the past, have you taken steps to lower your electric bill by using less electricity?

- Frequently
- Often
- Sometimes
- Never

- If they answered Frequently, Often or Sometime this question should display:

- Did you notice any reductions in your electric bill after taking these steps?
 - Yes
 - Don't recall
 - No

16. Which of the following statements best describes your current attitude toward reducing your electric bill?

- Would like to do more to reduce my electric bill and am interested in new ideas
- Would do more to reduce my bill but doubtful that further steps would be effective
- I have done a lot to save energy in my home and there is little more that can be done
- Not sure
- Not concerned, little or no interest in reducing my bill

17. Looking ahead five years, how concerned are you about the affordability of electricity?

- Very Concerned
- Somewhat Concerned
- Not Very Concerned
- Not at all Concerned
- Don't Know

TIME-OF-DAY AWARENESS & UNDERSTANDING

18. Have you heard of the term “smart grid,” or of the product “smart meters”? Smart Grid refers to new technology and infrastructure that improves customer service and reduces costs by studying how customers use power. Smart meters are advanced versions of household meters that transmit information back to Minnesota Power frequently during the day and are part of the overall smart grid. Smart meters allow Minnesota Power to offer new programs to customers that give them more control over their bill.

- Yes
- No
- Don't Know

19. Which of the following energy-related concepts are you familiar with? (select all that apply)

- Time-of-Use Rate, Time-of-Day Rate or Time-Varying Rate
- Off-Peak or On-Peak
- Critical Peak Pricing
- Peak Event Day or Peak Time Rebate

20. How interested would you be in a Minnesota Power “Time-of-Day” program that gave you the ability to potentially save money by shifting some of your energy usage to “Off-Peak” times like nights and weekends?

- Very Interested
- Somewhat Interested
- Neutral
- Not Interested
- Don't Know

21. How interested would you be in this “Time-of-Day” program if you knew that excessive energy usage during “On-Peak” times - like during the day on weekdays - might result in a higher electricity bill?

- Very Interested
- Somewhat Interested
- Neutral
- Not Interested
- Don't Know

22. A “Peak Event” refers to a 3 or 4 hour window when electricity is in extremely high demand and is very expensive. If you were on a “Time-of-Day” program, and Minnesota Power could reward you for reducing your usage during these “Peak Events,” which would you prefer:

- A cash rebate, or
- Having the reward built into your monthly bill

23. If you were on the Time-of-Day rate, would you be okay if the On-Peak and Off-Peak periods shifted from season to season (e.g. Winter On-Peak 5 – 9 PM, Summer On-Peak 12 – 4 PM)?

- Yes

- Neutral
- No

24. If you were on “Time-of-Day” program and Minnesota Power could warn you about an upcoming “Peak Event” and an opportunity to reduce your bill, what would be your preferred method of communication?

- Text
- E-mail
- Mobile App Notifications
- An automated phone call