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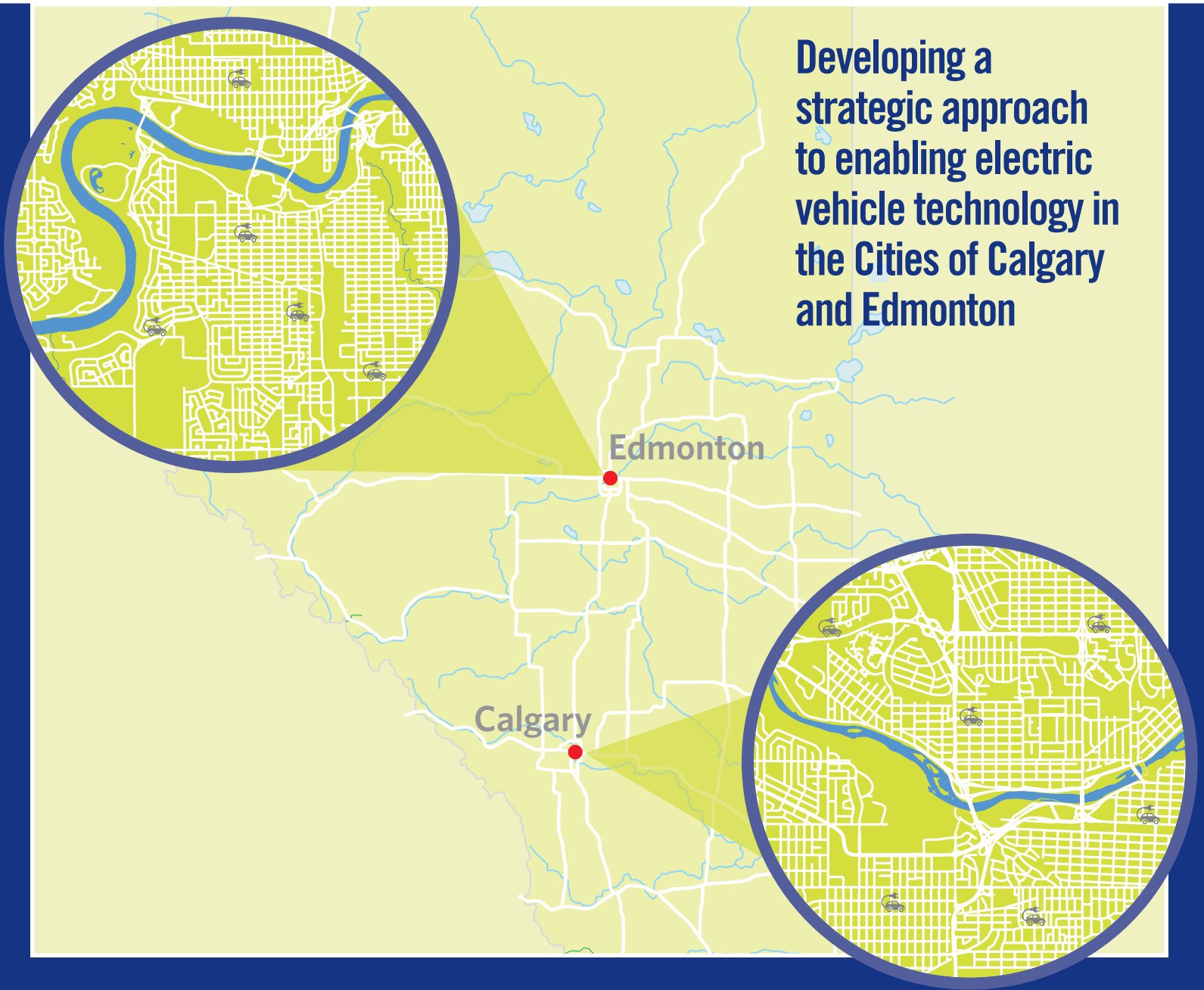
ELECTRIC MOBILITY ADOPTION AND PREDICTION



Developing a strategic approach to enabling electric vehicle technology in the Cities of Calgary and Edmonton

ABOUT POLLUTION PROBE

Pollution Probe is a national, not-for-profit, charitable organization that exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

ABOUT ELECTRIC MOBILITY CANADA

Electric Mobility Canada (EMC) is a national, not-for-profit industry association advocating for electric transportation as the primary solution to Canada's transportation sector issues. Established in 2006, EMC members include the automotive industry, infrastructure and battery suppliers, electricity providers, end-user fleets, research and development institutions, and others who strive to maximize Canada's green potential.

ABOUT ENMAX CORPORATION

ENMAX Corporation, through its subsidiaries, makes, moves and sells electricity to residential, small business and large commercial customers and is headquartered in Calgary, Alberta, with offices in Edmonton. ENMAX Power Corporation owns and operates transmission and distribution infrastructure in Calgary, and ENMAX Energy Corporation owns diverse electricity generation facilities throughout the province. Since 2007, ENMAX has been named one of Alberta's Top Employers.

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About This Report

The Electric Mobility Adoption and Prediction (EMAP) methodology is a tool of predictive analysis, capable of improving the efficiency of capital investments in electricity distribution system assets and electric vehicle (EV) charging infrastructure by ensuring that they align with the needs of early adopter markets. In 2011, Pollution Probe collaborated with the Centre for Urban Energy (CUE) at Ryerson University on a pilot EMAP study for the City of Toronto. Building on the Toronto study, Pollution Probe partnered with Electric Mobility Canada and utilities in other Canadian municipalities (Ottawa; Hamilton and St. Catharines; London; Markham, Richmond Hill and Vaughan; and Calgary and Edmonton) to conduct further EMAP studies with support from the utilities and the ecoENERGY Innovation Initiative led by Natural Resources Canada.

This report summarizes the application of the EMAP methodology to the cities of Calgary and Edmonton and the potential implications of the EMAP analysis for ENMAX Corporation ("ENMAX"). ENMAX, through its subsidiaries, makes, moves, and sells electricity to residential, small business and large commercial customers and is headquartered in Calgary, Alberta. One of its subsidiaries, ENMAX Power Corporation, is the local wire service provider (WSP) in Calgary. Another subsidiary, ENMAX Energy Corporation, is the generation and retail service arm of ENMAX, offering retail electricity products and related services to customers across Alberta. Specific to the application of the EMAP methodology to Calgary and Edmonton was an exploration of the role that solar photovoltaic (PV) technology could potentially play in supporting EV deployment.

This report proposes a set of strategic objectives and recommendations intended to prepare ENMAX to manage and support the use of EVs in its service area.

As part of the study, representatives of ENMAX and select stakeholder organizations integral to the future of electrified transportation in Calgary and Edmonton met regularly, contributing to the overall project scope, sharing technical expertise and providing guidance for all milestones and deliverables. The participation of these individuals helped to ensure that a local perspective informed the project, thus enhancing its credibility and the value and relevance of the outputs. In addition, a complementary, full-length report on the EMAP market research was produced by Environics Research Group. These resources provide a comprehensive look at the implications of EV technology uptake for Calgary and Edmonton and served as the basis for this report.

This report summarizes the process, findings and implications emerging from the EMAP study. It also proposes a set of strategic objectives and recommendations intended to prepare ENMAX to manage and support the use of EVs in its service area.

Report Outline

This report describes the process, findings and implications of the EMAP study and explores options for a strategic path forward. The report is divided into two sections:

Section One provides a brief description of the EV as an emerging technology and the role that solar PV technology can play in supporting EV deployment. It also proposes a three-point strategy for enabling EV use in Calgary and Edmonton, based on key findings from the EMAP study.

Section Two describes the specific process, outputs and assumptions made in the development and application of the market research. This section builds a detailed picture of the characteristics of potential early adopters, including a broad demographic profile, typical personal mobility patterns, and the barriers to and opportunities for the uptake of EVs and solar PV.

SECTION ONE: A Strategic Approach to Enabling EV Use in Calgary and Edmonton

The Electric Vehicle as an Emerging Technology

For EVs to become a viable part of a successful sustainable transportation system in Calgary and Edmonton, the social, environmental and financial needs of the user must be met. If early users of the technology are unable to experience and appreciate its full value, a broader market will not emerge. These early users will play a key role in expanding and developing the EV market and, for this reason, it is important to better understand exactly how to address their needs and incorporate the technology into their lives.

While the results of the EMAP study identify barriers and opportunities specific to EVs, the technology's adoption cycle also shares a number of characteristics with other emerging technologies. The process of technology adoption tends to follow a classical bell curve. The first users are known as innovators, followed closely by an early adopter group. Innovators are generally a very small number of risk takers who thrive on the challenge of a new technology and are willing to buy into a product even though the technology may ultimately fail. Early adopters, on the other hand, are generally more cautious in their adoption of a new technology and are not as willing to form new routines or behaviours to incorporate it into their lives. This observation is supported by the early adopter profile generated through the EMAP market research, which suggests that, in Calgary and Edmonton, this group is unaccustomed to inconvenience and perhaps somewhat reluctant to make the sacrifices they perceive to be necessary to transition to an EV, given current market and technological considerations.

Support or endorsement of a technology from the early adopter group is one of the most important factors contributing to its adoption by a broader market. Whereas innovators may be perceived as extravagant or in a better position to take risks than the general public, early adopters demonstrate a high degree of opinion leadership capable of generating confidence in the usefulness of a technology among the broader public. The early majority of the mass market tends to take its cues and base its decisions on the experiences of and feedback from early adopters because their choices are perceived to be more discerning. It is for this reason that the EMAP study focuses on this influential consumer group.

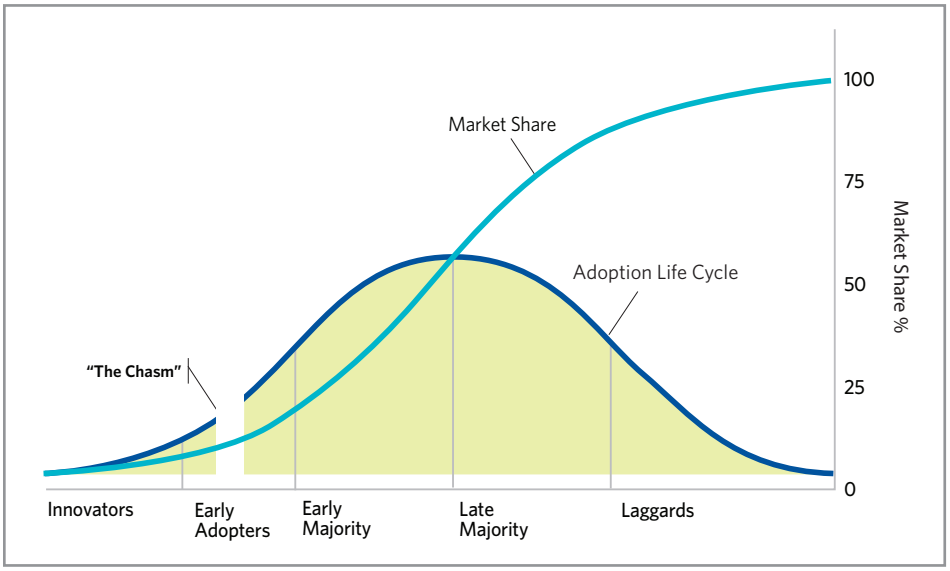
Support or endorsement of a technology from the early adopter group is one of the most important factors contributing to its adoption by a broader market.

While the traditional bell curve has long been the typical visual representation of market development for an emerging technology, more recently, Geoffrey Moore* has introduced the notion of a "chasm." Moore argues that there is a gap (or chasm) between the early adopter group and the early majority because the latter not only wants a useful product but also a well-established infrastructure to support it. Moore believes that, during the chasm phase, an emerging technology experiences a pause in market development. The length of this pause depends entirely on how disruptive the technology is to "business as usual."

**Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*. HarperCollins, 1991.

The actual market share held by an emerging technology does not follow the traditional bell curve for market development. Market share shows an upward trend before reaching full market saturation. This is because each adoption group is made up of a different number of people. For example, innovators and early adopters are relatively small groups and, as such, their interest in a technology translates into a relatively small percentage of the overall market. By the time the late majority and laggards adopt a technology, the market share is close to approaching saturation because these groups make up a much larger proportion of the population. See Figure 1.

Figure 1: Technology Adoption Life Cycle and Market Share



There have been many attempts to forecast the rate at which the adoption of EVs will occur – whether it will move quickly, like the Internet or the radio, or whether it will resemble the slower adoption curve of the washing machine, considered a luxury item for many years. Radically new or different technologies may have a difficult time breaking through, not because of the merits of the technology itself, but because regulations, infrastructure, maintenance networks and user practices are aligned to an existing technology. This is certainly a major consideration in the case of EVs. The current automotive marketplace revolves primarily around gasoline-powered vehicles. In addition to automakers themselves, there is an entire aftermarket involved in manufacturing, distributing, retailing and installing vehicle parts, equipment and accessories for gasoline-powered vehicles. Low gasoline prices and the general state of the economy may also play a role in the rate at which the EV market expands. This is not to say, however, that emerging technologies are unable to overcome these challenges.

While technological advances will go a long way to overcoming barriers to EV adoption, these alone may not be enough to appeal to the broader market. EVs will not succeed in the market if perceptions about their usefulness are not positive. For example, Consumer Reports, an independent organization that tests consumer products and services, awarded the Tesla Model S a rating of 99 out of 100 in 2013. This matches the best score earned by any vehicle, not just an EV, in the history of Consumer Reports. Yet many were quick to point out that, because of the lack of infrastructure to support its use, particularly infrastructure for fast charging, the Model S is hardly just one point shy of perfect.

The electricity distribution system's capacity to respond to the power demand for EV charging will play a critical role in the adoption of the technology, particularly in the broader market.

The electricity distribution system's capacity to respond to the power demand for EV charging will play a critical role in the adoption of the technology, particularly in the broader market. A number of variables, such as the size of the vehicle's on-board charger and the time of charge, have the potential to affect the capacity of the electricity distribution system to accommodate anticipated EV-related loads (see the appendix to this report for more information about the factors affecting the capacity of the electricity distribution system to accommodate EV-related loading). As such, careful planning on the part of the WSP will be important to ensure that it is prepared for EV deployment.

Better understanding the needs and perceptions of the early adopter community is important for developing effective and targeted information and awareness campaigns, incentives, bylaws and local policy capable of supporting the market and infrastructure for EVs. By documenting the needs of early adopters, the EMAP study can enhance the value proposition of EV use among end-users and establish a solid foundation for EV deployment. At the same time, gaining a better understanding of the technologies that can complement EV use (e.g., using renewable energy to power the vehicle or as part of a home energy management system) will go a long way in supporting the integration of EVs into the transportation landscape.

The Role of Solar Photovoltaic Technology in Supporting Electric Vehicle Use

Opportunities for powering EVs with renewable energy such as solar power are already being explored to determine if integrated applications of these emerging technologies have the potential to accelerate their market adoption. The EMAP market research indicates that the value propositions of EV and solar PV technology for the early adopter group are based primarily on the promise of social and environmental benefits rather than lower costs for home energy or transportation. As such, the use of solar PV could be an important way to support the adoption of EV technology while at the same time contributing to a reduction in greenhouse gas (GHG) and other emissions associated with conventional gasoline-powered vehicles and electricity generation from fossil fuels.

Solar Photovoltaic Power

Solar PV technology converts solar energy into usable electricity. Most solar PV systems consist of several components, including photovoltaic modules (or panels), which absorb and convert sunlight into electricity, as well as inverters, cables and other electrical components. A solar inverter converts the direct current (DC) voltage of the electrical output from the solar panel to alternating current (AC), the form of voltage supplied by the electricity distribution system for household use. Solar PV arrays range from small systems capable of generating a few kilowatts of power for residential use to large-scale power stations capable of generating hundreds of megawatts. Solar panels can be ground mounted, installed on rooftops or integrated into certain building materials during the manufacturing process. Solar PV systems can be sized to provide all the electricity an end-user needs or to supplement power from the electricity distribution system.

Alberta is currently home to approximately 5.5 megawatts of grid-tied solar PV. Under the province's Micro-Generation Regulation (Alberta Regulation 27/2008), excess power generated by solar PV can be fed into the local grid system. This grid-connected or grid-tied configuration allows the user to purchase power from the WSP as needed to supplement the power generated by solar PV and to sell power back to the WSP when the solar PV installation has generated more power than is required. This is done through the use of a two-way metering system that measures the flow of electricity in and out of a home or building. In Alberta, payment for the generation of solar power is set at the customer's retail rate.

The Integration of Electric Vehicles and Solar Photovoltaic Power

It is anticipated that EV charging patterns will mean that vehicles are plugged in during periods of peak demand for power from the electricity distribution system. The generation of solar power has the potential to ease the load on the system resulting from EV use by supplementing the power required for charging. In combination with smart-grid-enabled technologies that allow for an element of control over the time of day when the vehicle charges, EVs could respond to signals to reduce charging when electricity from renewable sources is scarce and to resume charging when generation from solar PV is plentiful. This capability could help to maximize the use of energy from solar PV while minimizing additional loading from EV charging on the electricity distribution system. In turn, the WSP could avoid or minimize the need for potentially costly upgrades to electricity infrastructure to accommodate EV charging during periods of peak demand. Coupling EVs with vehicle-to-grid or vehicle-to-home technology – a form of smart grid technology that allows energy to flow in both directions between the vehicle and either the grid system or home – would allow EVs to act as battery storage, drawing power generated by solar PV during daylight hours and discharging it as required once the sun goes down.

A number of automakers have already recognized the potential synergy of these emerging technologies and are pursuing opportunities to demonstrate how households could potentially achieve electricity savings and even self-sufficiency by integrating EVs, solar PV and energy-efficient home appliances as part of an overall home energy management system. An example of one such initiative is BMW Canada's offer of a discount on a home solar PV system with the purchase of an EV. Automakers are also working together with WSPs and private companies to assist homeowners in assessing the suitability of their property for the installation of solar PV and are helping to navigate any related paperwork in an effort to make the process of integrating EV and solar PV technology more seamless. These types of initiatives are in line with the EMAP market research findings, which indicate that early adopters are more likely to consider the purchase of an EV if solar-powered charging stations are available.

The EMAP study shows that interest in EVs is directly linked to interest in solar PV, and vice versa, but that energy self-sufficiency is also an important consideration for early adopters. Coinciding with the expansion of the solar power industry in Canada, public support for options that allow consumers to both produce and consume electricity is growing. These findings point to opportunities to promote the integration of these technologies as a means of addressing the needs of the market. There is an important role for the WSP to play in enabling EV use and promoting solar PV as an energy source that, with fewer environmental impacts than other forms of electricity generation, can help to manage the demand from EV charging on the electricity distribution system.

The Potential Impacts of EV Use in Calgary and Edmonton

Patterns of EV charging in Alberta are not anticipated to represent a risk in the near future to the WSP's capacity to maintain a safe and reliable supply of power to all of its customers. Nor is the demand for power to charge EVs at home expected to exceed the capacity of current infrastructure assets in Calgary or Edmonton (see the appendix to this report for more information about the factors affecting the capacity of the electricity distribution system to accommodate EV-related loading). However, the prevailing trend in new EV technology is towards larger batteries and faster charging, as providers respond to market demand for greater driving range, convenience and overall utility. The compounding effect of these factors means that there is a need to continue to monitor the potential effects of EV charging on the electricity distribution system.

The EMAP market research shows that there may be opportunities to integrate the use of solar PV to effectively mitigate some of the possible effects of EV charging on the electricity distribution system and potentially even turn risks into cost advantages for the WSP and its customers. For example, the findings show that early adopters may return home to charge their vehicles during periods of peak demand, which could contribute to overload conditions for the electricity infrastructure on some streets. However, if enough solar power were generated to offset at least a portion of the demand for charging, overloading could be avoided. Taking proactive approaches such as this to managing EV charging could, in the long term, help the WSP to level the overall load on the system.

Using electricity to replace the combustion of gasoline and diesel to power transportation in Calgary and Edmonton could produce local air quality improvements due to avoided tailpipe emissions. In addition, when the source of electricity is factored into a life cycle analysis, there is the potential for further GHG and criteria air contaminant reductions. However, because EV adoption could, in the long term, pose challenges for the electricity distribution system, it is prudent for ENMAX to study and address the risks and highlight the benefits associated with EV charging in Alberta. Such a strategy is consistent with ENMAX's mandate to ensure a safe and reliable supply of power for its customers.

Enabling Electric Vehicle Use in Calgary and Edmonton – A Strategy to Manage the Risks and Optimize the Benefits

By studying EV use in Calgary and Edmonton, ENMAX can enhance its current organizational capacities to be responsive to consumers' basic needs and to the evolving state of EV technology. Adopting such a strategy will also allow ENMAX to leverage opportunities associated with EV use and to be proactive in addressing any barriers to it to support customers in their transition to driving electric. Flexibility, timeliness and foresight will be key to ensuring the success of this approach to enabling EV adoption as it evolves within the broader electricity utility landscape of smart grid technologies, distributed generation and enhanced energy services.

Key stakeholders internal and external to ENMAX must be considered in the deployment of EV technology in Calgary and Edmonton and, more generally, in Alberta as a whole. The success of EV technology depends on actions and decisions taken by a range of individuals as well as public and private organizations. The need for collaboration is particularly important given that there is currently no legislative imperative or financial incentive for regulated WSPs to deploy EV charging infrastructure in Alberta's partially deregulated electricity market, making it difficult for energy retailers to justify the installation of public EV charging stations under current market conditions. In addition to ENMAX, key stakeholders include

- the Cities of Calgary and Edmonton, in particular municipal planning staff and parking authorities
- private companies operating public parking lots
- businesses and workplaces that provide parking for employees
- ENMAX customers, including current and future EV or solar PV owners and users
- academia, including local polytechnic institutes and universities
- electric vehicle supply equipment (EVSE) providers
- organizations that provide education about EV and solar PV use in Alberta

A strategic approach to enabling successful EV use in Calgary and Edmonton can be built on the following recommendations, drawn from the EMAP market research:

1 Enhance utility responsiveness to evolving patterns of EV charging.

- Monitor and evaluate the progress of the EV market and the evolving impacts of EV charging on the local distribution system in the ENMAX Power service area. This means gathering market information and keeping apprised of changes in EV products and technologies, operating standards, regulations and general market adoption. It could also be helpful to request notification from automotive dealerships when an EV is sold within the service area.
- Identify opportunities for integrating EV charging with renewable energy sources such as residential solar PV. The EMAP study shows that early adopters are likely to charge their vehicles at periods of peak demand. The use of residential solar PV could help to ease the impacts of EV charging on the electricity distribution system during periods of peak power demand.
- Take into consideration the impacts of EV charging in developing infrastructure design criteria to ensure that they do not present barriers to EV use. Accounting for anticipated levels of EV uptake in the course of scheduled asset replacement will help to optimize the number of vehicles that can be charged without compromising the reliability of the power supply.

Key stakeholders internal and external to ENMAX must be considered in the deployment of EV technology in Calgary and Edmonton and, more generally, in Alberta as a whole.

2 Build partnerships to address barriers and leverage opportunities for EV deployment, consistent with the needs of early adopters.

- Engage the Cities of Calgary and Edmonton in meaningful discussion of the role EVs can play in promoting sustainable growth and development in the region. Strategic planning for EV deployment has the potential to contribute to municipal efforts to reduce GHG emissions and improve local energy efficiency, particularly when combined with grid-tied solar PV.
- Foster dialogue among electricity utilities on best practices related to EV technology. As the EV market continues to evolve, utilities across Canada will face some common challenges and opportunities related to EV use within their service areas. Shared strategies and lessons learned can contribute to better understanding and, in turn, to enhanced opportunities to successfully enable and promote EV use across the country.
- Collaborate with key stakeholders on developing a process for identifying optimal locations for public and workplace-based charging stations. The EMAP study identifies range anxiety among potential early adopters as a barrier that can be addressed by providing fast-charging services away from home. At the same time, early adopters would be more likely to consider an EV if there were an option to charge at a public, solar-powered charging station, which suggests that there are opportunities to integrate renewable energy sources and EV charging. This report points to some desirable locations for charging stations (e.g., in relation to commuter parking patterns), but further planning by and coordination among various ENMAX departments, municipal governments, property managers and other stakeholders will be necessary to achieve the expansion of charging facilities.
- Engage internal business units and key stakeholders in exploring the benefits offered by providing services that would support the integration of EV charging and residential solar PV use. The EMAP study shows that interest in EVs is linked to interest in residential solar PV, and vice versa, pointing to opportunities to develop products and services that capitalize on the synergies between EVs and ENMAX Energy's other lines of business, including solar PV.

3 Educate customers about EV technology.

- Contribute to building understanding of EV technology, particularly from a social perspective. The EMAP study shows that early adopter interest in EV technology is more strongly linked to environmental performance (e.g., mitigating air pollution and climate change) than it is to the financial advantages of reduced fuel and maintenance expenses.
- Create targeted messaging about the potential benefits of combining EV charging with residential solar PV. The EMAP study suggests that ENMAX, through its subsidiaries, is considered a trusted source of information about residential solar PV technology and a trusted provider of residential solar PV services. This provides a solid foundation for effective communication with customers – both early adopters and the general public. Developing messaging that points to residential solar PV as an environmentally responsible choice that can add to the GHG emissions reductions of driving electric would resonate strongly with the EV early adopter market.
- Equip ENMAX communications and customer service groups with the necessary information, including sample scripting where appropriate, to respond to general customer inquiries about EV technology. This could include information about the environmental and consumer impacts of using residential solar PV to power EVs.

SECTION TWO:
Market Research

Purpose of Surveying the Cities of Calgary and Edmonton

Understanding the perceptions, both positive and negative, of EVs and residential solar PV among the early adopter community in Calgary and Edmonton will make it possible to support the development of these technologies and to define the local policy context for their implementation. Market research can generate critical information on the needs and views of the early adopter population, using demographic and psychographic analyses to understand the barriers that must be addressed to encourage and enable the uptake of EVs and residential solar PV.

It is important to understand how EVs and residential solar PV can be used in order to ensure that their deployment in communities is a successful experience for owners, and that the range of potential benefits associated with the technologies can be fully realized.

Methodology

The market research process involved two separate but related sets of investigations:

- secondary research to identify the geographic distribution of potential early adopters of EV and residential solar PV technology
- primary research to characterize early adopters and identify potential opportunities and barriers to EV and residential solar PV adoption

The specific process, outputs and assumptions made in the development and application of the research are described below.

Secondary Research to Identify the Geographic Distribution of Potential Early Adopters

The secondary research sought to identify the behavioural and attitudinal characteristics of likely early adopters of EV and residential solar PV technology and to map the neighbourhoods in which early adopters may tend to cluster. This research was the basis for the primary research that followed, allowing for a more efficient and targeted household survey of the characteristics and preferences of likely early adopters of EV and residential solar PV technology.

The secondary research was undertaken in collaboration with Environics Analytics, using its proprietary PRIZM$_{c2}$ segmentation system database. The PRIZM$_{c2}$ system classifies every neighbourhood and postal code throughout Canada into one of 66 segments based on the most important drivers of consumer behaviour, including demographics, lifestyles and social values. It assumes that neighbourhoods that are classified similarly have comparable demographic, behavioural and attitudinal characteristics regardless of where they are located. As such, the PRIZM$_{c2}$ segments are an effective means of estimating behaviours and attitudes at a very local level, based on data collected at a very high level.

For the purpose of creating a profile of a potential early adopter of EV and residential solar PV technology, data from a number of different surveys as well as national and regional vehicle purchase information were linked to the PRIZM$_{c2}$ segments. These databases included the Environics Analytics DemoStats database, the Environics Research Group Social Values nationwide survey, IHS Automotive's New Vehicle Registrations (NVR) and Total Vehicles in Operation (TVIO) databases, and the Numeris RTS national survey.

Because EVs currently account for only a small portion of total vehicles in the marketplace, EV purchase data in surveys and databases are limited. Data reflecting the extent of home solar power use are similarly limited. Therefore, the following key variables were selected as indicators of the propensity to purchase an EV or residential solar PV:

- demographic characteristics
- social values
- vehicle purchase data
- recent completion of a home energy improvement project

These variables were developed using analogous products and services, appropriate demographics and relevant social values. The key variables are described in further detail below.

KEY VARIABLES USED AS INDICATORS OF THE PROPENSITY TO PURCHASE AN ELECTRIC VEHICLE

Demographic Characteristics

Early adopters were assumed to be those who met a set of demographic criteria based on an understanding of the current characteristics of the EV and residential solar PV markets and technologies. These demographic criteria are as follows:

- **Average household size of not less than two people:** Because of the potentially limiting vehicle range, it was assumed that early adopters of EV technology would at least initially see the vehicle as a second, rather than the sole, household vehicle. While EVs easily suit urban transportation needs, longer trips could require a second, conventional gasoline-powered or hybrid vehicle. If the EV were bought as a second vehicle, it was assumed that the current purchase price of an EV would be prohibitive for such purposes for a single household resident.
- **Smaller average household size:** Many EV models currently on the market tend to be small and, therefore, more suitable for small households than for large families. However, consideration was given to the increasing size and range of EV models being introduced as the market evolves.
- **Greater than average household income:** Based on the high purchase price of EVs and residential solar PV at the time the research was done, it was assumed that the household income of early adopters would be high compared to the general population in Calgary and Edmonton. Special consideration was, therefore, given to the types of neighbourhoods with high disposable incomes.

Social Values

Potential early adopters of EV or residential solar PV technology were assumed to be those who exhibited one or more of the following three attitudes:

- **Ecological lifestyle:** This indicator characterizes those individuals who value the integration of environmental concerns with purchasing decisions. Because of the potential environmental benefits and emissions reductions promised by EV and residential solar PV technology, early adopters were assumed to be environmentally conscious.
- **Enthusiasm for technology:** This indicator reflects a favourable bias towards technology. People with an enthusiasm for technology tend to believe that it is the best tool for adapting and responding to the demands of daily life. Because EVs and residential solar PV are not yet part of the mainstream marketplace, early adopters were assumed to have an enthusiasm for technology.

- **Consumptivity:** This indicator represents an enthusiasm for purchasing products or services in an area of particular interest (e.g., music, electronics) about which consumers make an effort to stay informed. Because information about EVs and residential solar PV is not yet widely available in the mainstream media, particularly in Canada where these markets are still small, it was assumed that early adopters of these technologies would have to be particularly enthusiastic or have made an effort to become informed about them.

Vehicle Purchase Data

For the purposes of the market research, EV purchase data, including both new vehicle registrations between January 2012 and June 2013 and total vehicles in operation in 2012, were used to identify early adopters of EV technology. Because EV purchases are low, potential early adopters of EV technology were assumed to share psychographic and demographic characteristics with early adopters of hybrid vehicle technology. Accordingly, hybrid vehicle purchases for the same periods were also used to help estimate potential EV demand.

Home Energy Improvement Projects

Because data related to current residential solar PV ownership are limited, potential early adopters were assumed to share characteristics with those who have a general interest in home energy conservation. As such, survey data related to having completed a home energy conservation project within the past two years were used to help estimate potential demand for residential solar PV.

SECONDARY RESEARCH RESULTS

The variables identified as indicators of the propensity to purchase an EV or residential solar PV were used to create profiles that were compared with the PRIZM$_{c2}$ system to identify a set of early adopter target segments. This section documents the findings from the secondary research, including a description of the target segments and their distribution in Calgary and Edmonton.

Target Segments

Twelve psychographic segments of the Calgary and Edmonton population were identified based on the selected demographics, social values and vehicle purchasing data. These segments include the types of individuals and households considered the most likely to be early adopters of EV and residential solar PV technology in Calgary and Edmonton.

The following are the twelve segments selected:

Cosmopolitan Elite: This group represents Canada's wealthiest people, including new-money entrepreneurs and heirs to old-money fortunes. The Cosmopolitan Elite are urban, middle-aged families and older couples. With household incomes five times the national average, this segment is concentrated in only a handful of established neighbourhoods throughout the country.

Urbane Villagers: Located in Canada's largest urban centres, this segment is a prosperous world of stately homes and high-end cars, charity auctions and golf club memberships. The nation's second wealthiest segment, it is characterized by married couples with university degrees and university-aged children, and includes a significant percentage of European, Asian and Middle Eastern immigrants.

Suburban Gentry: This segment is made up of Canada's up-and-coming business class, with a high percentage of managers, scientists, government workers, and other professionals. Suburban Gentry residents rank near the top for operating a small business, owning business software and taking business trips. They include dual-income couples with university degrees and large families, are big spenders, particularly on entertainment, and take pride in their healthy lifestyle.

Young Digerati: This segment consists of the nation's tech-savvy singles and couples living in fashionable neighbourhoods in a handful of big cities. Affluent, highly educated and ethnically mixed, Young Digerati communities are typically filled with high-rise apartments and expensive condos located near fitness clubs, clothing boutiques and bars. Because many residents in this segment have yet to start families, they have the time and discretionary income to pursue active social lives.

Winner's Circle: This segment is made up of large families living in bedroom communities and a few metropolitan areas in Canada. The average household income for this group is high and while they express concerns about saving enough money for the future, they don't mind spending. Winner's Circle residents live in newer homes surrounded by recreational parks, ball fields, golf courses and malls filled with big-box stores.

Money & Brains: The residents in this segment have high incomes, advanced degrees and sophisticated tastes. Many of them are empty nesters or married couples with university-aged children, who live in older, fashionable homes in both urban and suburban neighbourhoods.

Mr. & Ms. Manager: Made up of working couples, this segment has one of the highest dual-income rates in Canada. It includes prosperous executives living in the exurban sprawl beyond the nation's largest cities. Mr. & Ms. Manager typically commute by car to nearby cities but enjoy the lifestyle offered by their exurban settings. They own impressive collections of sporting equipment, prefer to camp over seeing the opera and drive pickup trucks rather than sedans.

Pets & PCs: Scattered around Canada's larger cities, this group is made up of younger, multi-ethnic families with pre-school-aged children. Residing primarily in single-family homes and row house subdivisions, Pets & PCs lead active, child-centred lives, including participation in team sports and visiting kid-friendly destinations.

Upward Bound: This segment consists of upper-middle-class homeowners, including couples, those with older children and large families. With almost equal numbers of university and high school graduates, this segment includes white-collar and service workers primarily in business, management and sales. The Upward Bound like to go to home shows, casual dining restaurants, and Canadian parks to hike and camp.

Electric Avenues: This group represents young singles and couples pursuing lively urban lifestyles. Concentrated in Canada's largest urban centres, these older, crowded neighbourhoods are known as havens for university graduates who rent apartments, have mid-level jobs and enjoy active leisure lives. While residents here have above-average household incomes, their spending power appears even greater because many of these households are childless.

Exurban Crossroads: This segment is made up primarily of younger, middle-class households with many children, living in small cities and satellite towns. The highest level of education for those in this segment ranges from high school to community college, and most residents have parlayed well-paying blue-collar and service sector jobs into average incomes and outdoorsy lifestyles. Exurban Crossroads tend to be skeptical about big business and unconcerned about status recognition.

Grads & Pads: This segment is made up of young, ethnically diverse city dwellers living near universities. Grads & Pads include well-educated singles, couples, students, recent graduates, professionals and service workers just entering the workforce. They enjoy keeping active and are politically active, working for social causes and volunteering for political parties that support their liberal views.

Geographic Distribution

Two maps were created, indicating the geographic distribution of each of the twelve target segments in Calgary and Edmonton, respectively, based on postal codes (see Figures 2 and 3). Each area identified on these neighbourhood maps represents a postal code area of potential early adopters, providing a visual representation of where they may be clustered throughout the two cities (the size of each area is determined by the boundaries of the postal code and is not a representation of the concentration of potential early adopters). These areas became the focus of the primary research described below.

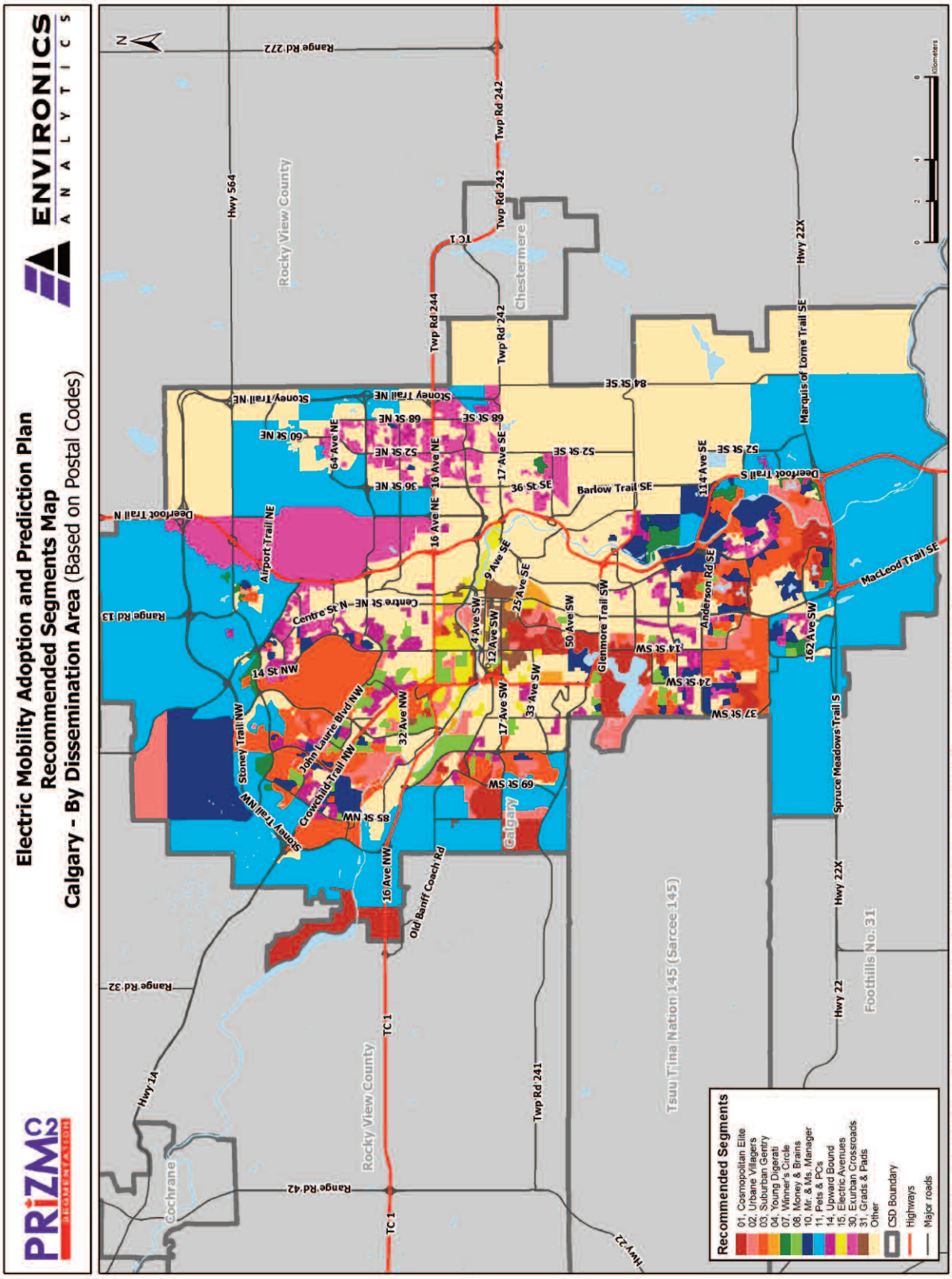
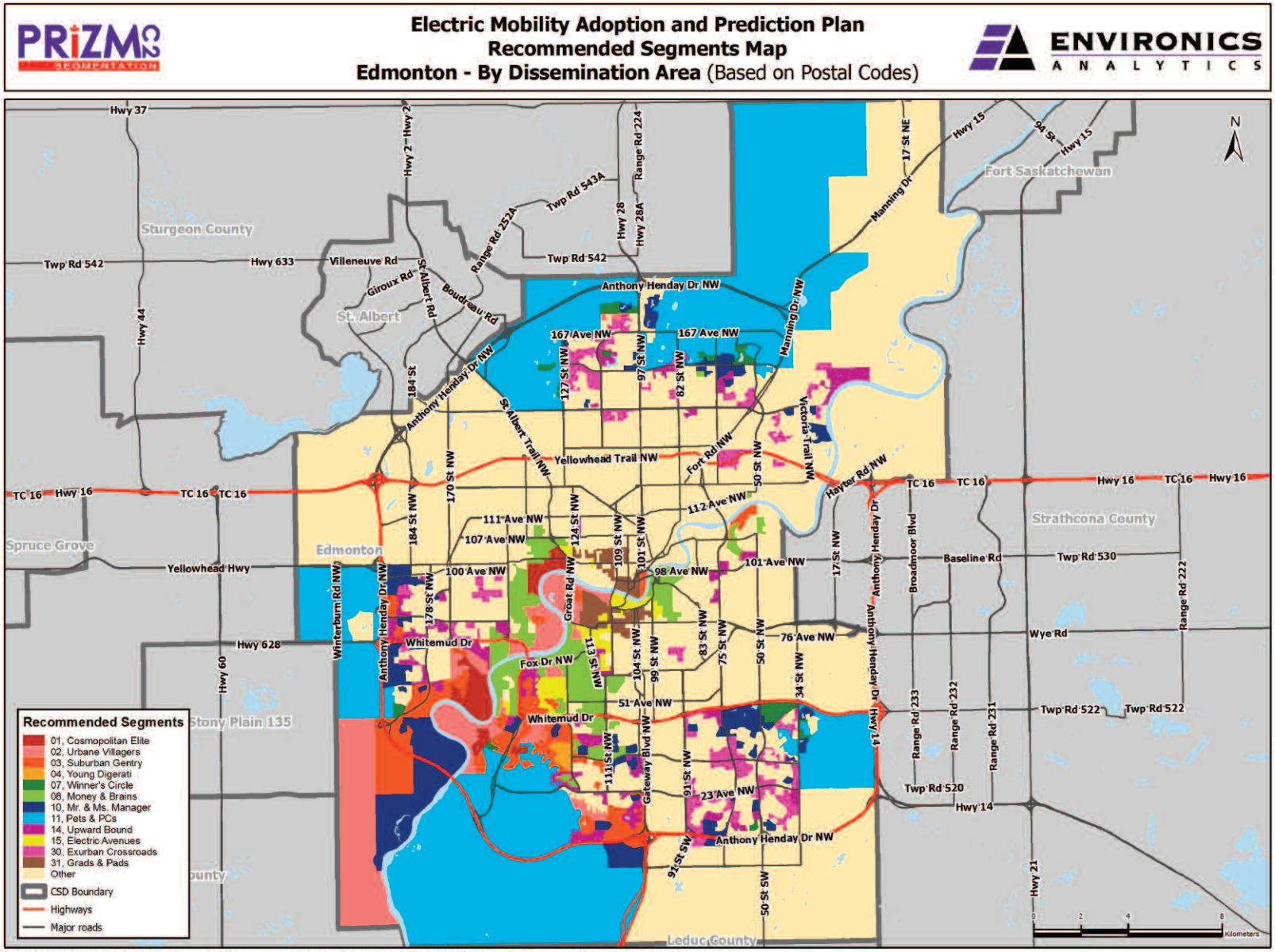


Figure 2: Distribution of Target Segments in the City of Calgary

Note: CSD – Census subdivision.

Figure 3: Distribution of Target Segments in the City of Edmonton



Note: CSD – Census subdivision.

Primary Research to Validate and Characterize Early Adopter Neighbourhoods

In addition to estimating the demand for EVs and residential solar PV in Calgary and Edmonton using PRIZM$_{c2}$-based tools, the secondary research informed the primary research that followed. A questionnaire was designed for use in a household telephone survey conducted by Environics Research Group. The survey was conducted in key locations containing high proportions of segments with behavioural and attitudinal characteristics linked to the early adoption of EV and residential solar PV technology. A total of 750 Calgary and Edmonton residents participated in the survey, which took place between August 20, 2014 and September 20, 2014 and averaged approximately 15 minutes in length. The use of a telephone survey rather than an online survey allowed for a targeted focus on residents in the geographic areas identified; it would have been difficult to screen for this online. In addition, the telephone survey allowed for a greater opportunity to test scenarios with survey respondents to build an understanding of how best to position EVs and residential solar PV in an enablement strategy.

Respondents were screened to ensure that they were licensed drivers, aged 18 or over, and involved in household vehicle purchase decisions. They also had to have bought or leased a 2011 or newer vehicle within the past three years or be intending to buy or lease a late-model vehicle in the following three years. Respondents who met these criteria were deemed to have an understanding of or experience with the factors contributing to purchasing decisions for a new vehicle.

The household survey was designed to gain insight into motivations for and interest in EV and residential solar PV use, the personal mobility patterns of the respondent, and the barriers to address and opportunities to leverage in relation to EV and residential solar PV use. The survey was divided into the following four sections:

- profile of the early adopter
- awareness and perceptions of EVs
- awareness and perceptions of residential solar PV
- market segmentation and respondent profile

KEY FINDINGS FROM THE PRIMARY RESEARCH

This section presents key findings and insights from the household telephone survey. It begins with a profile of potential early adopters and is followed by a discussion of their awareness and perceptions of EV and residential solar PV technology.

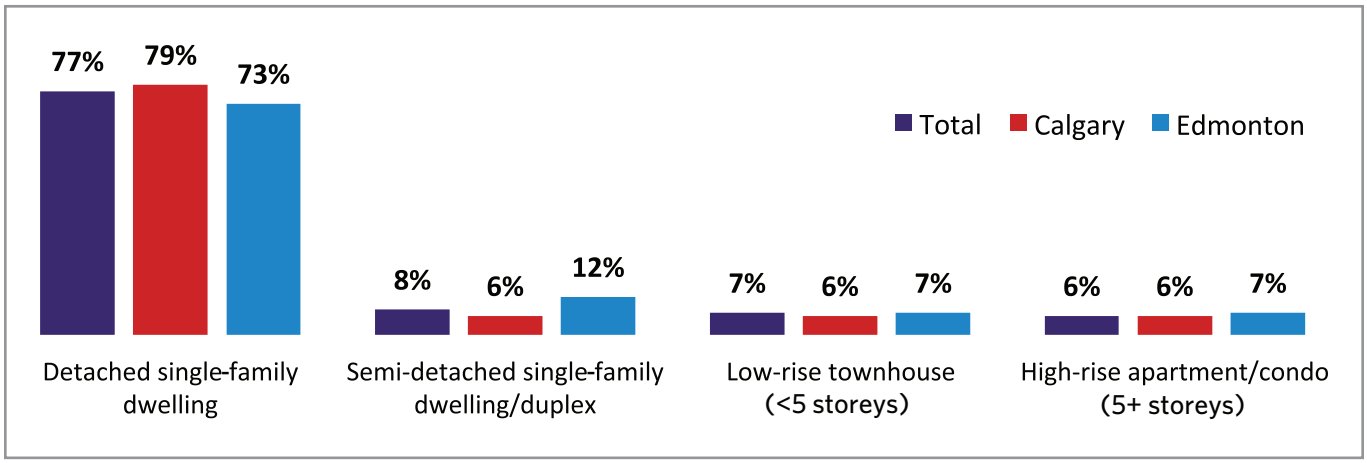
Profile of the Potential Early Adopter

Demographic Profile

Potential early adopters are older, better educated and more affluent than the general population. The majority live in detached, single-family homes.

Potential early adopters are considerably more likely to be over the age of 45 than the general adult population in Calgary and Edmonton. They are better educated, with more than half of those surveyed holding a university degree (bachelor or post-graduate), compared to only 35 per cent of the general population in Calgary and 26 per cent of the general population in Edmonton. Potential early adopters are nearly twice as likely as the average resident of the two cities to have a household income of $150,000 or more, and a strong majority live in detached single-family homes.

Figure 4: Dwelling Type



Vehicle Purchasing Preferences

Personal experience with an EV is linked to greater interest in owning one.

Personal experience with EVs is limited among the 750 participants in the household telephone survey. Only 7 per cent own or have driven one, while 19 per cent reported knowing someone who owns or drives one, and another 19 per cent have been a passenger in one. A strong majority (72 per cent) have not had any of these experiences with EVs. Those with personal experience with an EV were more likely than those without to indicate that they would either likely or definitely consider the purchase of an EV in the near future. Personal experience with and exposure to EVs is likely to increase and, as it does, it is expected that interest in purchasing them will likely also increase.

Figure 5: Experience with an Electric Vehicle

Experience with electric vehicles in terms of	(n=750) %
Owning or driving one	7
Knowing someone who owns/drives one	19
Riding in one as a passenger	19
None of the above	72

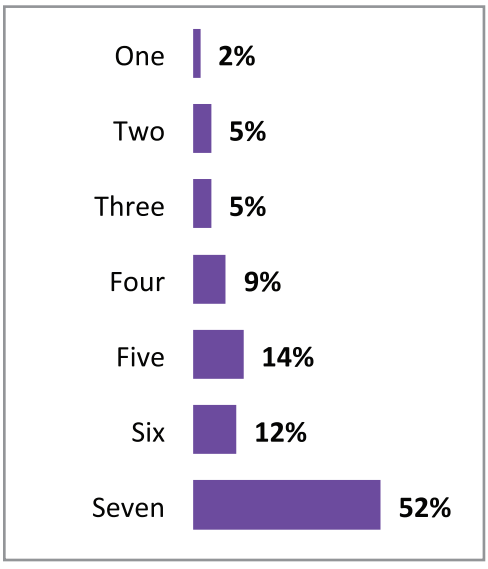
Note: Adds up to more than 100% due to multiple mentions

Personal Mobility Patterns

Around half of all potential early adopters use their vehicles every day.

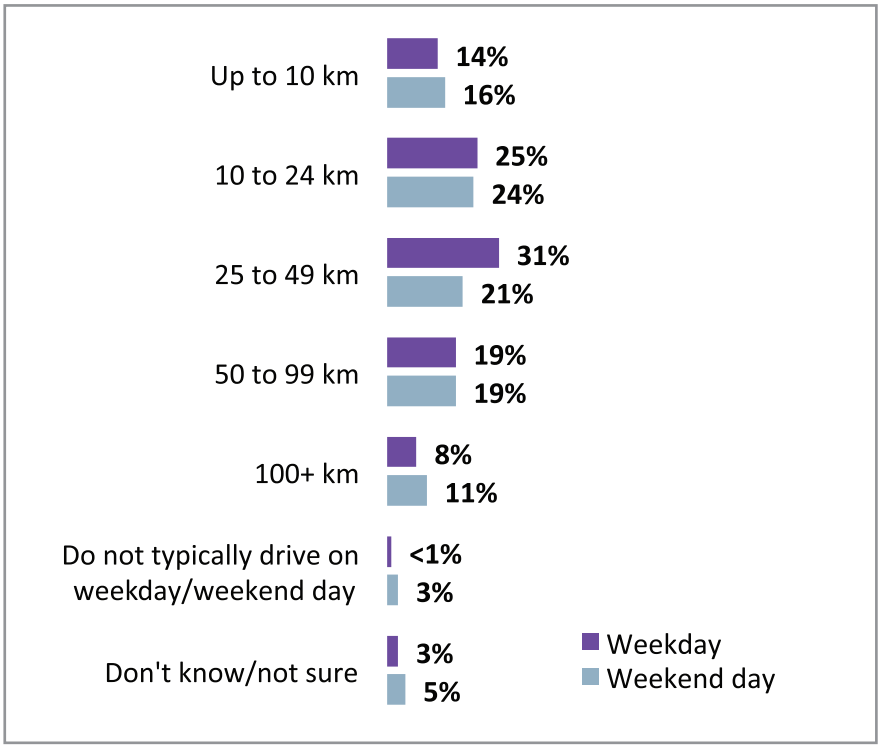
Just over half of potential early adopters (52 per cent) in both Calgary and Edmonton indicated that they use their vehicles seven days a week. Driving every day increases proportionally with the distance driven on a typical weekday. It is also higher among those with higher levels of education and income. Driving seven days a week, however, does not appear to have any relationship to the level of interest in purchasing an EV in the next couple of years.

Figure 6: Number of Days in a Week Potential Early Adopters Typically Use Their Vehicles



Around six in ten potential early adopters (58 per cent) travel more than 25 kilometres on a typical weekday, while 51 per cent drive the same distance on a typical weekend day. Driving 50 kilometres or more during the week or on the weekends was highest among those who would definitely not consider purchasing an EV.

Figure 7: Kilometres/Day Typically Driven



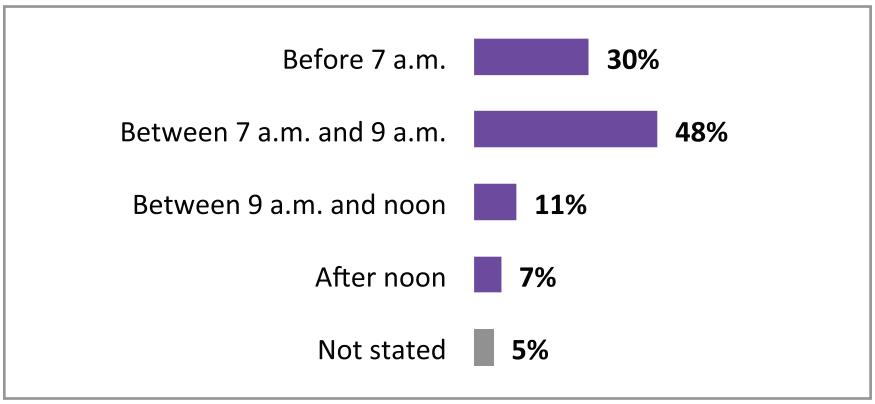
Just over half of potential early adopters are considered vehicle commuters.

Just over half of potential early adopters (53 per cent) in Calgary and Edmonton said that there is a specific location that they typically drive to at least three days per week and where they leave their vehicle for three or more hours (the selected proxy for vehicle commuting). Vehicle commuting increases with household income and is highest among those with incomes of $150,000 or more. Vehicle commuting is associated with those under the age of 60, households with two or more vehicles and with driving 25 km or more on a typical weekday.

Half of vehicle commuters leave home between 7 a.m. and 9 a.m., and the majority return home between 2 p.m. and 7 p.m.

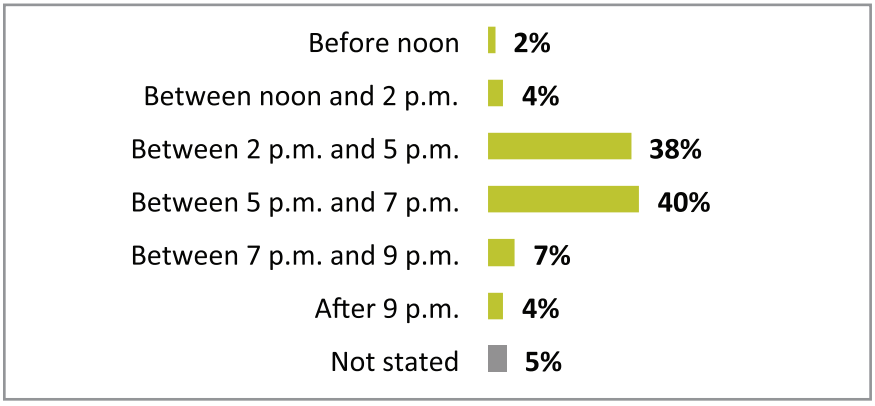
Most vehicle commuters described a typical workday as one on which they leave home before 7 a.m. (30%) or between 7 a.m. and 9 a.m. (48 per cent) and return home between 2 p.m. and 5 p.m. (38 per cent) or between 5 p.m. and 7 p.m. (40 per cent). The proportion of vehicle commuters who indicated that they leave home before 7 a.m. is higher among those in Calgary while leaving home after 9 a.m. is higher among drivers in Edmonton.

Figure 8: Time of Day When Vehicle Commuters Typically Leave Home



Subsample: Those who leave their vehicle at a specific location at least 3 days per week for at least 3 hours (N=380)

Figure 9: Time of Day When Vehicle Commuters Typically Arrive Home



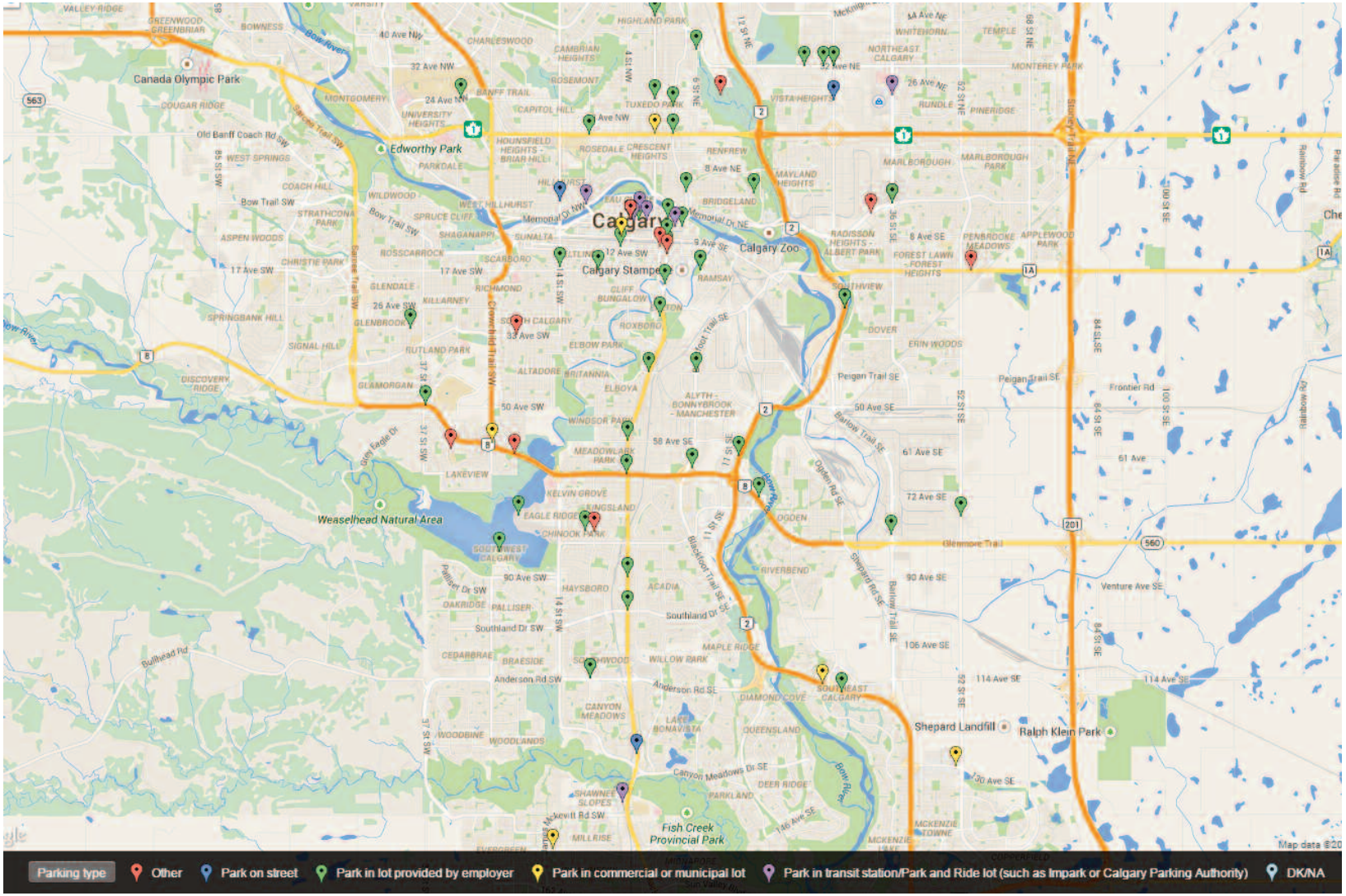
Subsample: Those who leave their vehicle at a specific location at least 3 days per week for at least 3 hours (N=380)

The majority of vehicle commuters park in an employer-provided lot

When asked which of several options describes their typical parking arrangements at the location where they park at least three days per week, a strong majority of vehicle commuters indicated that they park in an employer-provided lot. Potential early adopters in Edmonton were more likely than those in Calgary to say that they park in an employer-provided lot while a greater number of those who said that they park in a transit lot were from Calgary.

When asked to name the major intersection nearest the location where they typically leave their vehicle, vehicle commuters reported locations throughout the two cities surveyed. Many of the vehicle commuters reported that they commute downtown in the two cities. See Figures 10 and 11.

Figure 10: Vehicle Commuter Parking Locations in the City of Calgary by Lot Type



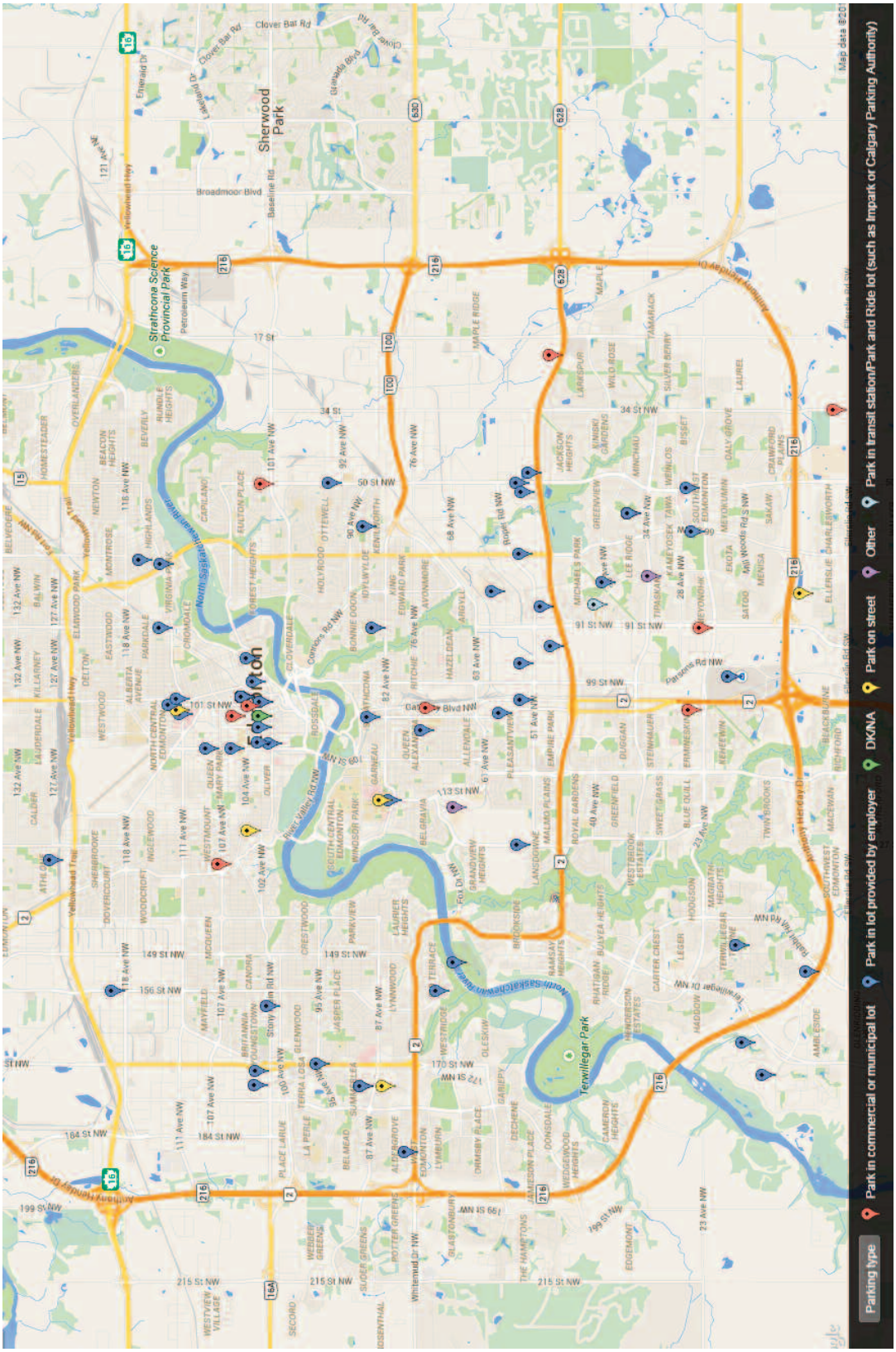


Figure 11: Vehicle Commuter Parking Locations in the City of Edmonton by Lot Type

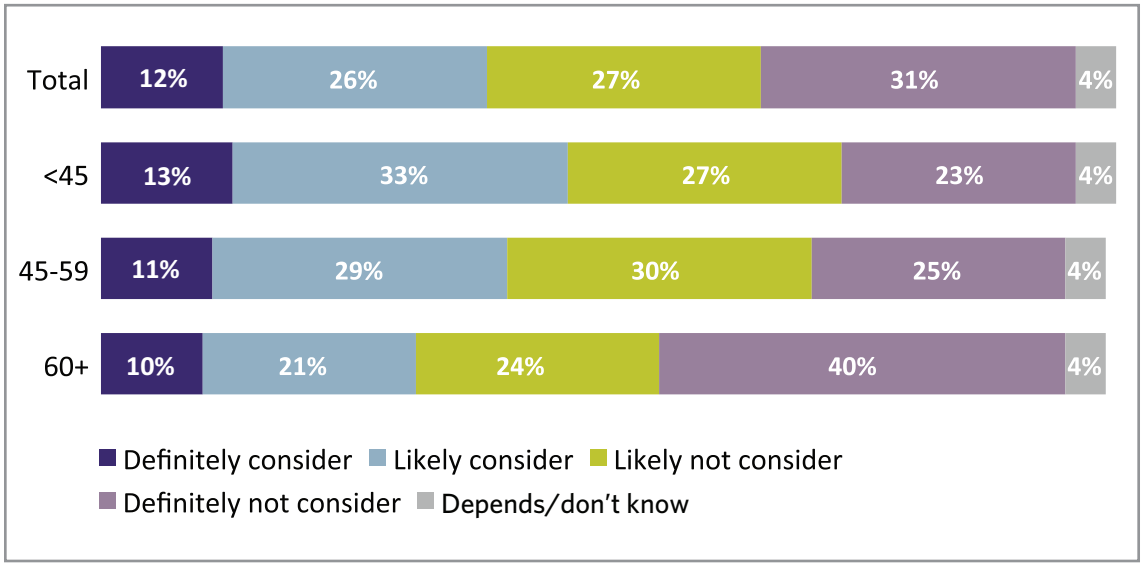
Awareness and Perceptions of Electric Vehicles

Likelihood of Considering an Electric Vehicle

Around four in ten potential early adopters would consider purchasing an EV in the next couple of years.

Only 38 per cent of potential early adopters said that they would likely (26 per cent) or definitely (12 per cent) consider an EV if they were purchasing or leasing a vehicle in the next couple of years. A majority of 58 per cent felt that they would likely not (27 per cent) or definitely not (31 per cent) consider an EV within the next two years. Age is an important factor in the potential purchase of an EV, with the likelihood of considering one lowest among those aged 60 and older (32 per cent versus 43 per cent of younger drivers). There is little difference between the number of early adopters likely to purchase an EV in Calgary (11 per cent) versus Edmonton (13 per cent). As previously noted, some experience with an EV is higher among those who would likely or definitely consider purchasing one in the next couple of years.

Figure 12: Likelihood by Age of Considering an Electric Vehicle in the Next Couple of Years



Relative Strength of Interest in Acquiring an EV

Each of the twelve early adopter segments was cross-referenced with the number of "definitely consider" responses about a potential EV purchase and rated according to strong, moderate or weak interest. The original segment maps were then recalibrated to reflect the relative strength of interest in acquiring an EV. The recalibrated maps (see Figures 13 and 14) identify the areas in Calgary and Edmonton where the adoption of EVs will likely take place.

Figure 13: Strength of Interest in Purchasing an Electric Vehicle by Dissemination Area in the City of Calgary

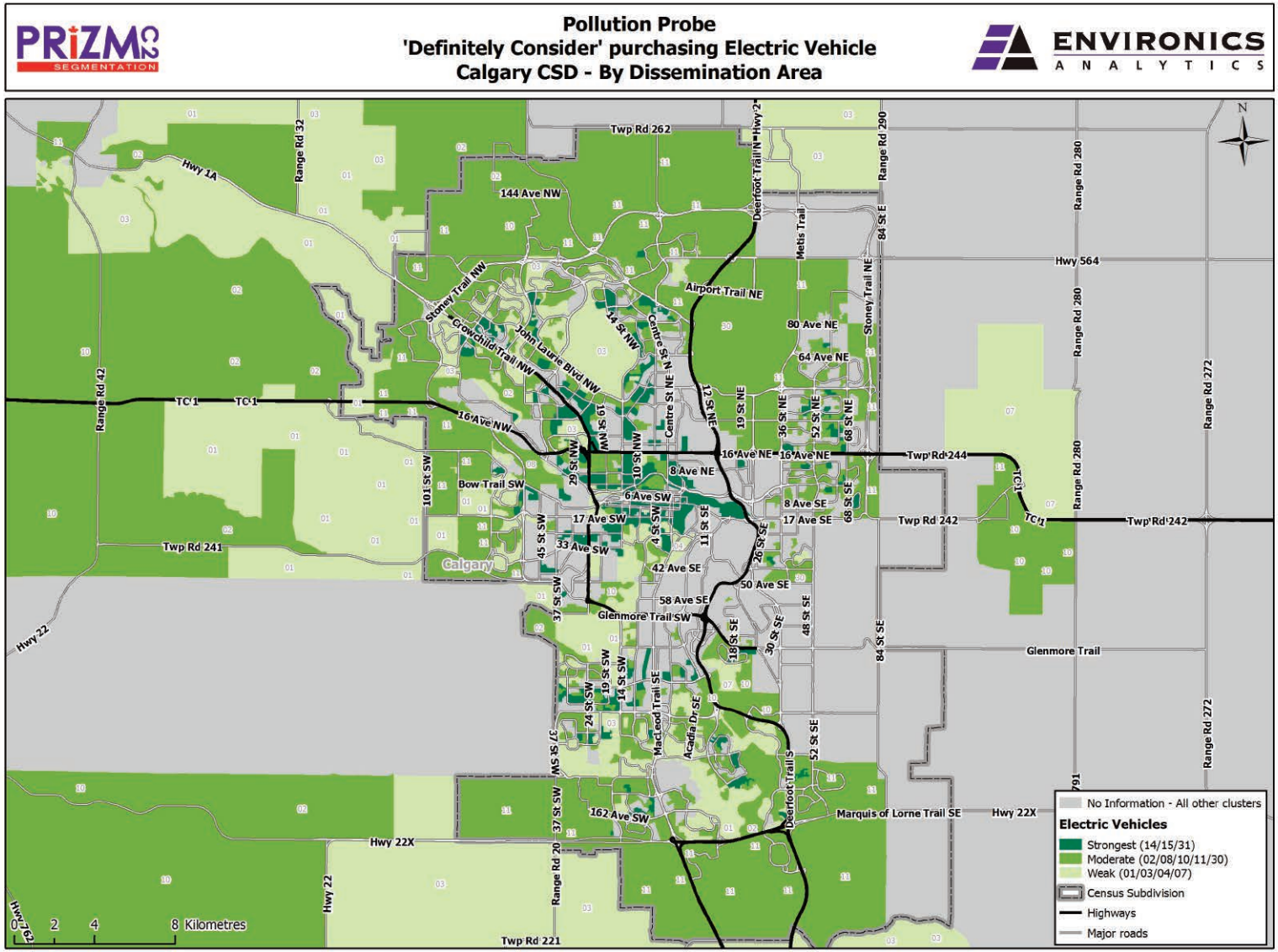
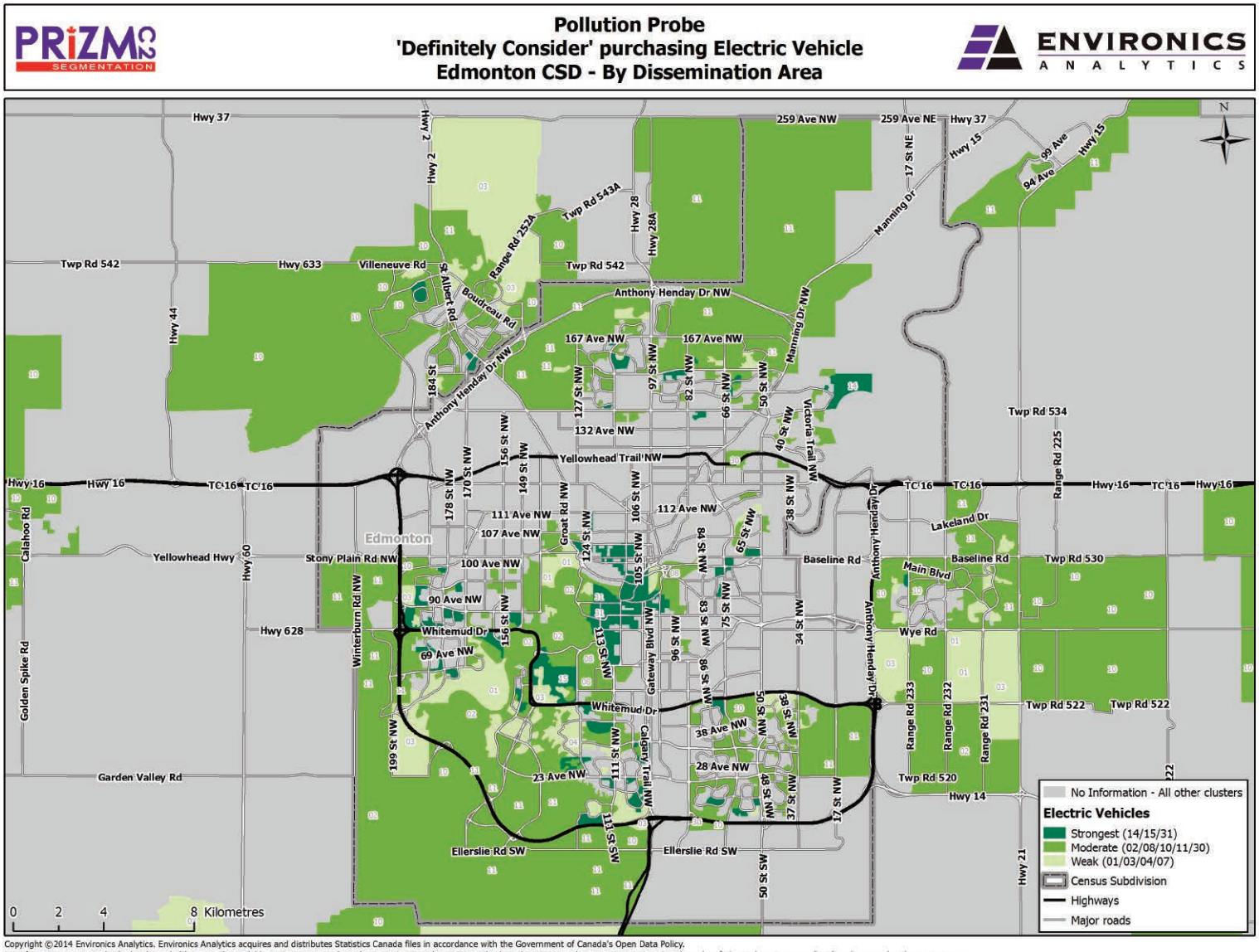


Figure 14: Strength of Interest in Purchasing an Electric Vehicle by Dissemination Area in the City of Edmonton

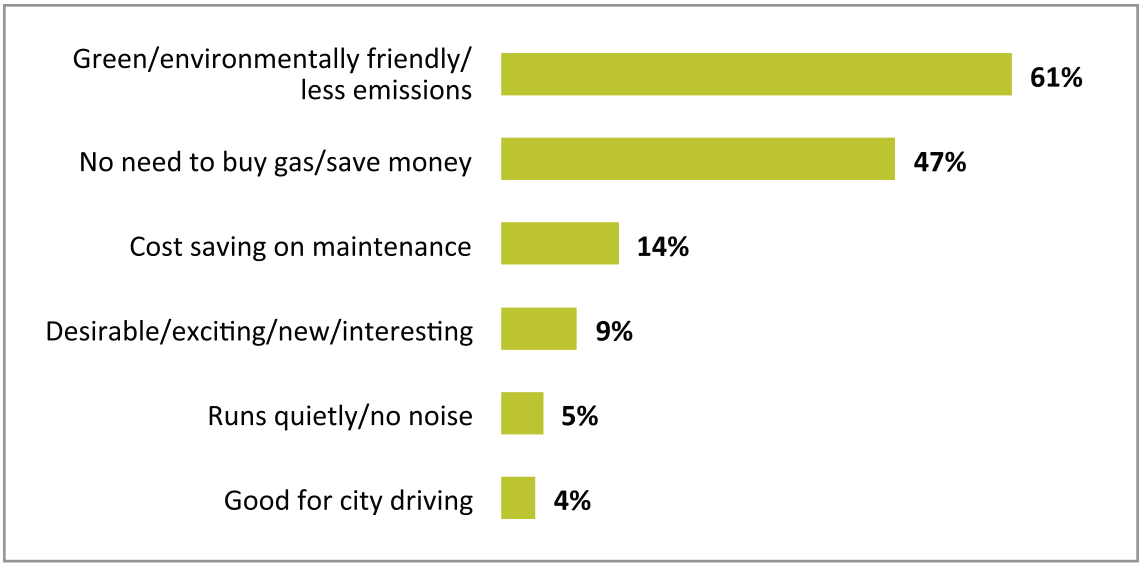


Perceived Barriers and Opportunities

Potential environmental benefits are the most mentioned advantage of EVs. Purchase price and limited range are the most mentioned barriers.

Close to two-thirds (61 per cent) of those who would likely or definitely consider purchasing an EV mention that the main advantages of the vehicle are the potential environmental benefits and the opportunity to reduce vehicle emissions. Forty-seven per cent mention not having to purchase gas and 14 per cent note the cost savings related to vehicle maintenance. A smaller number report an interest in EVs as an emerging technology, the quiet ride or the suitability of the vehicle for city driving.

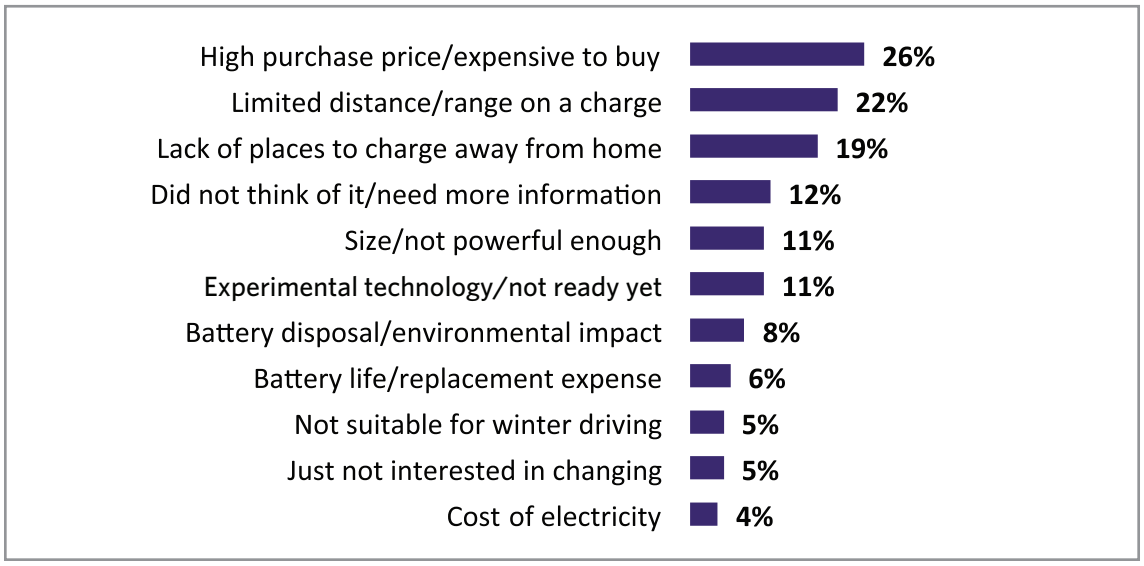
Figure 15: Top Reasons for Considering an Electric Vehicle



Subsample: Would definitely/likely consider an EV (N=279)

One quarter of those who indicated that they would definitely not or likely not consider an EV felt that the most important reason for not doing so was the high purchase price of the vehicle. A further 22 per cent mentioned the potentially limiting range of the vehicle, and 19 per cent noted a lack of charging locations away from home as a barrier. Twelve per cent felt that they needed more information about EVs, while equal numbers had concerns about the size and power of the vehicle (11 per cent) or whether the technology was ready (11 per cent). Smaller numbers mentioned concerns about environmental impacts such as battery disposal, battery life and replacement costs, suitability for winter driving or the cost of electricity as additional barriers to adoption; some indicated that they were simply not interested in changing. Potential early adopters in Calgary were slightly more likely than those in Edmonton to identify the high purchase price of the vehicle as the most important reason for not considering an EV.

Figure 16: Top Reasons for Not Considering an Electric Vehicle

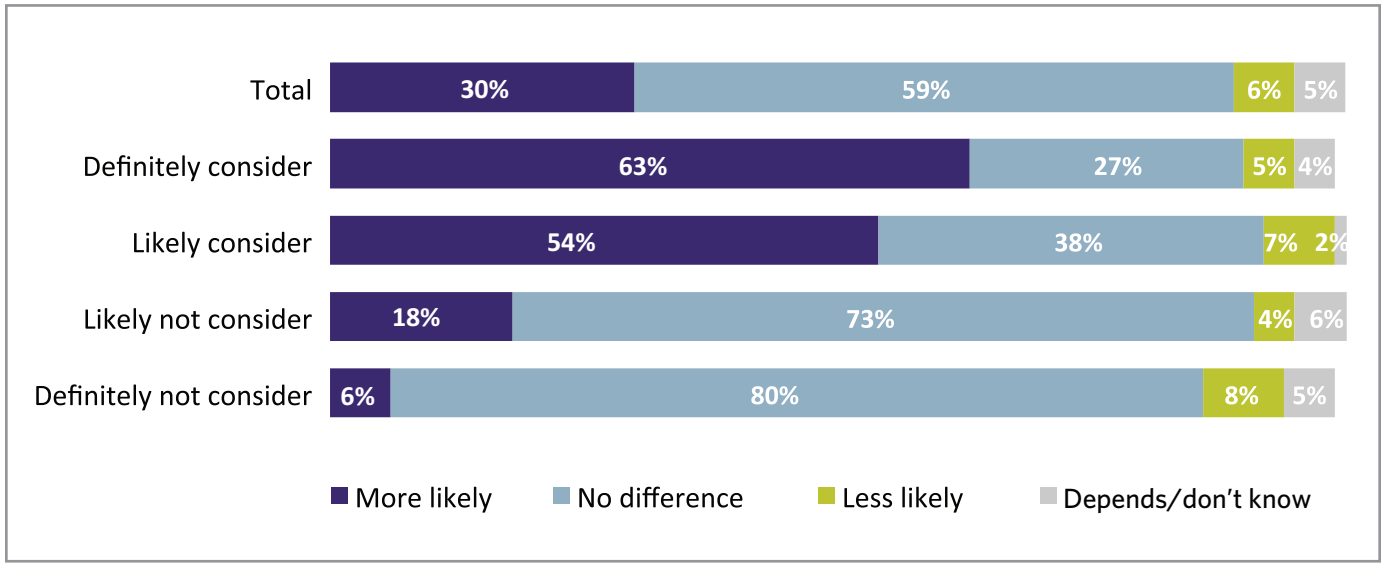


Subsample: Would definitely not/likely not consider an EV (N=436)

Three in ten potential early adopters are more likely to consider purchasing an EV when informed that operating costs are one-sixth that of a conventional gasoline-powered vehicle.

When informed that, although the initial purchase price for an EV may be higher, the cost of operating one is about one-sixth that of operating a conventional, gasoline-powered vehicle, 30 per cent of potential early adopters felt that they would be more likely to consider purchasing an EV. This increase in likelihood is highest among those who indicated an interest in considering an EV in the next couple of years. While another 59 per cent said that this information would make no difference in their decision, 6 per cent said that they would, in fact, be less inclined to purchase an EV.

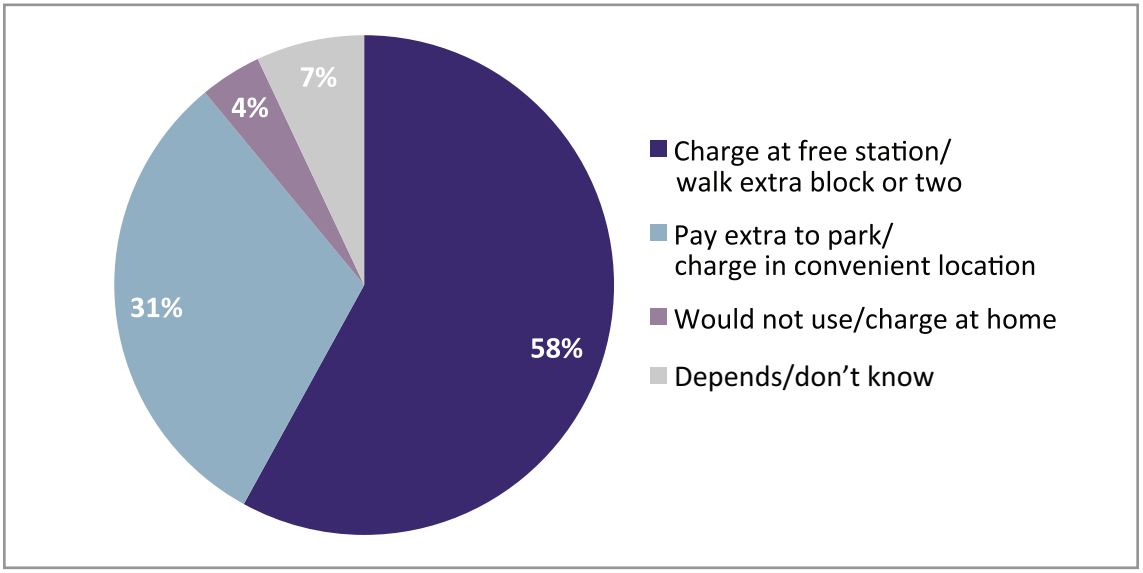
Figure 17: Impact of Operating Cost on Likelihood of Purchasing an Electric Vehicle



Potential early adopters are more concerned about price than convenience when it comes to parking an EV.

Potential early adopters who would at least marginally consider purchasing an EV were asked whether they would prefer to park in a spot with free EV charging and have to walk an extra block or two to their destination or to park at a more convenient location where they would have to pay to charge their vehicle. The majority indicated that they would prefer to charge at a free parking spot and walk to their destination, rather than having to pay for a more convenient location.

Figure 18: Preferred Public Parking Scenario

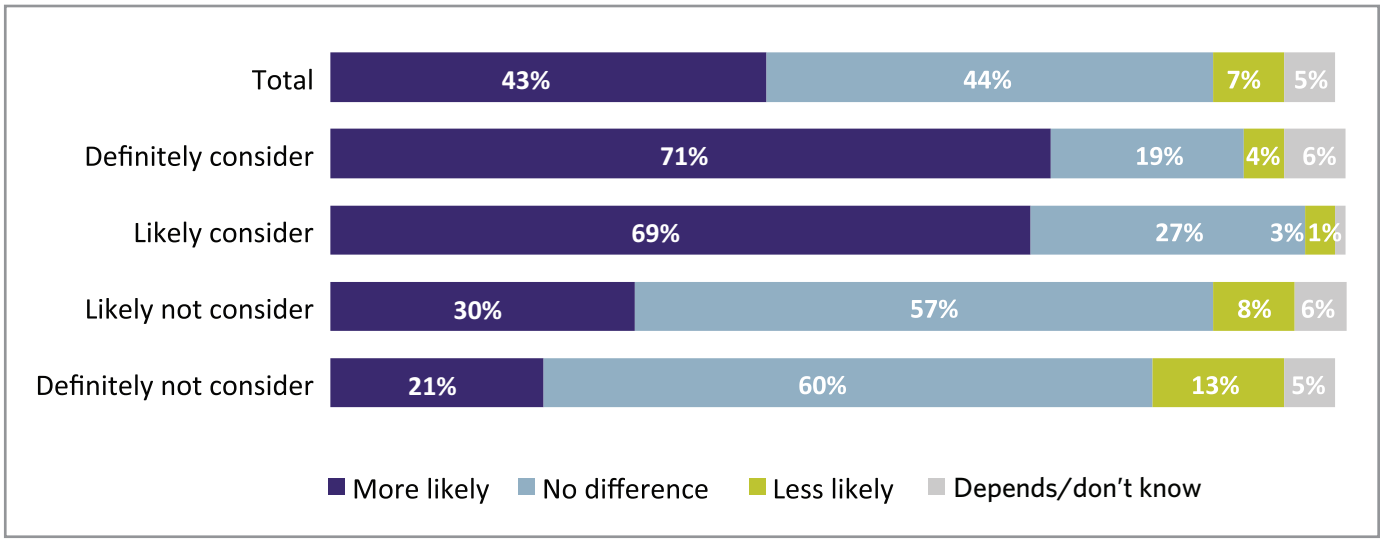


Subsample: Would definitely/likely/likely not consider an EV (N=518)

More than four in ten potential early adopters would be more inclined to purchase an EV if solar-powered charging stations were publicly available.

More than four in ten potential early adopters (44 per cent) would be more interested in purchasing an EV if solar-powered charging stations were publicly available in Calgary and Edmonton. Another 43 per cent felt that it would make no difference to their level of interest, and 7 per cent indicated that the availability of public, solar-powered charging stations would, in fact, make them less inclined to purchase an EV. While an increase in interest is highest among those early adopters who mentioned an interest in purchasing an EV, two in ten of those who would definitely not consider an EV said that availability of public, solar-powered charging stations would make them more inclined to do so.

Figure 19: Impact of Availability of Solar-Powered Charging Stations on the Likelihood of Purchasing an Electric Vehicle



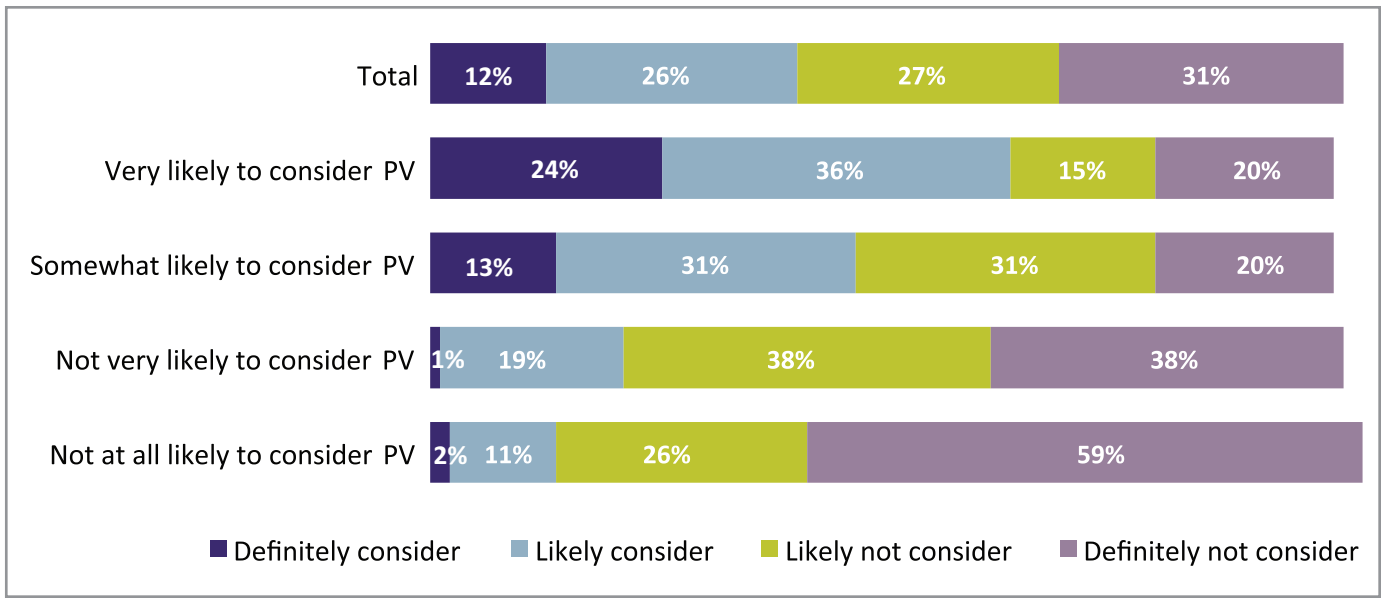
Awareness and Perceptions of Residential Solar Photovoltaic Systems

Likelihood of Considering a Residential Solar Photovoltaic System

Interest in purchasing residential solar PV is linked to interest in purchasing an EV in the next couple of years, and vice versa.

The likelihood of considering the purchase of residential solar PV is linked to interest in purchasing an EV in the next couple of years. More than half of potential early adopters who indicated that they would be very likely to consider purchasing residential solar PV also said that they would definitely consider (24 per cent) or likely consider (36 per cent) an EV. Another 44 per cent of those who said that they would be somewhat likely to consider residential solar PV would definitely (13 per cent) or likely (31 per cent) consider an EV. This finding is important when the potential role for residential solar PV in powering residential EV charging stations is being considered.

Figure 20: Likelihood of Considering an EV in the Next Couple of Years by Likelihood of Considering a Residential Solar Photovoltaic System

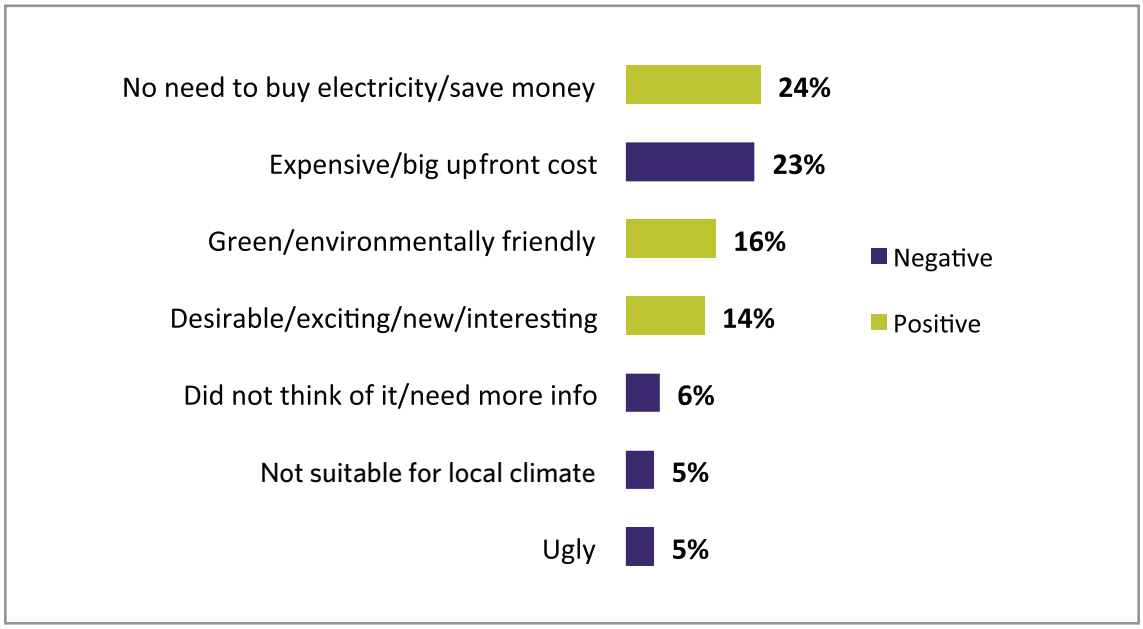


Perceived Barriers and Opportunities

Potential early adopter impressions of residential solar PV reflect both barriers and opportunities.

When asked to provide top-of-mind impressions of residential solar PV, potential early adopters gave a range of responses, covering both the advantages and the disadvantages. The most common positive responses were the potential to save on the cost of electricity (24 per cent), the green or environmentally friendly potential of residential solar PV (16 per cent) and excitement about a new and interesting technology (14 per cent). A smaller number of responses were negative, identifying barriers such as the high purchase price (23 per cent), the need for more information about the technology (6 per cent), its unsuitability for the local climate (5 per cent) or the ugliness of residential solar PV installations (5 per cent).

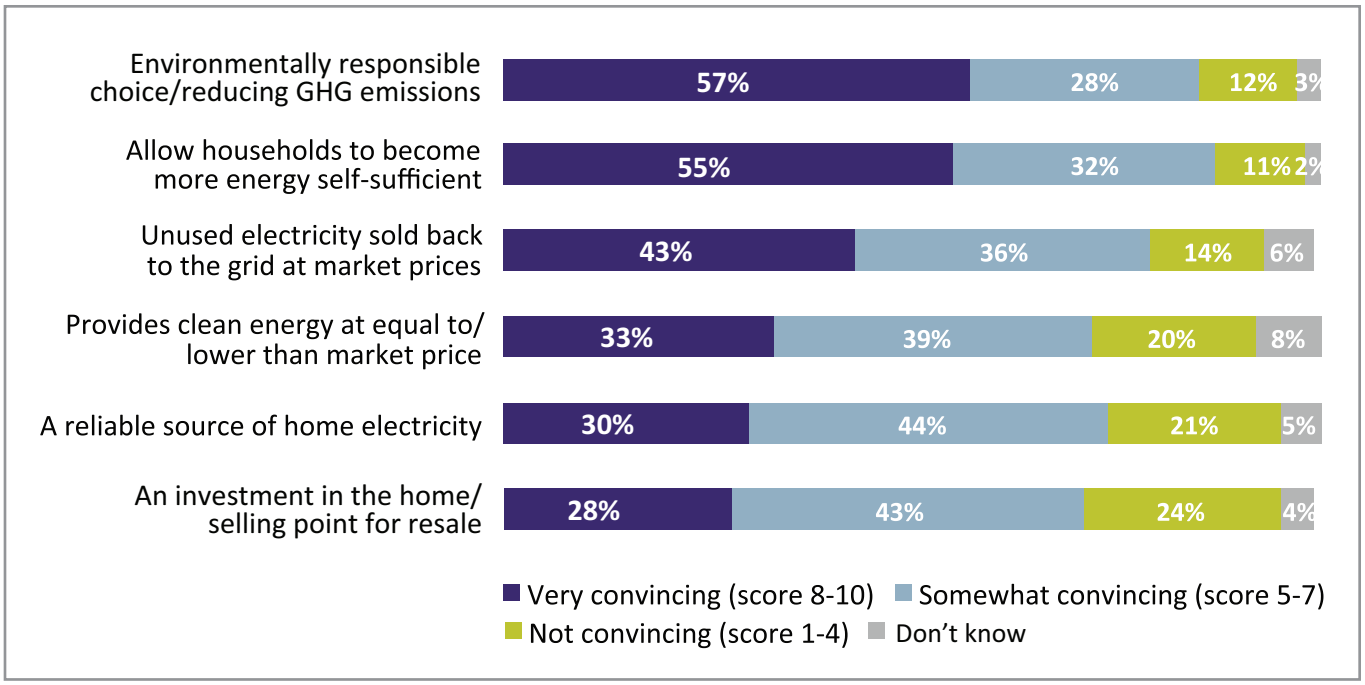
Figure 21: Most Mentioned Top-of-Mind Impressions of Residential Solar Photovoltaic Systems



Potential early adopters feel that statements related to environmental friendliness hold the most potential for influencing the decision to purchase residential solar PV.

Potential early adopters were asked to rank several statements on a scale of 1 to 10 in terms of how convincing they would be in influencing the purchase of residential solar PV. The statement considered to be most convincing reflects the environmentally friendly potential of the technology to help reduce GHG emissions (57 per cent). Potential early adopters also indicated that statements related to enabling households to become more energy self-sufficient (55 per cent) and to sell unused electricity back to the grid at market prices (43 per cent) would be very convincing in terms of influencing the decision to purchase residential solar PV. Potential early adopters in Edmonton were more likely than those in Calgary to say that all six of the statements about residential solar PV would be very convincing.

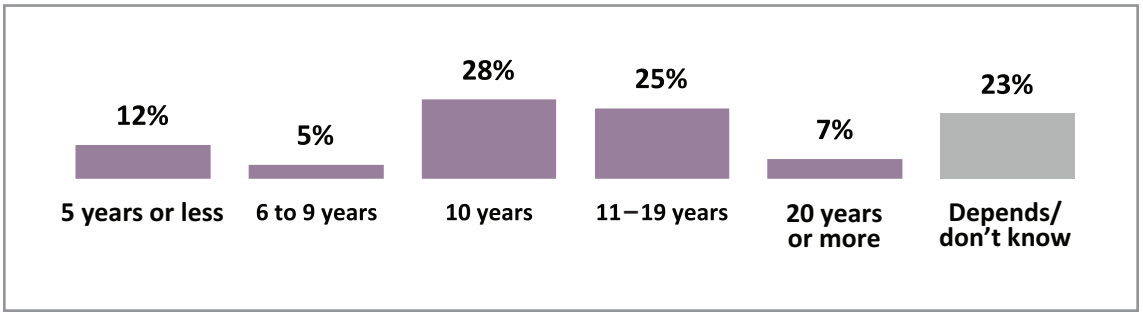
Figure 22: Impact of Statements on Consideration of a Residential Solar Photovoltaic System Purchase



Potential early adopters think that it would be reasonable for it to take 10 years for residential solar PV to pay for itself.

A range of opinions were expressed when potential early adopters were asked how many years it would be reasonable for it to take to break even on an investment in residential solar PV, assuming a guaranteed lifespan of 25 years for the system. Forty-five per cent think that it should take less than 11 years, with the most common response being 10 years. Those who said that they were likely to consider purchasing residential solar PV are somewhat more likely to accept a longer payback period than those who would likely not consider one.

Figure 23: Acceptable Length of Time for a Residential Solar Photovoltaic System to Pay for Itself

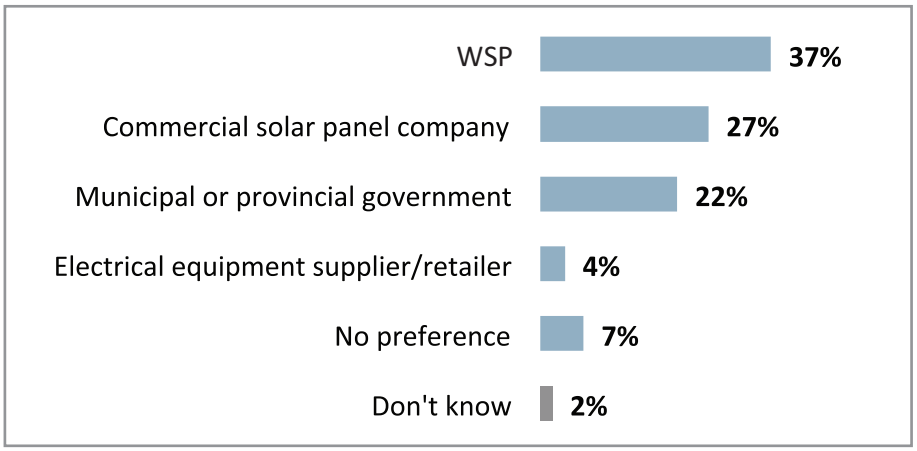


Subsample: Excluding those who are unable to install residential solar PV or who already have it (N=731)

Most potential early adopters would prefer the WSP to install and maintain residential solar PV.

Those who were very or somewhat likely to consider purchasing residential solar PV were asked which of four service providers they would prefer to have install and maintain it. More than one-third (37 per cent) said that they would prefer this to be done by the WSP, while 27 per cent would prefer a commercial solar panel company and 22 per cent would prefer the government to act as the primary service provider. Only 4 per cent mentioned an electrical equipment supplier or retailer. Potential early adopters in Calgary were slightly more likely than those in Edmonton to say that the WSP would be their preferred service provider.

Figure 24: Preferred Service Provider for Installing and Maintaining a Residential Solar Photovoltaic System



Subsample: Very/somewhat likely to consider purchasing residential solar PV (N=468)

Validation of Preliminary Assumptions

Potential early adopters who said that they would definitely consider an EV or residential solar PV expressed greater agreement with statements about ecological consciousness, interest in technology and consumptivity than those less likely to consider an EV or residential solar PV. This helps to validate the initial assumptions and criteria used to profile early adopters during the secondary research. In particular, potential early adopters felt strongly about their interest in technology and ecological consciousness.

Figure 25: Responses to the Statement "I am excited about the possibilities presented by new technologies" by Likelihood of Considering an EV in the Next Two Years

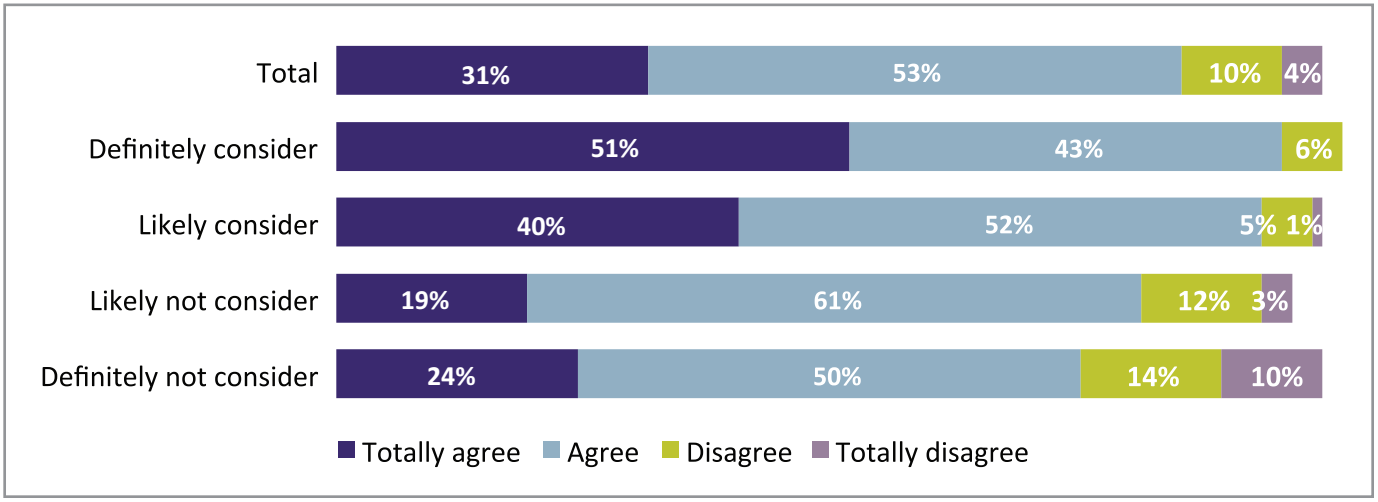
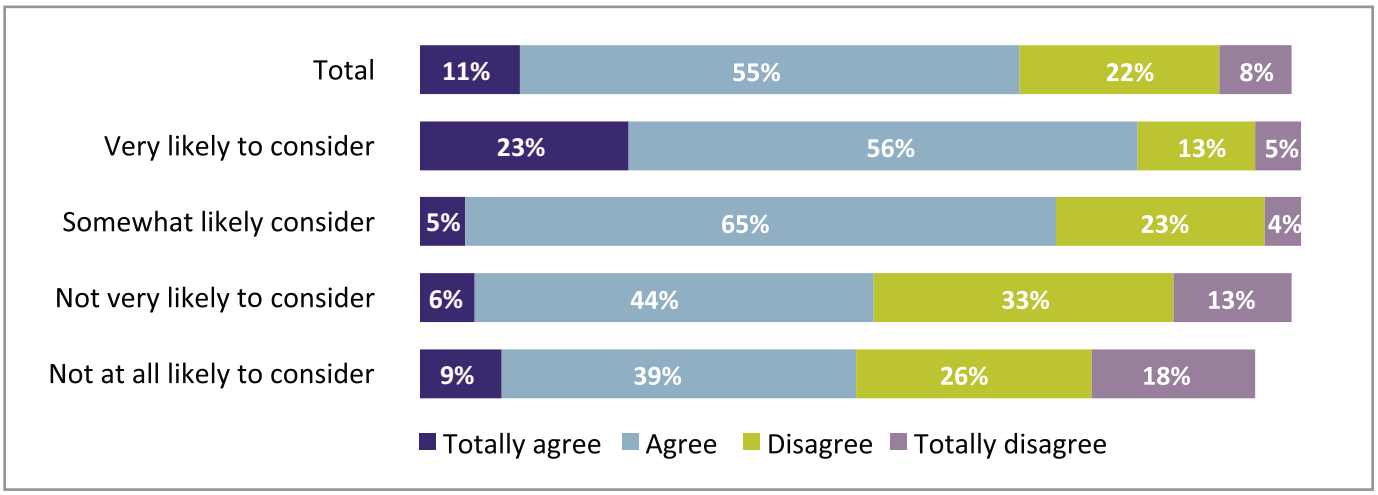


Figure 26: Responses to the Statement "I am prepared to pay more for an environmentally friendly product" by Likelihood of Considering a Residential Solar Photovoltaic System in the Next Two Years



Summary

The results of the household telephone survey build a better picture of the characteristics of potential early adopters, including a broad demographic profile, typical personal mobility patterns and clearly articulated perceptions of the barriers to and opportunities for the uptake of both EVs and residential solar PV.

Potential early adopters in Calgary and Edmonton are more likely to be over the age of 45, more affluent and better educated than the general population. The majority of this group live in detached, single-family homes, and few report having personal experience driving or riding in an EV. The survey results suggest that even among potential early adopters, purchasing or leasing an EV is not imminent. Concerns about the purchase price and potentially limiting range of the vehicle, as well as the current lack of infrastructure, are perceived as major barriers to the adoption of the technology. The likelihood of potential early adopters considering the purchase of an EV increases slightly, however, when they are informed or reminded that, although the purchase price of an EV is higher, the operating cost is roughly one-sixth that of a conventional gasoline-powered vehicle. These findings suggest that a lack of awareness of EVs may underlie much of the resistance to the technology and point to opportunities for further education and communications targeted at ENMAX customers.

The survey results also identified important opportunities for the combined promotion of EV and residential solar PV technology uptake. For example, the findings suggest that there is a direct correlation between interest in the purchase of an EV and consideration of residential solar PV. The interest of the potential early adopter in EV technology is tied to environmental performance; this means that solar power technology, with its environmental benefits, has the potential to play a vital role in supporting the EV value proposition. The survey findings point to an opportunity to promote residential solar PV technology as a complement to EV technology and as a means of lowering the carbon footprint associated with home charging of EVs. Potential early adopters also said that they would be more likely to consider an EV if public, solar-powered charging stations were available. This suggests that solar power technology could play a vital role in supporting EV deployment in Calgary and Edmonton if it is integrated with public charging infrastructure.

The market research can be used to determine methods for advancing awareness of the value proposition of EV and residential solar PV use among potential end-users, establishing a solid foundation for the growth of EV and solar power use in Calgary and Edmonton. The results can inform a comprehensive understanding of what is required to plan for the continued deployment of EVs and residential solar PV in the two cities. Unless the barriers identified in this report are addressed, scarce and valuable resources may be misallocated or misaligned with the needs of the emerging market for EVs and residential solar PV, thus decreasing the efficiency of such investments and increasing the cost of enabling EV and residential solar PV use in Calgary and Edmonton.

Appendix

Key Variables Affecting the Capacity of the Electricity Distribution System to Accommodate Electric Vehicle Charging

A number of variables have the potential to affect the capacity of the electricity distribution system to accommodate anticipated EV-related loads. In most cases, electricity distribution systems in urban centres are currently able to support the predicted home charging patterns of early adopters of EV technology. However, variables such as the capacity of the vehicle on-board charger, ambient temperature (seasonal demand) and time of charge all have the potential to impact the WSP's ability to accommodate additional loading as a result of EV charging.

Electricity generated at power stations and transmitted through high-voltage transmission lines is distributed to end-users through the electricity distribution system. A series of transformers lowers (steps down) the high voltages carried on transmission lines to levels appropriate for use by individual households (typically 120 V and 240 V). At the neighbourhood level, electricity distribution systems can be overhead systems (in which transformers are usually pole-mounted, i.e., mounted on utility poles) or underground systems (in which transformers are usually pad-mounted, i.e., mounted on concrete slabs). In overhead systems, a secondary connection system consisting of electrical conductors, cables and connection points supplies power from the pole-mounted transformer to the end-user. Pad-mounted transformers typically supply power to end-users through buried service cables that run from the transformer to the individual customer.

This appendix provides an overview of some of the key variables predicted to have the greatest potential for impacts on the capacity of the electricity distribution system to support EV-related loading. These variables include

- EV penetration rate
- EV charger capacity
- ambient temperature
- time of charge

ELECTRIC VEHICLE PENETRATION RATE

As the results of the market research show, the rate of EV penetration is influenced by several factors, including demographics, consumer attitudes and the availability of charging infrastructure. At the same time, the number of EVs that can be charged simultaneously is limited by the capacity of neighbourhood-level transformers to meet the demand for power, particularly given that early EV adopters may tend to cluster in particular neighbourhoods. If the sum of the household loads and the EV-related loads is less than the available capacity of the transformer, the system is deemed to be equipped to handle the load. If the household load plus the additional EV-related load exceeds the available capacity, overloading may occur. It should be noted that the load of any specific household that is charging an EV is of little concern; it is the total neighbourhood load on the transformer supplying that household that determines the available capacity to accommodate EV charging. For example, the load associated with 10 EVs with a 3.3 kW charger may easily be accommodated by a transformer rated at 50 kVA or greater, depending on its spare capacity; however, the same number of vehicles on a 25 kVA transformer could cause overloading. As such, both the size and the spare capacity of each transformer must be taken into consideration when the effects of EV charging on the electricity distribution system are being determined.

ELECTRIC VEHICLE ON-BOARD CHARGER CAPACITY

The charging process for an EV involves components both on and off the vehicle. Electricity delivered through an external device such as a household outlet or an EV charging station is converted to battery power by a small charger on board the vehicle. The charging level determines the rate at which electrical energy is drawn when an EV battery is being charged. Most of the first wave of mass-produced EVs on the market contain an on-board charger rated at 3.3 kW (e.g., the 2014 Chevrolet Volt plug-in hybrid electric) or 6.6 kW (e.g., the 2014 Nissan LEAF) when charging at 240 V – similar to the power delivered through a clothes dryer receptacle. This is known as Level 2 charging. Compared to a 3.3 kW charger, a 6.6 kW charger significantly reduces the length of time required to charge the vehicle, but it also doubles the demand for power from the electricity distribution system.

Most EVs can also be charged using a standard 120 V household outlet; this is known as Level 1 charging. A vehicle charging at Level 1 draws power at a lower rate, between 1.0 kW and 1.9 kW – similar to a typical hair dryer. For example, the 2014 Nissan LEAF can charge at 6.6 kW at 240 V, but when the vehicle is charging at 120 V, power flows at only 1.2 kW.

With advances in technology, some newer EVs have significantly more powerful on-board chargers – in some models, rated up to 20 kW (e.g., the Tesla Model S). Some models have the capacity to use Level 3 charging (also known as DC fast charging). Operating at up to 500 V, Level 3 chargers use greater amounts of power to provide a fast charge – in minutes rather than hours. The amount of power required to supply a fast charge is so great that, without significant upgrades, very few homes would be able to support a Level 3 charging station; as such, Level 3 charging is primarily found at public charging stations.

Table 1 summarizes the specifications for three popular EV models and their charger capacities.

Table 1: Charger and Battery Specifications for Various Electric Vehicle Models

EV model	Charging level, V	On-board charger capacity, kW	Battery size, kWh
2014 Chevy Volt	240	3.3	16
2014 Nissan LEAF	240	6.6	24
2014 Tesla Model S	240	20	85

Note: The Tesla website references both 20 kW and 22 kW as the on-board charger capacity for the Tesla Model S.

The current trend in the evolving EV market is towards vehicles with more powerful chargers to accommodate the early adopter's preference for faster charging. As the size of the on-board charger increases, the number of vehicles that can be charged simultaneously without overloading the electricity infrastructure at the neighbourhood level decreases. Under certain conditions, only a handful of vehicles with greater on-board charger ratings charging at the same time could cause the electricity infrastructure on some streets to be overloaded.

AMBIENT TEMPERATURE

Seasonal ambient temperature is a key factor in determining the number of EVs that can charge simultaneously. In summer, there is an increase in the demand for electricity to power air conditioners to cool houses. There is also a higher demand for power during the winter months; people tend to be inside longer, with the lights on and furnace fans and heaters running. These seasonal factors increase the load on neighbourhood-level transformers. This means that the electricity distribution system could reach capacity during the summer and winter months at a lower EV penetration rate than it would during the times of the year with less extreme temperatures.

TIME OF CHARGE

Because the demand for electricity fluctuates over the course of a day, the time at which EVs are plugged in could also have significant implications for the electricity distribution system. EV charging during periods of peak electricity demand poses a greater risk of transformer overload than charging at times when the demand for electricity is lowest. The EMAP market research showed that early adopters are likely to return home to charge their vehicles at periods of peak demand, making time of charge a critical variable.

There are a number of strategies that could reduce the effects of time of EV charging on the electricity distribution system while at the same time maximizing the number of vehicles that can be accommodated. For example, in contrast to simultaneous charging, managing staggered charging start times for households in a given neighbourhood could dramatically increase the number of vehicles that could charge over a 24-hour period. In addition, a staggered approach to EV charging could help to level the demand for power over the course of a day, reducing the need to adjust power generation up or down to meet demand.

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