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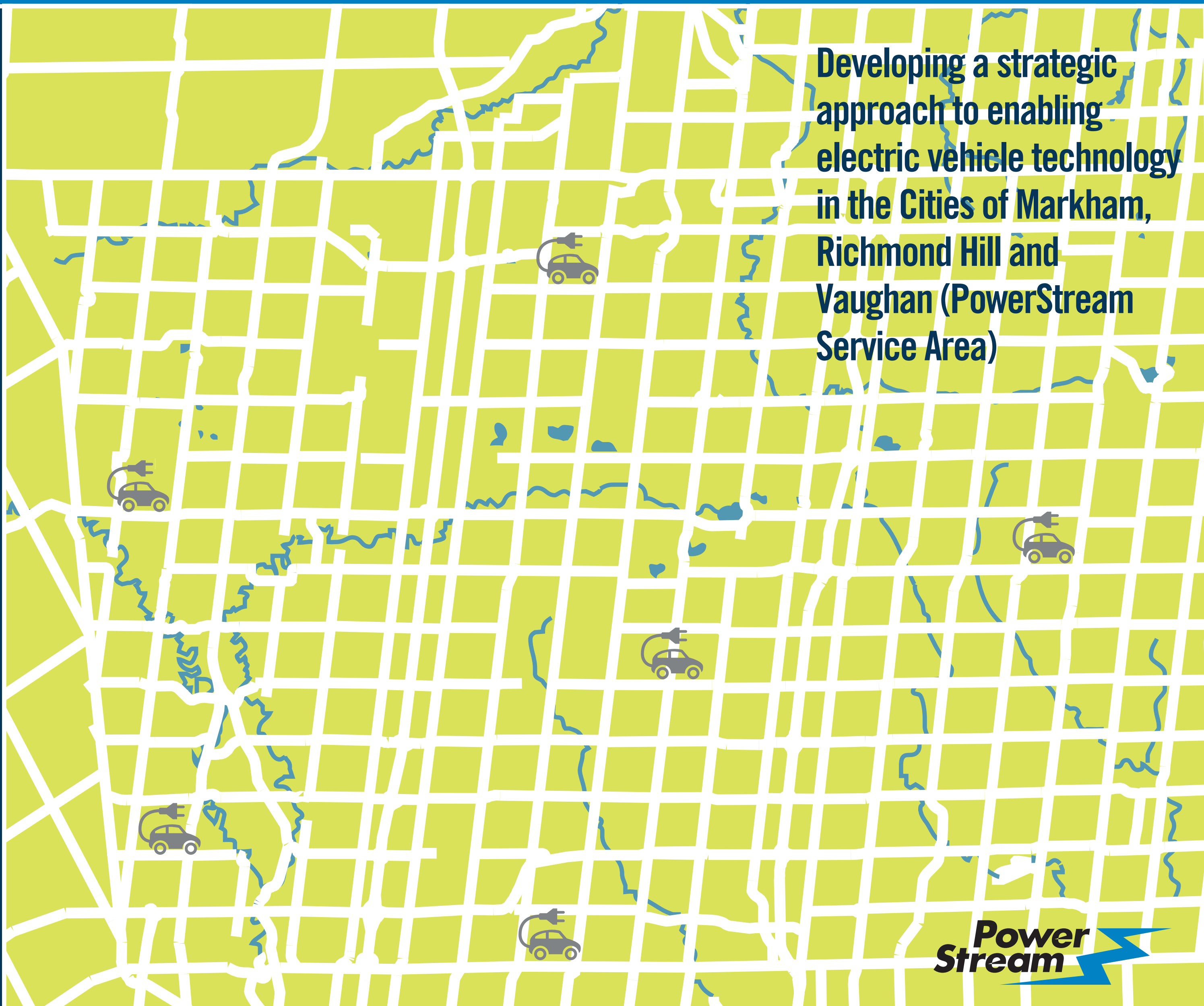
EMAP

MARKHAM, RICHMOND HILL & VAUGHAN

ELECTRIC MOBILITY ADOPTION AND PREDICTION



Developing a strategic approach to enabling electric vehicle technology in the Cities of Markham, Richmond Hill and Vaughan (PowerStream Service Area)

PowerStream

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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.

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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 POWERSTREAM

PowerStream is a municipally owned energy company that provides power and related services to more than 375,000 customers residing or owning businesses in communities located immediately north of Toronto and in Central Ontario. It is jointly owned by the Cities of Barrie, Markham and Vaughan.

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Georgian College plays a leadership role in student co-op work experience and entrepreneurship education. With more than 125 career-focused programs offered across seven locations in Central Ontario – Barrie, Midland, Muskoka (Bracebridge), Orangeville, Orillia, Owen Sound and South Georgian Bay (Collingwood) – Georgian has 11,000 full-time students and 28,000 continuing education registrations annually and is home to the one-of-a-kind University Partnership Centre. Georgian has been named one of Canada's Top 100 Employers seven times and one of Canada's Greenest Employers five years in a row.

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About This Report

Electric Mobility Adoption and Prediction (EMAP) combines sophisticated market research methodologies with detailed grid integration and impact analyses. The 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 Markham, Richmond Hill and Vaughan and the implications of the EMAP analysis for PowerStream, the local distribution company (LDC).

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 PowerStream to manage and support the use of EVs in its service area.

Representatives of stakeholder organizations integral to the future of electrified transportation in the PowerStream service area met regularly as an advisory group for the study, contributing to the overall project scope, sharing technical expertise and providing guidance for all milestones and deliverables. The participation of these expert advisory group members helped to ensure that a local perspective informed the project, thus providing further credibility and enhancing the value and relevance of the outputs. This study also led to the production of a number of complementary reports, including full-length reports on the EMAP market research and the electricity distribution system assessment produced by Environics Research Group and Georgian College, respectively. Taken together, these resources provide a comprehensive look at the implications of EV technology uptake for Markham, Richmond Hill and Vaughan 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 PowerStream to manage and support the use of EVs in its service area.

Objectives for the EMAP Study

EMAP is an investigative tool designed to be used to better understand how to support the uptake of EVs among early adopters in urban areas. The EMAP research methodology identifies and characterizes potential early adopter communities in the context of both the consumer market and electricity distribution system asset planning and management. This provides a solid and objective foundation upon which to build a successful EV deployment strategy for an urban area, comprehensively addressing the consumer, technological and infrastructure dimensions of the challenge.

The following objectives specific to the application of the EMAP methodology to the PowerStream service area were determined at the outset of the study to guide the process and tailor the research:

1. **Identify locations where EV adoption is most likely to occur and determine the impact of the technology on PowerStream's distribution assets in these areas:** Based on EMAP's predictive methodology, identify and investigate areas in the PowerStream service area with the potential for high proportions of EV adoption and study the impact of the load associated with EV charging on various distribution assets to help to plan for EV penetration. The outputs of this research will help to plan for EV deployment and provide a foundation for recommendations related to asset planning.
2. **Investigate the impact of the incremental load from EV charging on power quality:** Study the impact of EV charging on the voltage waveform and recommend mitigation options.
3. **Gain a better understanding of customer preferences regarding home energy management, including EV-related services:** Determine customer preferences related to a variety of energy management scenarios (e.g., off-peak charging, remote monitoring, demand response control and EV energy storage).

2

Investigate the impact of the incremental load from EV charging on power quality

3

Gain a better understanding of customer preferences regarding home energy management, including EV-related services

These objectives informed the market research and the assessment of the local electricity distribution system as well as the development of a strategy to support and enable the deployment of EV technology in the PowerStream service area. While PowerStream provides power and services to a number of communities located immediately north of Toronto and in Central Ontario, the identification of potential EV early adopter neighbourhoods for the market research survey indicated that the most likely areas for EV adoption are in the Cities of Markham, Richmond Hill and Vaughan. As such, the market research and the assessment of the electricity distribution system for this study focus only on these cities. The findings emerging from this research, and the EV strategy based on it, can, however, be applied to PowerStream's service area as a whole.

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 three sections:

Section One provides a brief description of the EV as an emerging technology and proposes a three-point strategy for enabling EV use in the PowerStream service area, based on key findings from the EMAP market research and the electricity distribution system assessment.

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.

Section Three describes the methodology and results of simulation work conducted by Georgian College, using data provided by PowerStream. The simulations address the capacity of the electrical distribution system at the neighbourhood level to support additional loading resulting from EV charging under a number of conditions.

SECTION ONE: A Strategic Approach to Enabling EV Use in Markham, Richmond Hill and Vaughan

The Electric Vehicle as an Emerging Technology

For EVs to become a viable part of a successful sustainable transportation system in the PowerStream service area, 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 Markham, Richmond Hill and Vaughan, 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.

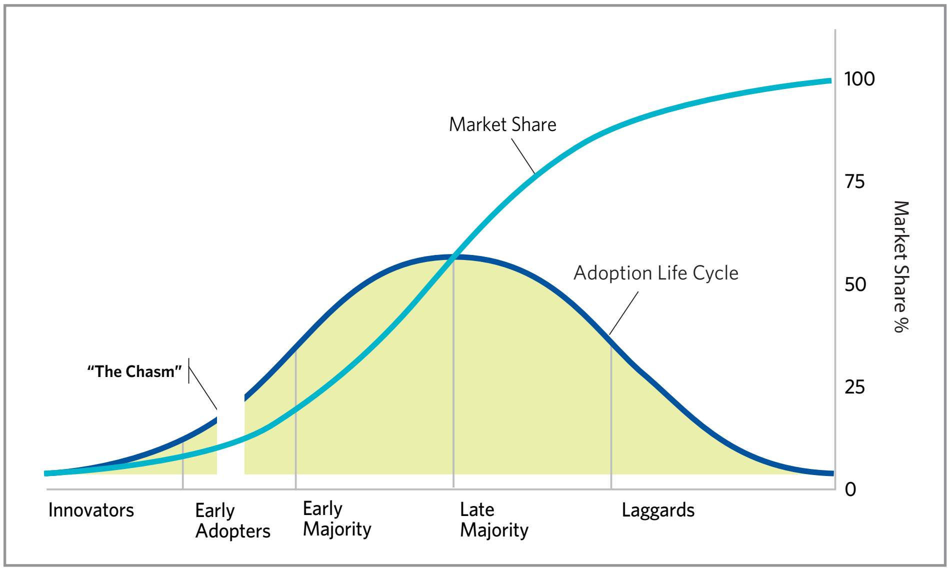
Support or endorsement of a technology from the early adopter group is one of the most important factors contributing to its adoption by a broader market. Whereas innovators may be perceived as extravagant or in a better position to take risks than the general public, early adopters demonstrate a high 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.

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 oil prices 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 ability 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 ability 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. One of the key factors affecting the ability of the electricity distribution system to accommodate EV-related loading is the capacity of the vehicle's on-board charger. 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 or

6.6 kW when charging at 240 V – similar to the power delivered through a clothes dryer receptacle. This is known as Level 2 charging. 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.

With advances in technology, some newer EVs have significantly more powerful on-board chargers – in some models, rated up to 20 kW. Some models have the capacity to use Level 3 charging (also known as DC fast charging). Level 3 chargers use greater amounts of power, operating at up to 500 V, 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. Because these fast chargers can address concerns about the limiting range of EVs ("range anxiety") and the amount of time required to charge the vehicle away from home, implementing them will likely be a key factor influencing EV adoption and will require careful planning on the part of the LDC.

Summary of Key Findings

The following section briefly summarizes key findings from the market research and the assessment of the electricity distribution system. For a more comprehensive description of the market research methodology, process and outcomes, refer to Section Two of this report. A more in-depth investigation of the electricity distribution system assessment is provided in Section Three.

Market Research

The results of the market research provide a detailed picture of the demographic characteristics and social values shared by potential early adopters, their typical personal mobility patterns, their expectations of the technology, and the barriers and opportunities they associate with the uptake of EVs.

PROFILE OF THE POTENTIAL EARLY ADOPTER

Potential early adopters are more affluent, better educated and older (i.e., likely to be over the age of 45) than the general population in Markham, Richmond Hill and Vaughan. The majority are considered vehicle commuters, characterized as those who drive to a specific location at least three times a week, where most park in an employer-provided lot, many for at least eight hours. Early adopters typically travel more than 25 kilometres in a day, leaving home between 7 a.m. and 9 a.m. and returning between 5 p.m. and 7 p.m. This suggests that they would likely return home and begin charging their EVs during periods of peak energy demand.

Early adopters who have owned or driven in an EV were more likely than those who have not to say that they would definitely consider buying or leasing an EV in the next couple of years. Only a quarter of early adopters reported that an EV was suggested as a potential purchase option during their most recent visit to a dealership or that an EV was available for purchase at the time. This points to opportunities to explore further engagement with customers regarding EV technology, including providing information at dealerships to help those interested in driving electric to make informed decisions about it.

BARRIERS AND OPPORTUNITIES TO EV ADOPTION

Early adopters feel that the main advantages of EVs are the environmental benefits and the fact that there is no need to purchase gasoline. Early adopters believe that it should take under four hours to fully charge an EV, which suggests that the provision of faster home charging could be a key factor in promoting EV deployment. However, despite the potential advantages that early adopters associate with EV ownership, they also identify a number of barriers to the uptake of the technology, indicating that, even among this group, a decision to purchase or lease an EV is not imminent. The potentially limiting range of the vehicle and the lack of charging infrastructure are perceived as major barriers to the adoption of EVs. Although very few early adopters drive more than 50 kilometres on a typical day, the majority feel that an EV would have to be able to travel more than 200 kilometres on a single charge for them to feel comfortable. Interestingly, while vehicle range is the most mentioned barrier, only a small number of potential early adopters would be more inclined to purchase a plug-in hybrid electric vehicle (PHEV) than an EV, even when they are reminded that PHEVs have the same driving range as conventional, gasoline-powered vehicles. This suggests that the resistance to EV technology may be related to a combination of factors, rather than any one single barrier.

The market research also identified important opportunities for the further promotion of EV uptake. Early adopters report that they generally wait for off-peak hours to use high electricity consumption devices and would be open to participating in a demand response program, particularly if they had the option to override it if necessary. Early adopters also feel that workplace charging would be an important factor in their consideration of an EV, indicating that there may be an opportunity to support and promote the uptake of the technology by facilitating workplace charging. These insights can help the LDC to play a vital role in the promotion and success of EV deployment while at the same time tailoring its services so that existing distribution assets can reliably service EV charging.

Electricity Distribution System Assessment

The results of the assessment of the electricity distribution system provide a better understanding of factors key to the system's capacity to accommodate anticipated EV-related loads at the neighbourhood level. The majority of the scenarios investigated show that the system is currently able to support EV-related loading. However, variables such as the capacity of the vehicle's on-board charger and the time of charge have the potential to significantly impact the system under certain conditions. While the likelihood that these conditions will occur, particularly in combination, is not high, planning and asset management will nonetheless require consideration of these factors.

KEY VARIABLES INFLUENCING HOW EV CHARGING AFFECTS THE ELECTRICITY DISTRIBUTION SYSTEM

The capacity of the vehicle's on-board charger is one of the key factors affecting the capacity of the electricity distribution system at the neighbourhood level to accommodate EV-related loading. Under most of the conditions investigated, all households serviced by a single transformer could charge an EV with a charger rated at 3.3 kW with little effect on the electricity distribution system. As the size of the charger increases, the number of EVs that can be charged simultaneously decreases. EVs with a 6.6 kW or 20 kW charger can be charged much more quickly than vehicles with a 3.3 kW charger, but the demand for power from the electricity distribution system for charging at these higher rates also increases dramatically. As few as two EVs with a 6.6 kW charger or one EV with a 20 kW charger could overload a 50 kW transformer, depending on the time of charge and the ambient temperature.

Because the demand for electricity fluctuates over the course of a day, the time during which EVs are plugged in could also have significant implications for the electricity distribution system. The results of the electricity distribution system assessment showed that EV charging during periods of peak electricity demand would pose an increased risk of system overload and potential power outages, compared to charging during off-peak times. If EV charging were to occur during periods when demand on the transformer is lowest, a much greater number of EVs could be accommodated without overloading the transformer. For example, the results of the assessment of the electricity distribution system show that a single transformer with a rated capacity of 50 kW that is already overloaded between the hours of 2 p.m. and 12 a.m. could not accommodate any additional loading from EV charging during that period. However, if charging were to occur between the hours of 12 a.m. and 6 a.m., as many as five EVs with a 3.3 kW charger could charge simultaneously without exceeding the capacity of the transformer.

The Potential Impacts of EV Use in Markham, Richmond Hill and Vaughan

Current patterns of EV charging in the PowerStream service area do not represent a risk to the utility's capacity to maintain a safe and reliable supply of power to all its customers. Nor is the demand for power to charge EVs at home expected, in the short term, to exceed the rated capacities of PowerStream's current infrastructure assets at the neighbourhood level. But, in the coming years, EV charging could increasingly put the integrity of the utility's service at risk if it is not factored into asset planning. The prevailing trend in new EV technology is towards larger batteries and faster charging, as automakers respond to market demand for greater driving range, convenience and overall performance. The compounding effect of these factors means that, in the absence of proactive measures, PowerStream's capacity to accommodate the demand for electricity could be exceeded.

While additional transformer and secondary distribution system capacity may eventually be necessary to accommodate greater numbers of EVs charging, taking EV use into consideration in the process of scheduled upgrades will help to mitigate risks. The EMAP grid assessment shows that, if just a handful of neighbouring households charge EVs with greater on-board charger ratings at the same time during periods of peak demand, the electricity infrastructure on some streets could be overloaded. Encouraging charging when demand for power is otherwise at its lowest would allow greater numbers of EVs to charge without necessitating changes to the existing electricity distribution assets.

In addition to the potential benefits for consumers, using electricity to replace the combustion of gasoline and diesel to power transportation in the PowerStream service area also offers broader social benefits, such as cleaner air and reduced emissions of greenhouse gases (GHGs). Because EV adoption may, in the long term, pose challenges for the electricity distribution system and at the same time deliver significant consumer and environmental benefits, it makes sense for PowerStream to respond pre-emptively to address the risks and proactively to capitalize on the benefits associated with EV charging. Such a strategy is consistent with the mandate of PowerStream to ensure a safe and reliable supply of power for its customers and with its long-standing commitment to routinely assessing the capacity of the electricity distribution system on an ongoing basis, identifying and addressing issues before they become a problem.

Enabling Electric Vehicle Use in the PowerStream Service Area – A Strategy to Manage the Risks and Optimize the Benefits

By developing a strategy for enabling EV use in its service area, PowerStream can enhance its current organizational capacities to be responsive to consumers' basic needs and to the evolving state of EV technology; to be proactive in addressing barriers and leveraging opportunities associated with EV use; and to be progressive in promoting EV technology within the current regulatory framework, informing customers' decisions about becoming EV drivers and supporting their transition. Flexibility will be key to ensuring the success of this strategy for enabling EV adoption as it evolves within the broader electricity utility landscape of smart grid technologies, distributed generation and demand response programming.

Key stakeholders internal and external to PowerStream must be engaged in the development of this strategy because the successful deployment of EV technology in the PowerStream service area depends on actions and decisions taken by a range of individuals as well as public and private organizations. Stakeholders internal to PowerStream include its Executive Management Team as well as those responsible for asset management, communications, customer service, and conservation and demand management. Stakeholders external to PowerStream include

- the Ontario Energy Board (OEB)
- the Independent Electricity System Operator (IESO)
- the Ontario Ministry of Energy
- the Ontario Ministry of Transportation
- the Cities of Barrie, Markham, Richmond Hill and Vaughan, in particular, municipal planning staff
- academia, including local colleges and universities
- PowerStream customers, including current and future EV owners and users
- electric vehicle supply equipment (EVSE) providers
- real estate developers
- EV dealerships
- organizations that promote EV use and education

A strategic approach to enabling successful EV use in the PowerStream service area can be built on the following recommendations, drawn from the EMAP market research and the electricity distribution system assessment:

1 Enhance responsiveness to evolving patterns of EV charging.

- Monitor the progression of the EV market in the PowerStream service area. This means dedicating resources to maintaining knowledge and awareness of changes in EV products and technologies, operating standards, regulations and general market adoption. It also includes monitoring and evaluating the evolving impacts of EV charging on the local distribution system and keeping PowerStream's Board of Directors updated about potential opportunities for enabling EV adoption within the service area, as the EV market continues to evolve.
- Promote and facilitate EV charging habits that reduce daily peaks in demand for power and that optimize use of the distribution system's existing assets. The EMAP assessment shows that EV charging has the potential to affect the electricity distribution system if early adopters charge their vehicles during periods of peak demand. Encouraging EV charging during off-peak hours will help to ensure that EVs do not add to peak demand on the distribution system.

Key stakeholders internal and external to PowerStream must be engaged in the development of this strategy because the successful deployment of EV technology in the PowerStream service area depends on actions and decisions taken by a range of individuals as well as public and private organizations.

- Consider implementing a program through which PowerStream customers can volunteer information about their purchase of EV technology (e.g., vehicle model, charging services) or their intention to purchase an EV. With this information, PowerStream can conduct predictive assessments of the infrastructure that will be affected to ensure that quality of service can be maintained.
- 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.
- Investigate the effects of EV charging on the electricity distribution system when the load is actively managed (e.g., by way of smart grid automation or user-programmable charging parameters, such as level of charge or timing of charge). Building on the analysis in the EMAP grid assessment, determine the degree to which greater levels of demand for charging services could be accommodated if the timing and duration of EV charging were actively managed.

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

- Engage the Cities of Barrie, Markham, Richmond Hill and Vaughan in meaningful discussion of the role EVs can play in promoting sustainable growth and development in the region, e.g., by incorporating consideration of the potential impacts of EV deployment into each city's Municipal Energy Plan. Strategic planning for EV deployment has the potential to contribute to municipal efforts to reduce GHG emissions and improve local energy efficiency.
- 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.
- Develop a process for identifying, in collaboration with key stakeholders, optimal locations for public and workplace-based charging stations. The EMAP study identifies range anxiety among potential early adopters of EVs as a barrier that can be addressed by providing fast-charging services away from home. Consistent with PowerStream's ongoing commitment to facilitate EV charging, the utility operates a Level 3 charging station at its offices in Vaughan. Having additional charging stations available within the service area could help to enhance and accelerate the deployment of EV technology. This report points to some desirable locations for charging stations, but further planning by and coordination among PowerStream, the municipal government, property managers and other stakeholders will be necessary to achieve the expansion of charging facilities.

- Leverage existing partnerships with local academic institutions and educational facilities to increase capacity for training and graduating students who can participate in, and contribute to, a thriving electric mobility industry in the region and across the country. This can help to establish the region as a leader in and destination for EV studies, as well as generating ongoing benefits to the academic community, electricity utilities, the public and industry across Canada.
- Consider engaging the system regulator, other utilities and stakeholders in exploring the potential benefits of differential electricity service rates for EV owners. Such rates for EV owners would constitute a financial reward for customers who charge their EVs in a time frame that helps to optimize system utilization. The EMAP study shows that many early adopters feel that the difference between on- and off-peak rates is not currently great enough to discourage them from using high electricity consumption appliances whenever it is most convenient for them to do so. This suggests that the current rate structure would not necessarily prevent them from charging their vehicles during periods of peak demand.

3 Establish an active engagement with customers on EV technology.

- Contribute to building understanding of the benefits and limitations of EV technology, particularly from a social perspective. For example, 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. Educating customers about how optimal charging behaviours can help to maintain the reliability and adequacy of existing distribution system assets and keep rates low could be a useful strategy in this regard.
- Create targeted communications to address the concerns identified in the analysis of the early adopter community, as summarized in this report. This could be achieved by equipping PowerStream's communications and customer service groups with the necessary information, including sample scripting where appropriate, to respond to general customer inquiries about EV technology.
- Provide information and links to resources related to EV charging on the PowerStream website. Such resources could include tips for consumers considering a new vehicle purchase or lease on how to decide if an EV might be a good fit, information about public charging infrastructure within the service area (including the Level 3 charger at the PowerStream offices) or details about residential charging station installation. Directing customers to PowerStream for information about installing a charging station at home could help them to make more informed decisions and better plan for the costs involved.
- Identify opportunities to educate businesses and workplaces about EV charging so that they can directly support EV deployment across the PowerStream service area. The EMAP study indicates that an overwhelming majority of early adopters currently park in employer-provided lots but that employers are not, on the whole, well informed about how appropriate charging services are installed, the costs involved in doing so, and the potential economic opportunities and benefits associated with offering workplace and/or public charging. Making such information available to employers can help to encourage them to support EV owners

- Work in collaboration with organizations that promote EV use and education to provide residents of the PowerStream service area with resources and opportunities to experience EV technology firsthand. Offering test drives, along with providing general information about EV use and charging needs, could prove a useful strategy for this purpose.

SECTION TWO:
Market Research

Purpose of Surveying the Cities of Markham, Richmond Hill and Vaughan

Understanding the perceptions of EVs – both positive and negative – among the early adopter community in Markham, Richmond Hill and Vaughan will make it possible to develop effective and targeted information and awareness campaigns and to provide a framework to facilitate local policy 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 the uptake of EV technology.

It is important to understand how EVs 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 technology 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 technology
- primary research to characterize early adopters and identify potential opportunities and barriers to EV 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 technology and to map the neighbourhoods in which they 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 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 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, and IHS Automotive's New Vehicle Registrations (NVR) and Total Vehicles in Operation (TVIO) databases.

Because EVs currently account for only a small portion of total vehicles in the marketplace, EV purchase data in surveys and databases are limited. Therefore, the following key variables were selected as indicators of the propensity to purchase an EV:

- demographic characteristics
- social values
- vehicle purchase data

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 market and technology. 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 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 Markham, Richmond Hill and Vaughan. Special consideration was, therefore, given to the types of neighbourhoods with high disposable incomes.

Social Values

Potential early adopters of EV 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 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 are not yet part of the mainstream marketplace, early adopters of EVs 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 is not yet widely available in the mainstream media, particularly in Canada where the market is still small, it was assumed that early adopters of the technology would have to be particularly enthusiastic or have made an effort to become informed about the topic.

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.

SECONDARY RESEARCH RESULTS

The variables identified as indicators of the propensity to purchase an EV 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 within the Cities of Markham, Richmond Hill and Vaughan.

Target Segments

Six psychographic segments of the population in Markham, Richmond Hill and Vaughan 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 technology in Markham, Richmond Hill and Vaughan.

The following are the six 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.

Asian Affluence: This segment is primarily made up of educated, middle-aged families, 37 per cent of whom speak Chinese as their first language. Most of the people in this group came to Canada in the 1980s and 1990s, settling in a small number of prosperous neighbourhoods in Toronto and Vancouver. Characterized by large families, this segment represents households with a number of teenage and twenty-something children. Asian Affluence residents enjoy sophisticated lifestyles thanks to their healthy incomes.

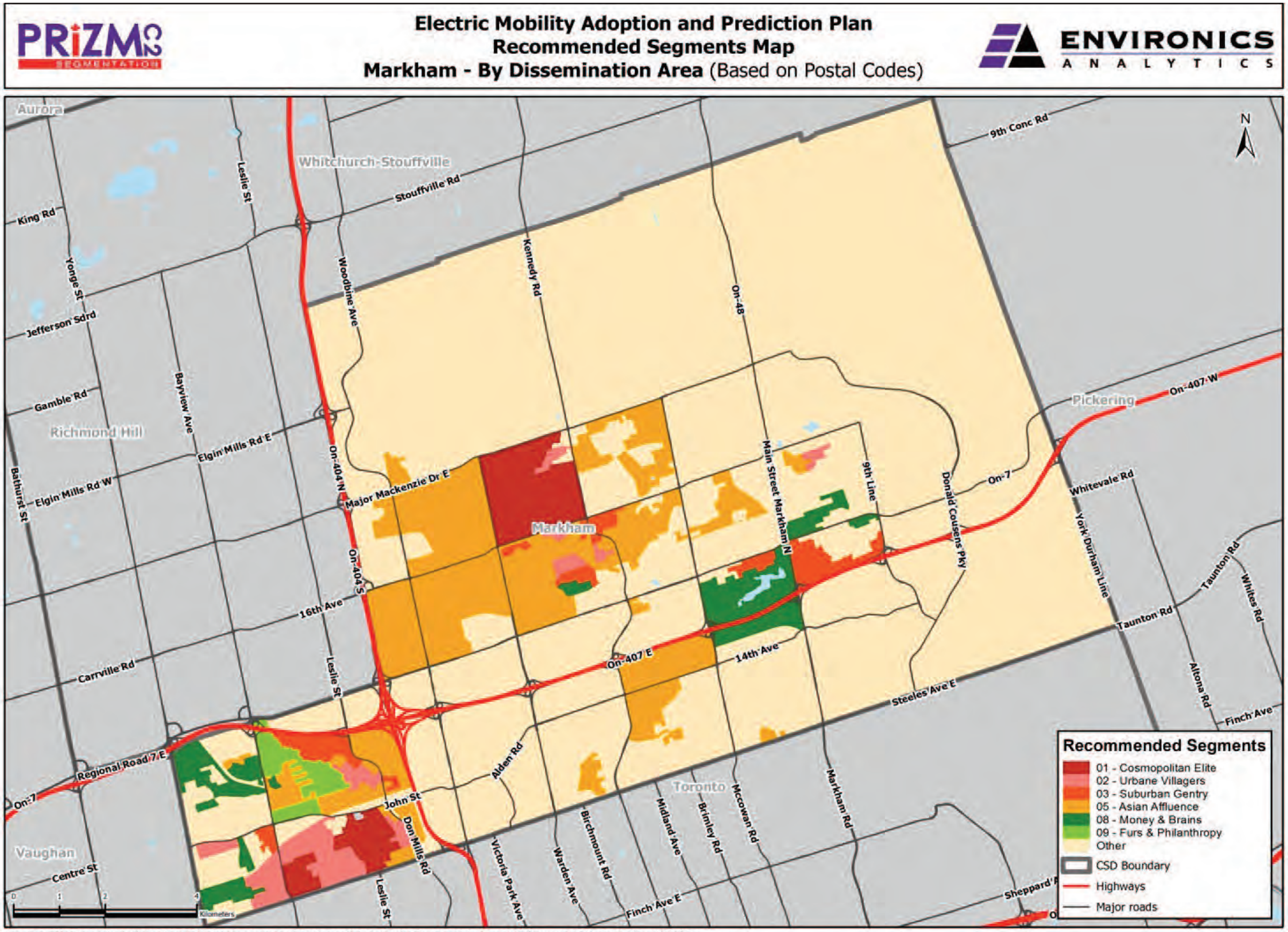
Money & Brains: The residents in this segment have high incomes, advanced degrees and sophisticated tastes. Many of them are empty nesters or married couples with university-aged children, who live in older, fashionable homes in both urban and suburban neighbourhoods.

Furs & Philanthropy: This segment consists of larger families, white-collar professionals and executives concentrated in a few big-city neighbourhoods. Many of the residents of this segment are first- and second-generation Jewish Canadian and Russian émigrés with older children. Furs & Philanthropy are well travelled and philanthropic, donating to a wide range of medical, cultural and religious groups.

Geographic Distribution

Three maps were created, indicating the geographic distribution of each of the six target segments within Markham, Richmond Hill and Vaughan, respectively, based on postal codes (see Figures 2, 3 and 4). 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 city (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 Markham



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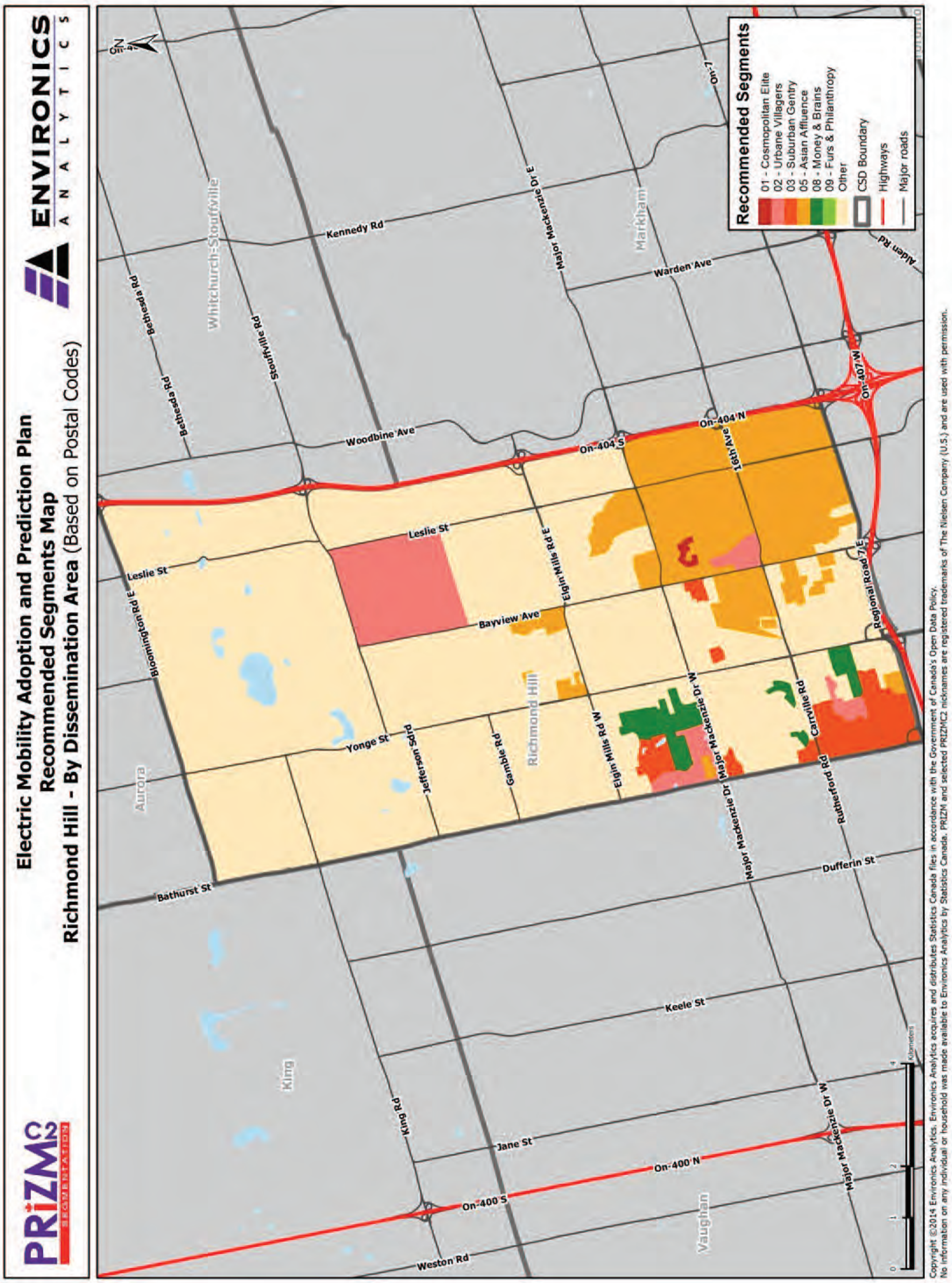
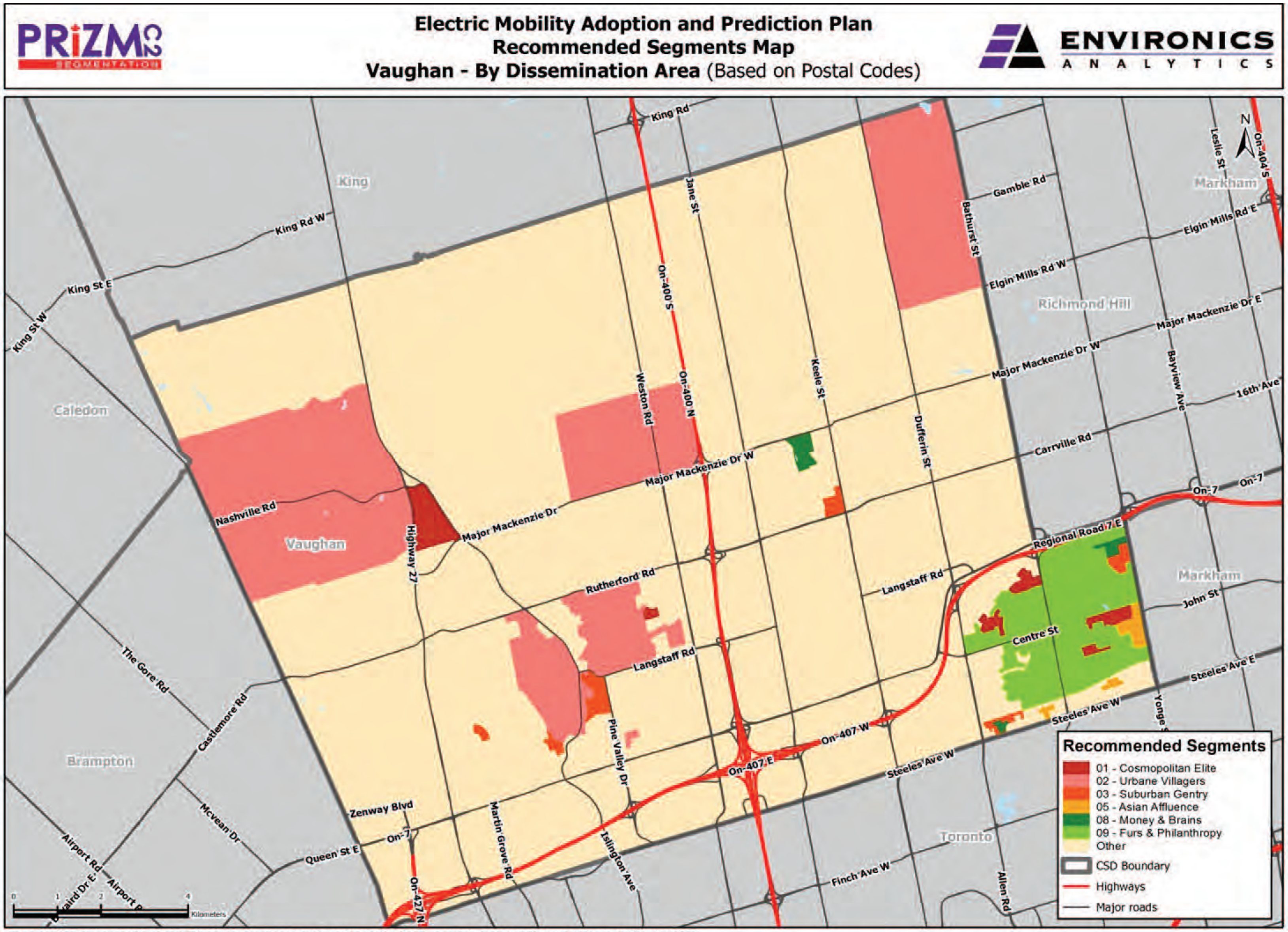
Note: CSD – Census subdivision.

Figure 3: Distribution of Target Segments in the City of Richmond Hill



Note: CSD – Census subdivision.

Figure 4: Distribution of Target Segments in the City of Vaughan



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Note: CSD – Census subdivision.

Primary Research to Validate and Characterize Early Adopter Neighbourhoods

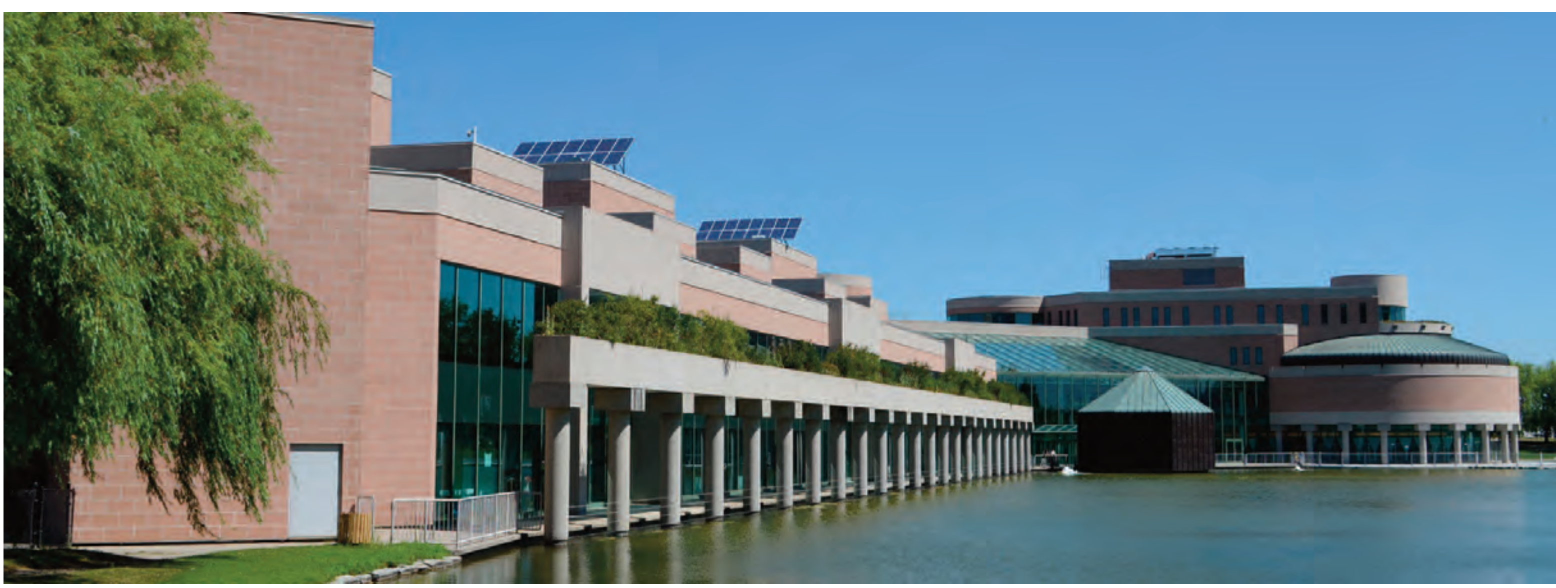
In addition to estimating the demand for EVs in Markham, Richmond Hill and Vaughan using $PRIZM_{c2}$-based tools, the secondary research informed the primary research that followed. A questionnaire was designed for use in a household telephone survey conducted by Environics Research Group. The survey was conducted in key locations containing high proportions of segments with behavioural and attitudinal characteristics linked to the early adoption of EV technology. A total of 750 residents of Markham, Richmond Hill and Vaughan participated in the survey, which took place between May 15, 2014 and June 4, 2014 and averaged approximately 14.5 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 in a deployment 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 use, the personal mobility patterns of the respondent, the expectations of EV technology, and the barriers to address and opportunities to leverage in relation to EV use. The survey was divided into the following four sections:

- vehicle ownership and use
- awareness and perceptions of EVs
- charging capabilities
- market segmentation and respondent profile

While most of the survey addressed topics common to all vehicles powered by electricity, a small number of questions made the distinction between plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). PHEVs are vehicles that have both an internal combustion engine powered by gasoline and a battery that is charged by being plugged into an electrical outlet or charging station. BEVs are vehicles that do not have a combustion engine or fuel tank and are powered only by a rechargeable battery pack that can be charged by being plugged into an electrical outlet or charging station. Unless otherwise noted, the term “EV” refers to both PHEVs and BEVs. These distinctions are noted and clarified as required in the following section.



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 technology and their expectations for residential charging.

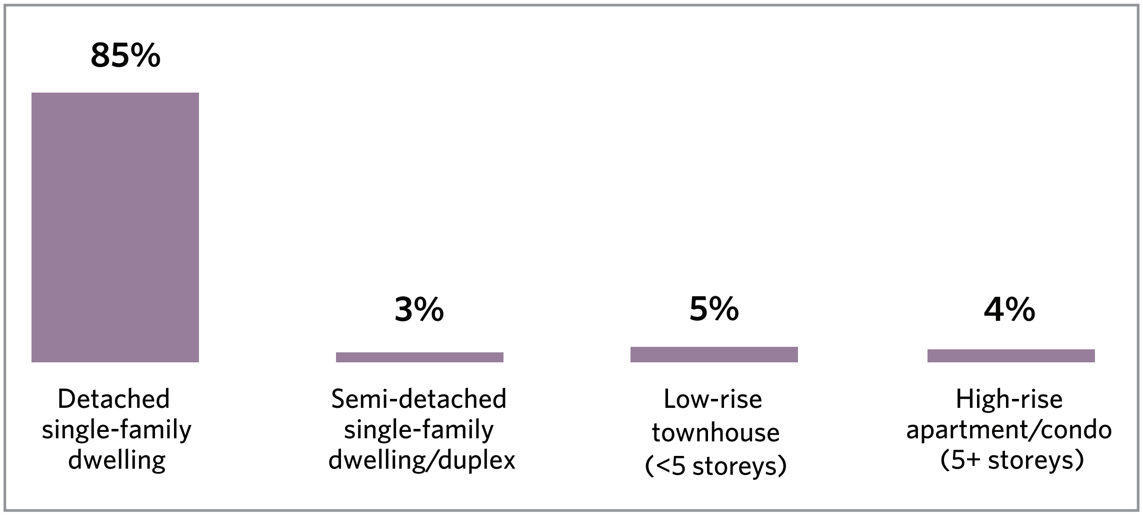
Profile of the Potential Early Adopter

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 Markham, Richmond Hill and Vaughan. They are better educated, with seven in ten of those surveyed holding a university degree (bachelor or post-graduate), compared to only 31 per cent of the general population in these cities. Potential early adopters are also more likely than the average city resident to have a household income of $150,000 or more, and a strong majority (85 per cent) live in detached single-family homes.

Figure 5: Dwelling Type



Vehicle Purchasing Preferences

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

Of the 750 participants in the household telephone survey, 33 people indicated that they currently own a hybrid vehicle (not a plug-in), one person reported owning a PHEV, and six people own a BEV. Among potential early adopters who do not currently own an EV, personal experience with EVs is limited. Only 7 per cent have driven one, while 6 per cent have been a passenger, and one quarter reported knowing someone who drives one. A strong majority (seven in ten) have not had any of these experiences with EVs. One in four of those who later indicated that they would either definitely or likely consider the purchase of an EV in the near future have some previous personal experience with one. Personal experience with or exposure to EVs is likely to increase and, as it does, it is expected that interest in purchasing them will likely also increase.

Figure 6: Experience with an Electric Vehicle

Experience with plug-in electric vehicles (among those who do not own an EV)	Total (n=743) %	BEV likely (n=195) %	BEV unlikely (n=518) %
Owning or driving one	7	9	6
Knowing someone who owns/drives one	24	28	22
Riding in one as a passenger	16	21	14
None of the above	69	61	71

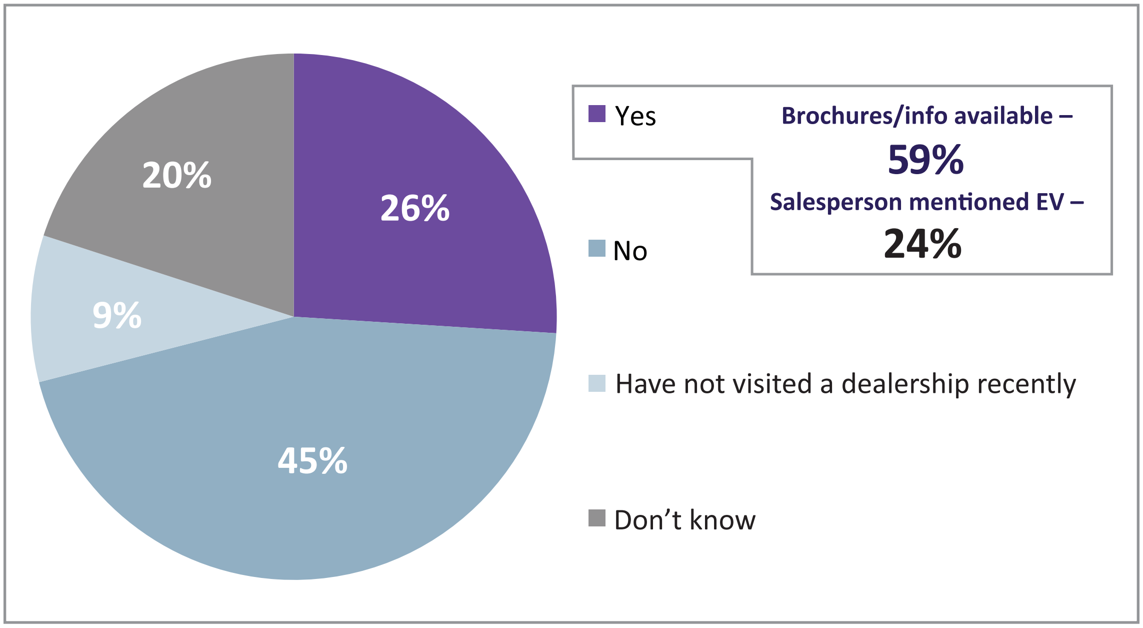
Subsample: Intending to purchase a new vehicle and recent purchasers who do not currently own an EV.

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

One quarter of early adopters reported an EV being suggested as a purchase option during their most recent visit to a dealership.

Potential early adopters were asked if, on their most recent visit to a dealership, there were any EVs available for purchase or lease. One quarter (26 per cent) indicated that there was an EV available while less than half said that there were none. One quarter of those who had recently visited a dealership indicated that the salesperson had suggested an EV as a potential purchase or lease option. Fifty nine per cent of those who responded that there was an EV available for purchase or lease indicated that brochures or other information were available at the dealership to review.

Figure 7: Electric Vehicle Availability during Most Recent Visit to a Dealership

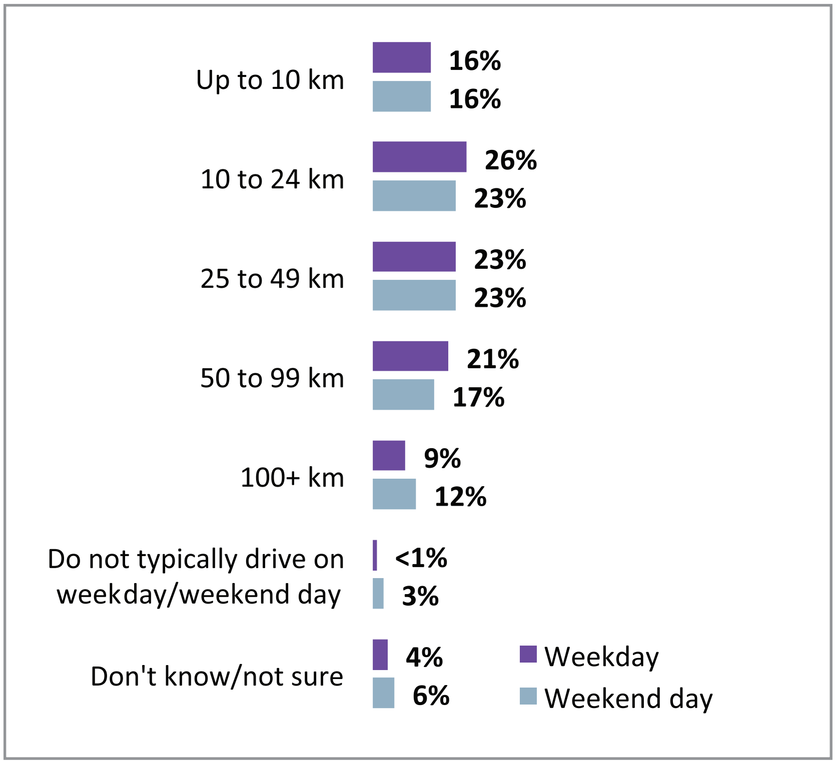


Personal Mobility Patterns

Fifty-seven per cent of all potential early adopters use their vehicles every day.

Fifty-seven per cent of potential early adopters indicated that they use their vehicles seven days a week. Driving every day increases proportionally with the number of vehicles in the household and is highest among those who drive 50 kilometres or more on a typical weekday. 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. More than half (53 per cent) of potential early adopters travel more than 25 kilometres on a typical weekday, while 52 per cent drive the same distance on a typical weekend day. Residents of Markham are more likely than residents of Richmond Hill or Vaughan to report driving less than 25 km on a typical weekday.

Figure 8: Kilometres/Day Typically Driven



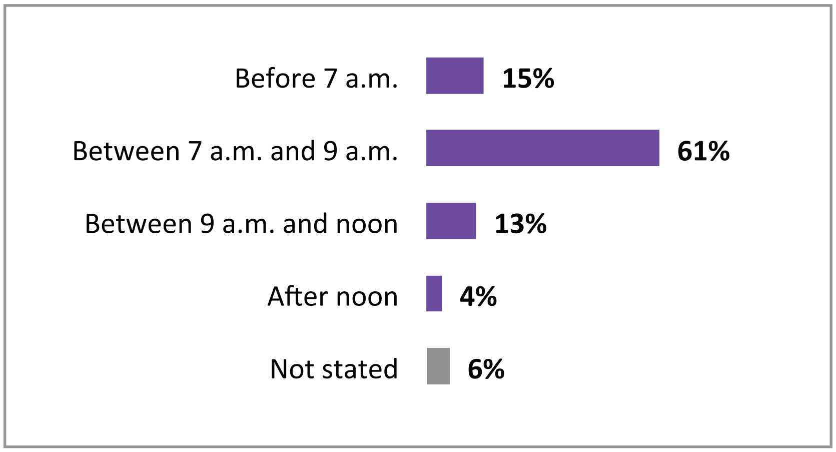
More than half of potential early adopters are considered vehicle commuters.

More than half of potential early adopters (54 per cent) 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.

The majority of vehicle commuters leave home between 7 a.m. and 9 a.m. and return home between 5 p.m. and 7 p.m.

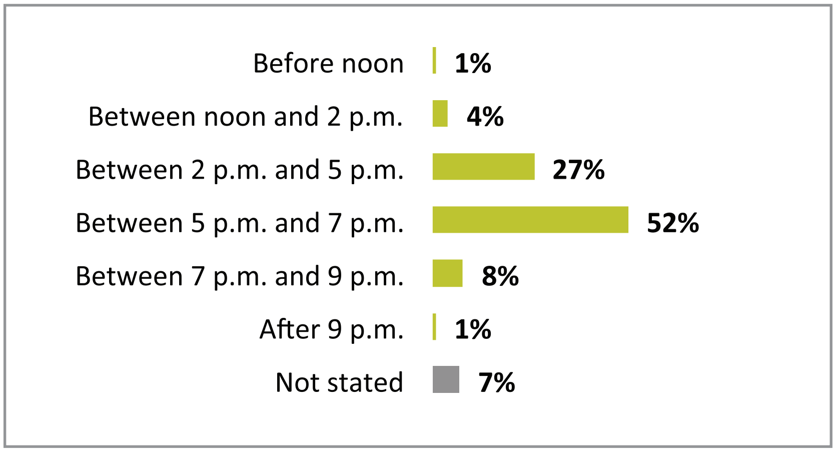
Most vehicle commuters described a typical workday as one on which they leave home between 7 a.m. and 9 a.m. (61 per cent) and return home between 5 p.m. and 7 p.m. (52 per cent). Vehicle commuters were also asked to indicate how many hours they park at the location where they typically leave their vehicle. The most common response was eight hours (38 per cent). Four in ten spend seven hours or less parked at this location, while 19 per cent spend nine or more hours.

Figure 9: 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=402)

Figure 10: Time of Day When Vehicle Commuters Typically Arrive Home



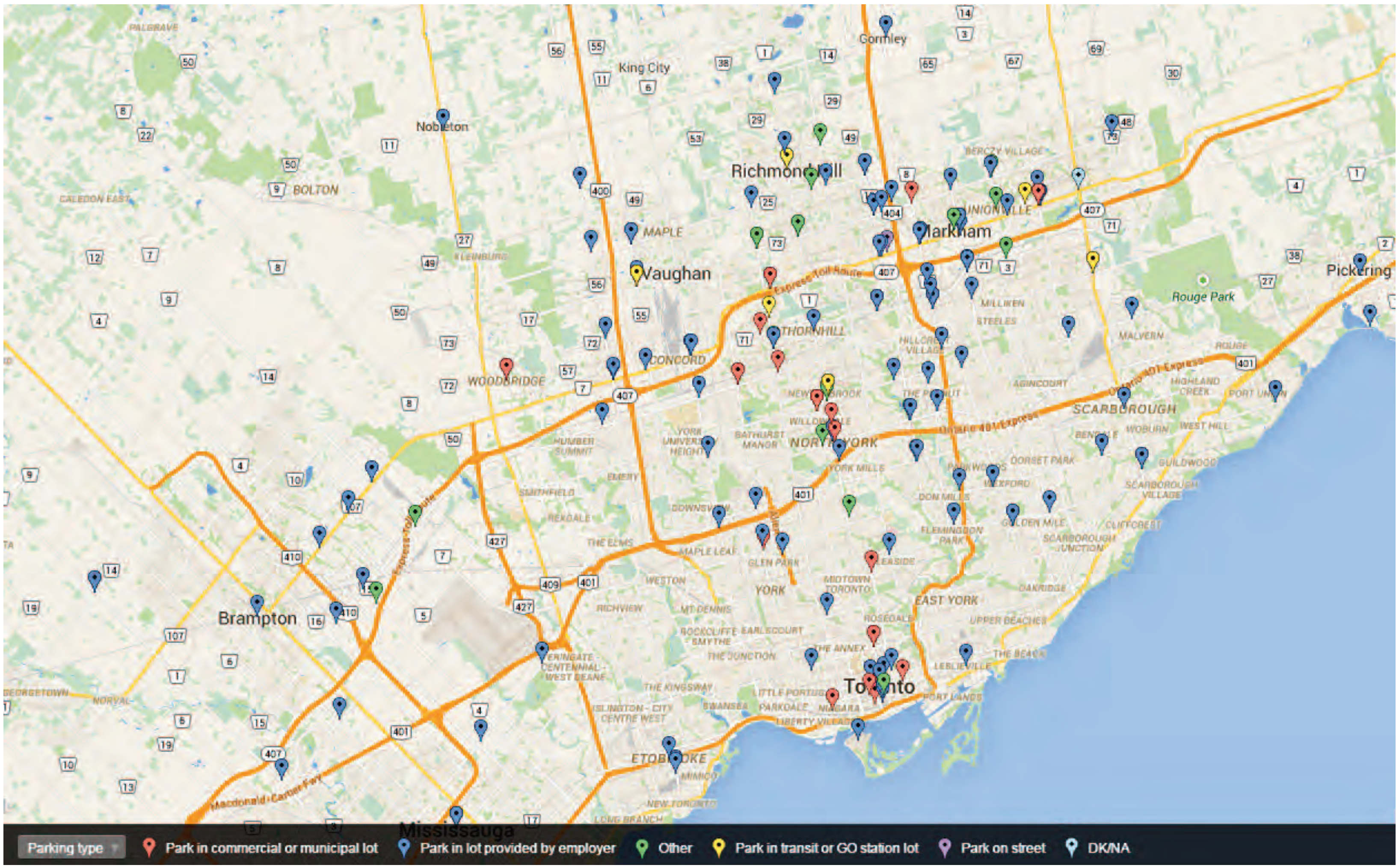
Subsample: Those who leave their vehicle at a specific location at least 3 days per week for at least 3 hours (N=402)

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, the majority (69 per cent) of vehicle commuters indicated that they park in an employer-provided lot.

When asked to name the major intersection nearest the location where they typically leave their vehicle, vehicle commuters reported locations throughout the Greater Toronto Area (see Figure 11).

Figure 11: Vehicle Commuter Parking Locations in Markham, Richmond Hill and Vaughan by Lot Type



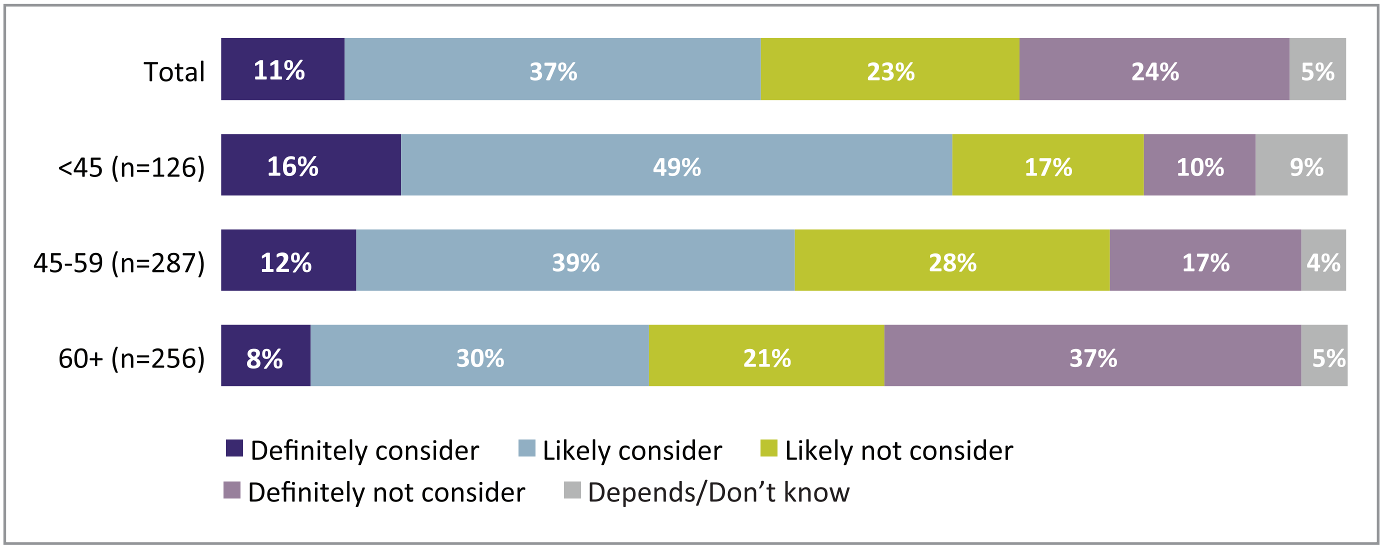
Awareness and Perceptions of Electric Vehicles

Likelihood of Considering an Electric Vehicle

Half of potential early adopters would consider purchasing a PHEV in the next couple of years.

Half of potential early adopters said that they would likely (37 per cent) or definitely (11 per cent) consider a PHEV if they were purchasing or leasing a vehicle in the next couple of years. A similar number felt that they would likely not (23 per cent) or definitely not (24 per cent) consider one within the next two years. Age is an important factor in the potential purchase of a PHEV, with the likelihood of considering one highest among those under the age of 45 (65 per cent) and decreasing with age. As previously noted, some experience with an EV is slightly higher among those who would likely or definitely consider purchasing a PHEV in the next couple of years.

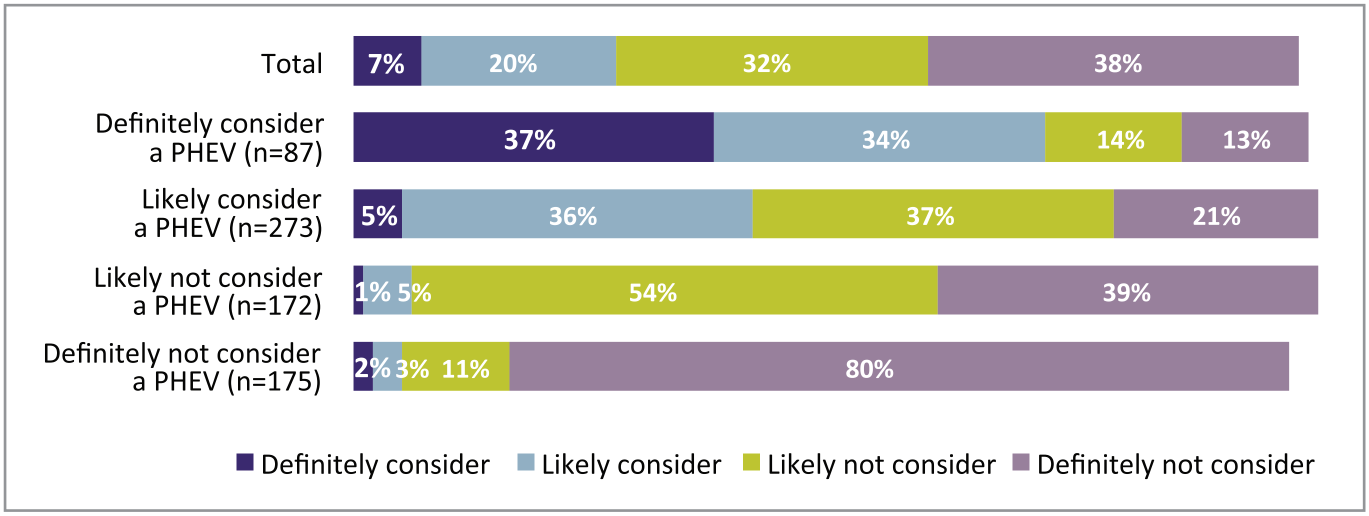
Figure 12: Likelihood by Age of Considering a Plug-In Hybrid Electric Vehicle



Around one quarter of potential early adopters would consider purchasing a BEV in the next couple of years.

Around one quarter of potential early adopters said that they would likely (20 per cent) or definitely (7 per cent) consider a BEV if they were purchasing or leasing a vehicle in the next couple of years. A majority of seven in ten said that they would likely not (32 per cent) or definitely not (38 per cent) consider one. Interest in a BEV is linked to interest in a PHEV, although a small number of those who said they would not consider a PHEV would consider a BEV (5 per cent). Age is also an important factor in the consideration of a BEV, with the likelihood lowest among those 60 years of age and older.

Figure 13: Likelihood of Considering a Battery Electric Vehicle by Likelihood of Considering a Plug-In Hybrid Electric Vehicle

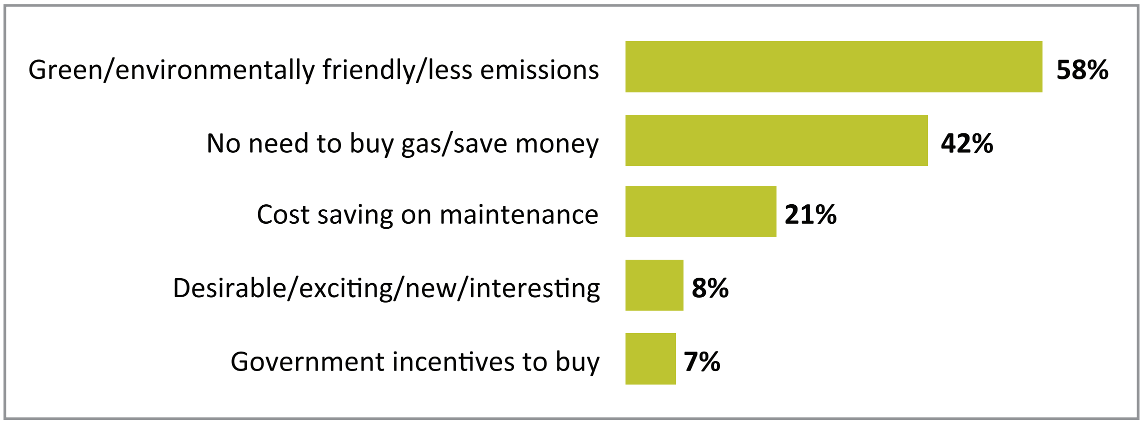


Perceived Barriers and Opportunities

Potential environmental benefits are the most mentioned advantage of BEVs. Limited range is the most mentioned barrier.

Close to two-thirds (58 per cent) of those who would likely or definitely consider purchasing a BEV mention that the main advantages of the vehicle are the potential environmental benefits and the opportunity to reduce vehicle emissions. Forty-two per cent mention not having to purchase gas, and 21 per cent note the cost savings related to vehicle maintenance. A smaller number report an interest in EVs as an emerging technology and in the current government vehicle purchase incentives.

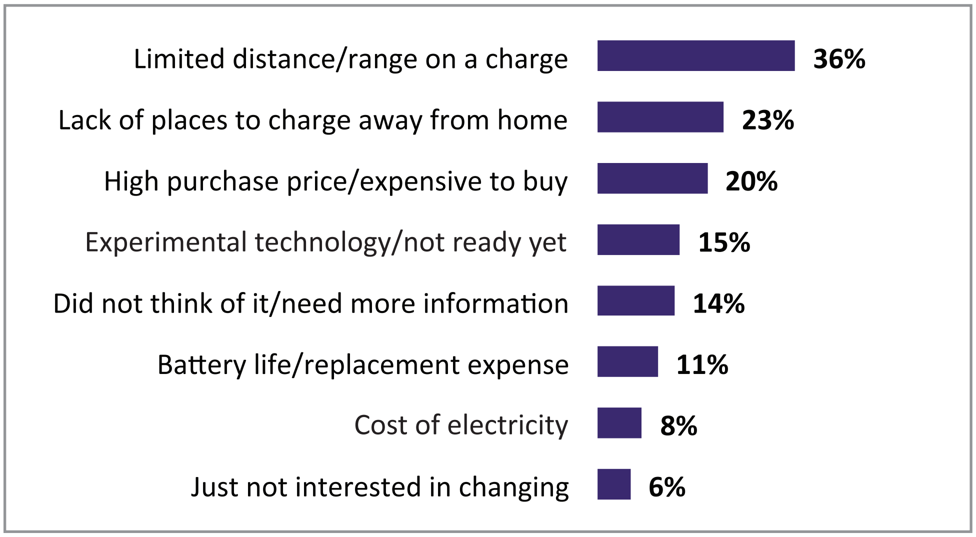
Figure 14: Top Reasons for Considering a Battery Electric Vehicle



Subsample: Would definitely/likely consider a BEV (N=195)

Thirty-six per cent of those who indicated that they would definitely not or likely not consider a BEV felt that the most important reason for not doing so was the potentially limiting range of the vehicle. A further 23 per cent mentioned the lack of charging locations away from home, and 15 per cent felt that the technology is still experimental and not ready yet.

Figure 15: Top Reasons for Not Considering an Electric Vehicle

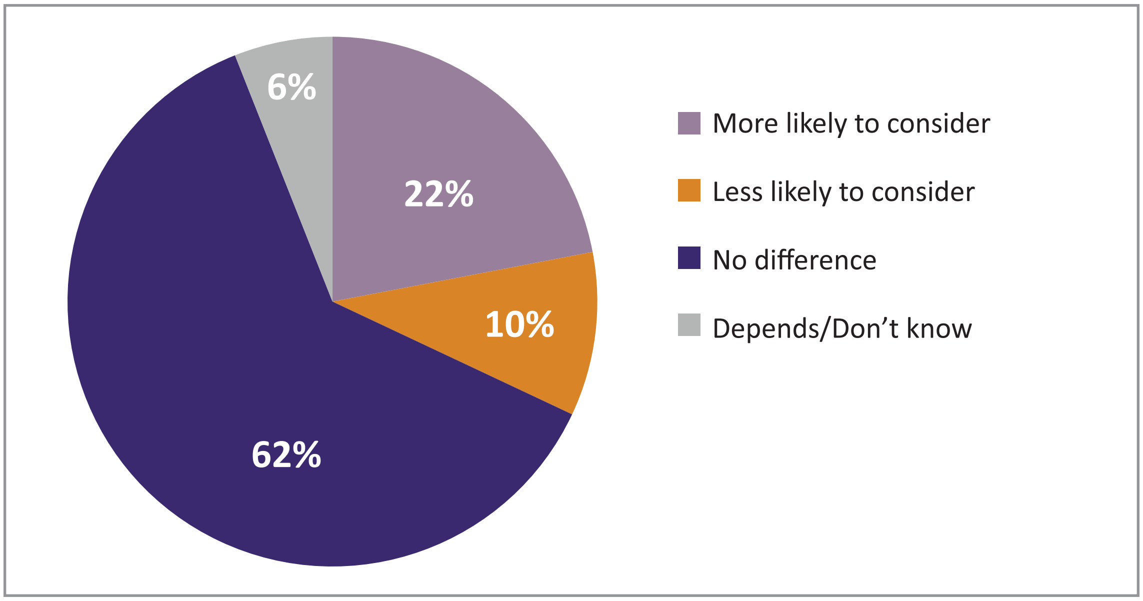


Subsample: Would definitely not/likely not consider a BEV (N=518)

Knowing that a PHEV has the same range as a gasoline-powered vehicle is not enough to sway the majority of those who are not likely to consider one.

Those who would likely not or definitely not consider either a PHEV or a BEV were informed/reminded that when a PHEV is running low on battery power, the gasoline engine takes over, meaning that the vehicle range is the same as that of a conventional, gasoline-powered vehicle. Six in ten said that knowing this made no difference to their willingness to consider a PHEV, while 22 per cent said that it did make them more likely to consider one. Interestingly, 10 per cent indicated that this would, in fact, make them less likely to consider a PHEV.

Figure 16: Likelihood of Considering a Plug-In Hybrid Electric Vehicle After Being Informed/Reminded That Its Range Is the Same as That of a Gasoline-Powered Vehicle

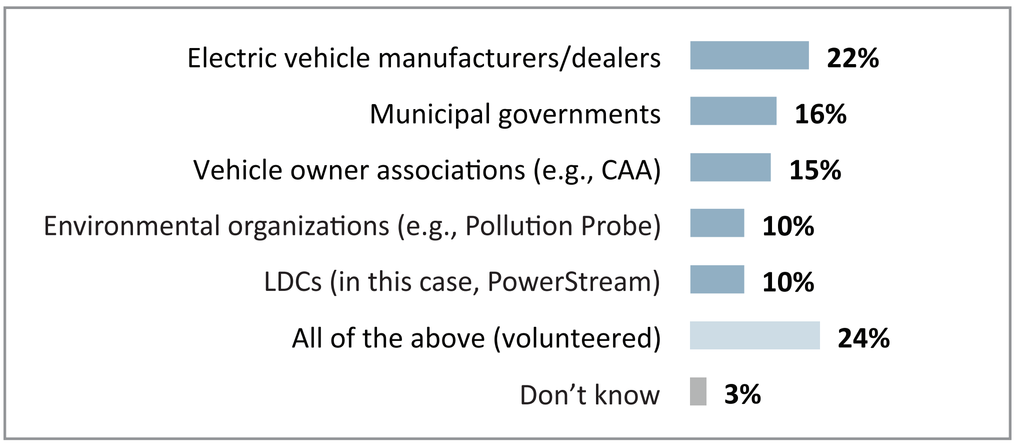


Subsample: Would definitely not/likely not consider a PHEV or BEV (N=359)

Nearly one-quarter of potential early adopters think that a range of stakeholders should play a role in providing consumers with information about EVs.

Potential early adopters were asked which organization (EV manufacturers and dealerships, municipal governments, vehicle owner associations, environmental organizations or the LDC) should be involved in providing information about EVs to consumers. Although it was not one of the options offered, the most common response was that all five of the organizations should be involved. This response was followed closely by EV manufacturers and dealerships (22 per cent), municipal governments (16 per cent) and vehicle owner associations (15 per cent). Both environmental organizations (10 per cent) and the LDC (10 per cent) were mentioned by one in ten potential early adopters.

Figure 17: Organizations That Should Be Involved in Providing Information about Electric Vehicles to Consumers

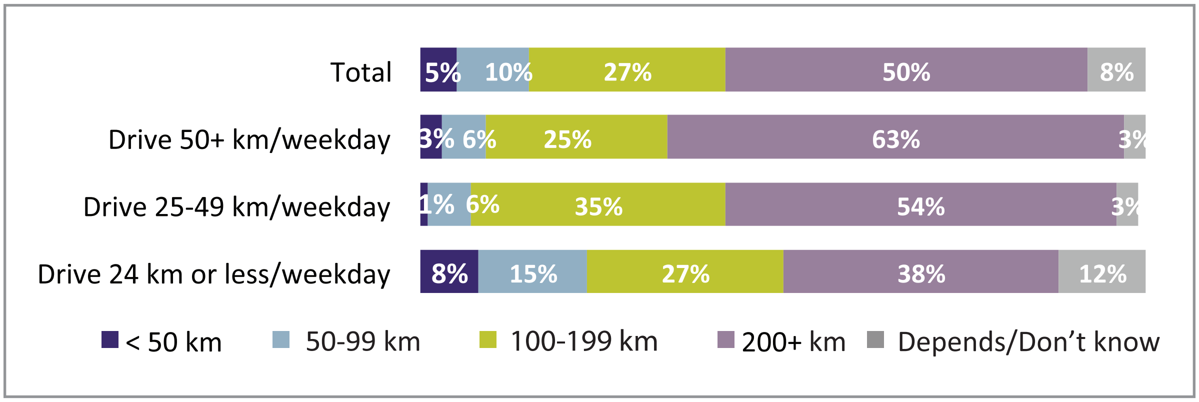


Charging Expectations

A BEV would have to have a range of at least 200 kilometres on a single charge for half of the potential early adopters to feel comfortable.

Half of potential early adopters (50 per cent) said that a BEV would have to be able to travel more than 200 kilometres on a single charge for them to feel comfortable that they would not get stuck somewhere without access to charging facilities. Just over one-quarter (27 per cent) would be comfortable with a charge that lasted between 100 and 200 kilometres, and fifteen per cent would find a range of less than 100 kilometres acceptable.

Figure 18: Acceptable Distance for Travel on a Single Charge

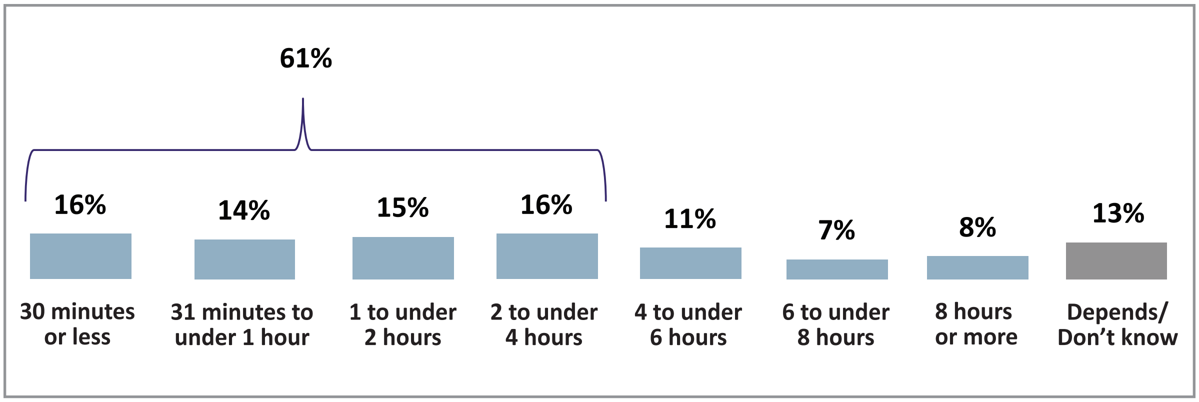


Subsample: Would definitely/likely/likely not consider a BEV (N=467)

The majority of those who would consider purchasing a BEV think that it should take less than four hours to fully charge.

A range of opinions were expressed when those who would be at least marginally likely to consider a BEV purchase in the next couple of years were asked what they felt would be an acceptable length of time to fully charge the vehicle. Almost two-thirds of potential early adopters think that it should take less than four hours to charge. About one-third of those who would consider purchasing a BEV felt that it should take less than one hour for a full charge.

Figure 19: Acceptable Length of Time to Fully Charge a Battery Electric Vehicle



Subsample: Would definitely/likely/likely not consider a BEV (N=467)

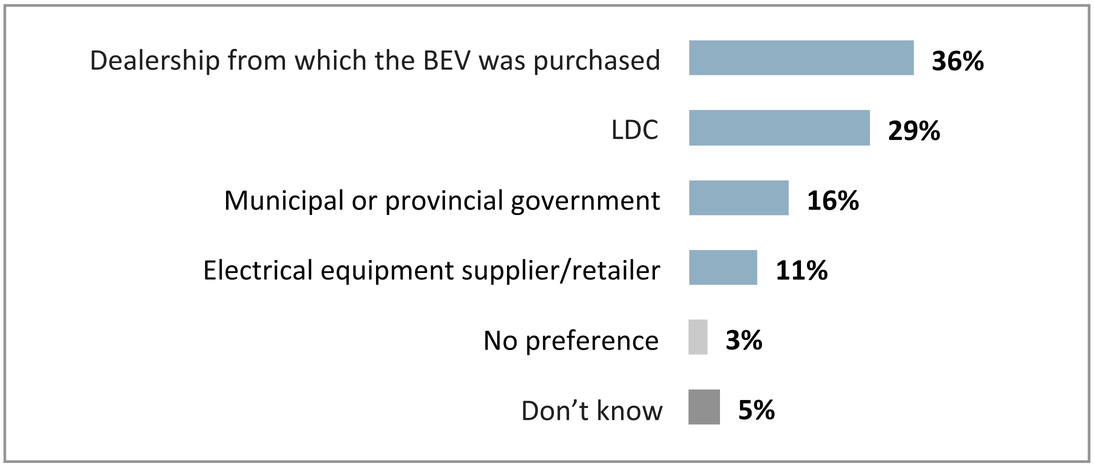
Access to faster home charging is considered very important.

Potential early adopters understand that BEVs need time to charge, unlike a gasoline-powered vehicle with a gas tank that can be filled quickly. However, more than half of potential early adopters think that it should take less than four hours (similar to the length of time it takes to charge an iPod) to fully charge the vehicle. When told that charging the vehicle could take 12 hours or more using a standard household outlet, depending on how depleted the battery is, an overwhelming majority said that it would be very (79 per cent) or somewhat (17 per cent) important to be able to charge faster – for example, with a more powerful Level 2 charger installed at home. This is consistent with almost two-thirds of those who would consider purchasing a BEV indicating that an acceptable length of time to fully charge the vehicle would be less than four hours.

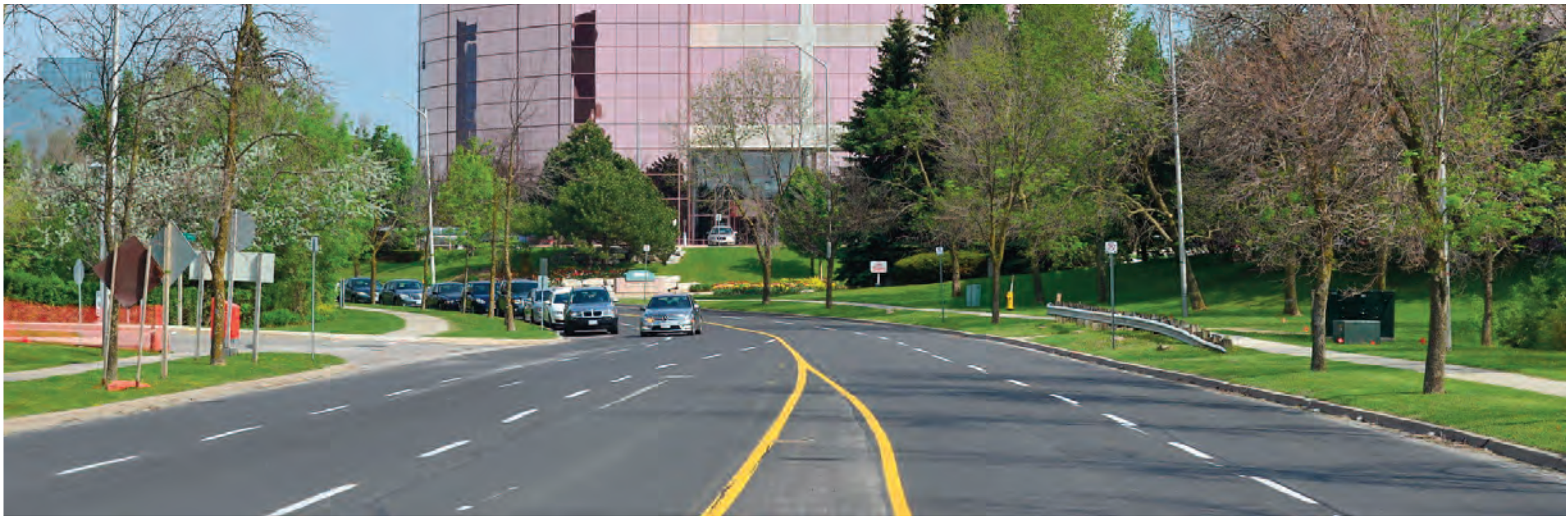
Potential early adopters would prefer the dealership to install and maintain a home charging station.

Those who said that it would be at least somewhat important to charge a BEV faster were asked which of four potential service providers they would prefer to have install and maintain a Level 2 charging station at their home. Thirty six per cent said that they would prefer this to be done by the dealership from which the BEV was purchased, while 29 per cent mentioned the LDC, 16 per cent chose the municipal or provincial government and 11 per cent preferred an electrical supplier/retailer to act as the primary service provider.

Figure 20: Preferred Service Provider for Installing and Maintaining an At-Home Charging Station



Subsample: Important to charge BEV faster (N=448)



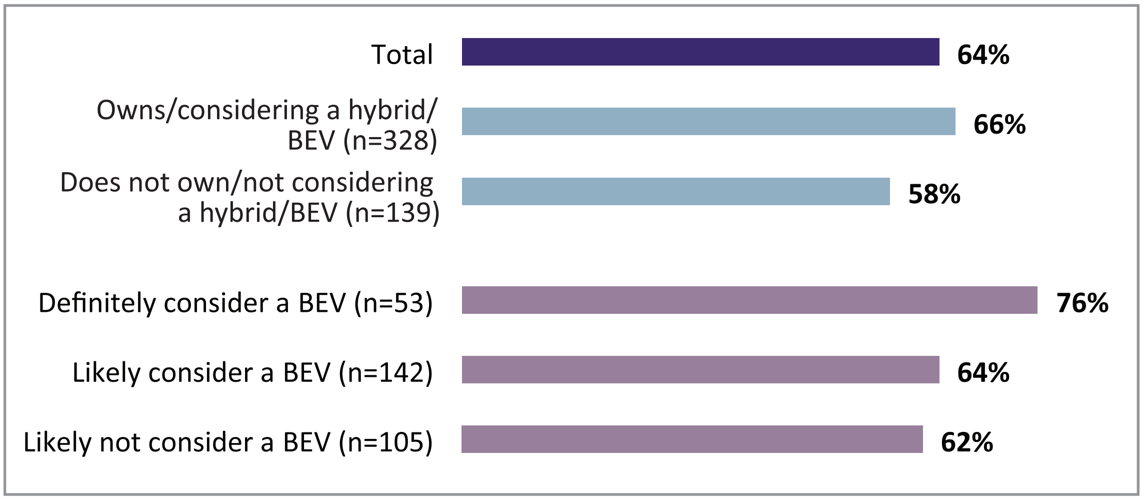
Access to workplace charging is considered very important in deciding whether to purchase a BEV.

Those who would at least marginally consider a BEV were asked how important access to workplace charging would be in influencing their decision to purchase a BEV in future. Six in ten (59 per cent) said that workplace charging would be a very important consideration while another two in ten (21 per cent) said that it would be somewhat important.

The majority of potential early adopters would be willing to pay two dollars more per hour to charge a BEV at a public parking space.

When those who own a BEV or would at least marginally consider one were asked if they would be willing to pay two dollars per hour more than the standard parking rate to be able to charge their vehicle while parking, 64 per cent said that they would be willing to do so. Twenty-nine per cent said that they would not pay extra, while four per cent said that it would depend, for example, on how much charge was needed or if other parking spots were available. It should be noted that, in practice, EV owners familiar enough with their vehicle's range might not be willing to pay an extra fee because they would feel confident that they could wait to return home to charge their EV.

Figure 21: Willingness to Pay an Additional Two Dollars per Hour to Charge at a Public Parking Space

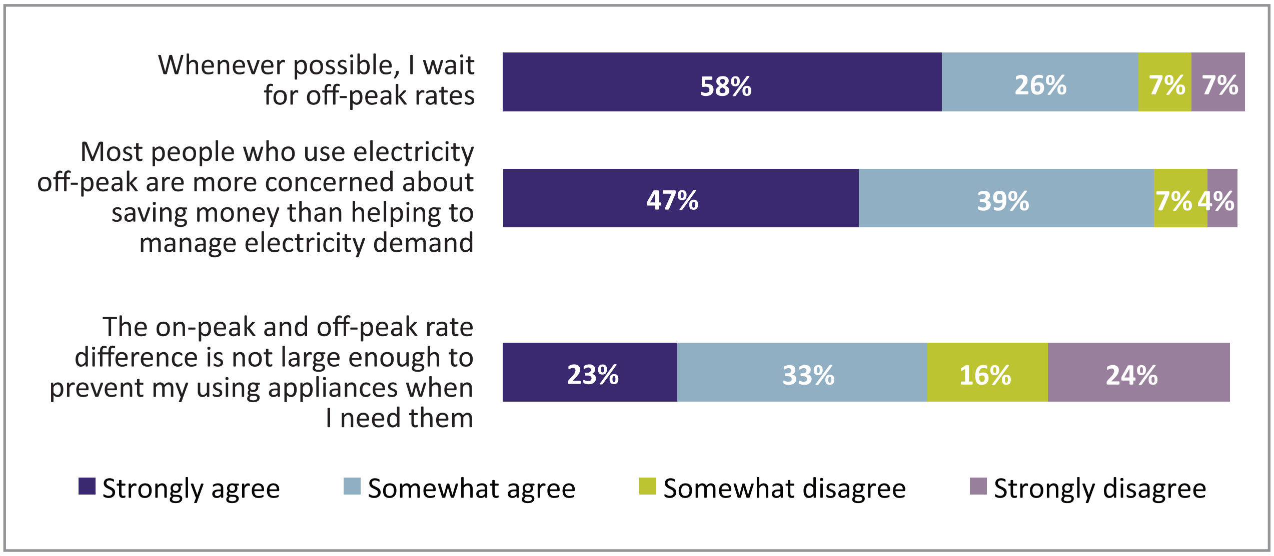


Subsample: Would definitely/likely/likely not consider a BEV (N=467)

The majority of potential early adopters wait to use high electricity consumption devices during off-peak hours.

Potential early adopters were asked to indicate their level of agreement with three statements about time-of-use rates. The majority (58 per cent) strongly agreed that "Whenever possible I wait for off-peak rates before using high electricity consumption devices, such as clothes dryers or dishwashers." About half (47 per cent) also agreed with the following statement: "Most people who use electricity off-peak are more concerned about saving money than about helping to manage electricity use across the grid." However, agreement was divided about the statement "The difference between on- and off-peak rates is not large enough to prevent me from using a high electricity consumption appliance whenever I need it." This suggests that EV charging behaviours would likely be similar, with most potential early adopters opting to charge off-peak to save money if possible but not regarding time-of-use rates as sufficiently compelling to prevent them from charging on-peak if need be.

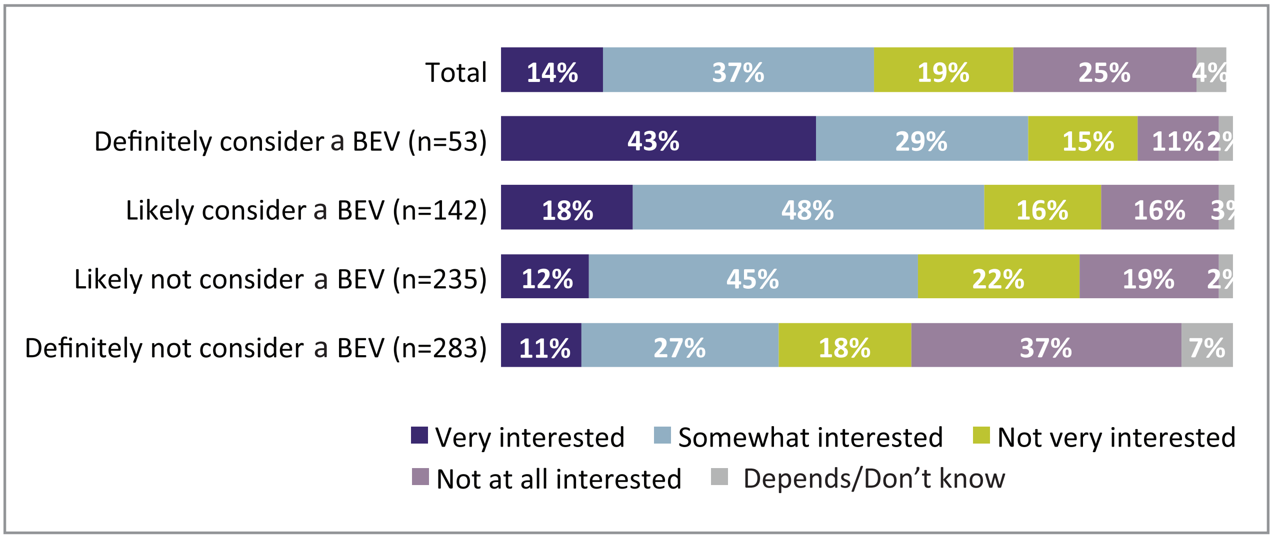
Figure 22: Statements for Encouraging Off-Peak Charging



Half of potential early adopters would be interested in participating in a demand response program.

Potential early adopters were asked to indicate their level of interest in participating in a demand response program that would allow the LDC to control energy-consuming devices within their homes for the purpose of better managing power consumption across the electricity grid, which would in turn save the participating customers money on their electricity bills. More than half indicated that they would be very (14 per cent) or somewhat (37 per cent) interested in such a demand response program. Interest in demand response programs is linked to an overall interest in BEVs, with 71 per cent of those who would definitely consider a BEV also showing interest in demand response programs, compared to 38 per cent who would definitely not consider one.

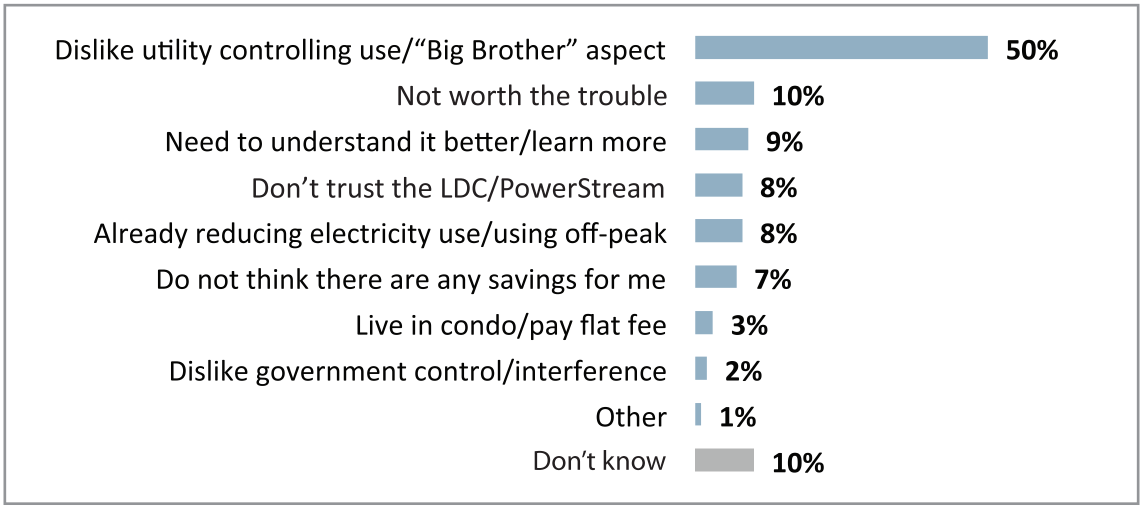
Figure 23: Interest in Demand Response Programs by Level of Interest in Battery Electric Vehicles



Trust is the most important consideration for those early adopters who are not interested in demand response programs.

When those who indicated that they were not interested in demand response programs were asked why, half mentioned that they dislike the idea of the LDC controlling their use of power. An additional 8 per cent said that they distrust the LDC in general, while 2 per cent mentioned not wanting government control or interference. One in ten felt that a demand response program would not be worth the trouble, 9 per cent said that they would need to learn more about the program and 8 per cent mentioned that they were already reducing electricity use or waiting to use electricity during off-peak times.

Figure 24: Reasons for Not Considering Participation in a Demand Response Program

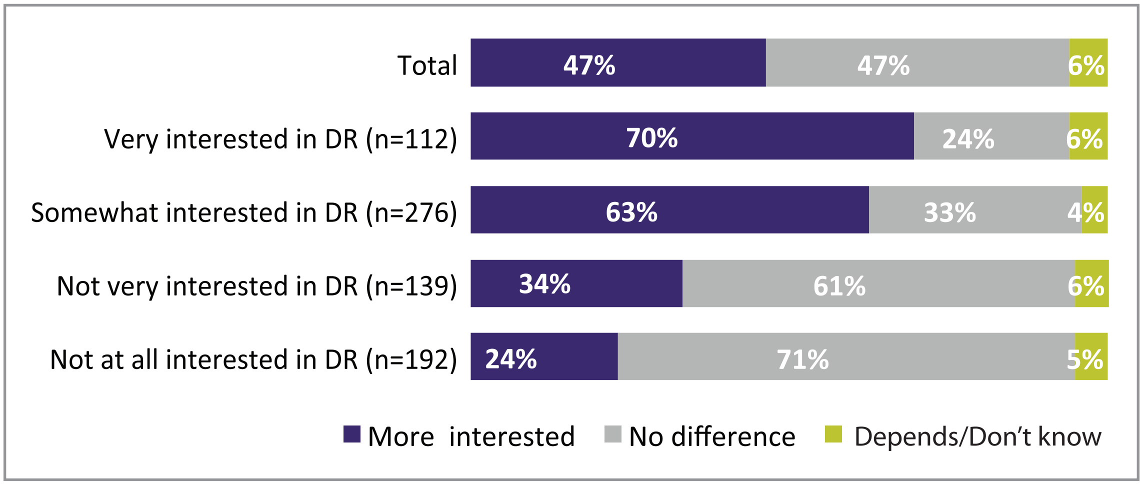


Subsample: Those not very/at all interested in demand response programs (N=331)

Close to half of early adopters feel that the ability to override a demand response program would increase their interest in participating in one.

Close to half (47 per cent) of early adopters indicated that the ability to override a demand response program would increase their interest in one, while the same proportion said that it would make no difference. Those who indicated that they would definitely consider either a PHEV or a BEV are more likely than others to say that an override feature would increase their interest in such a program.

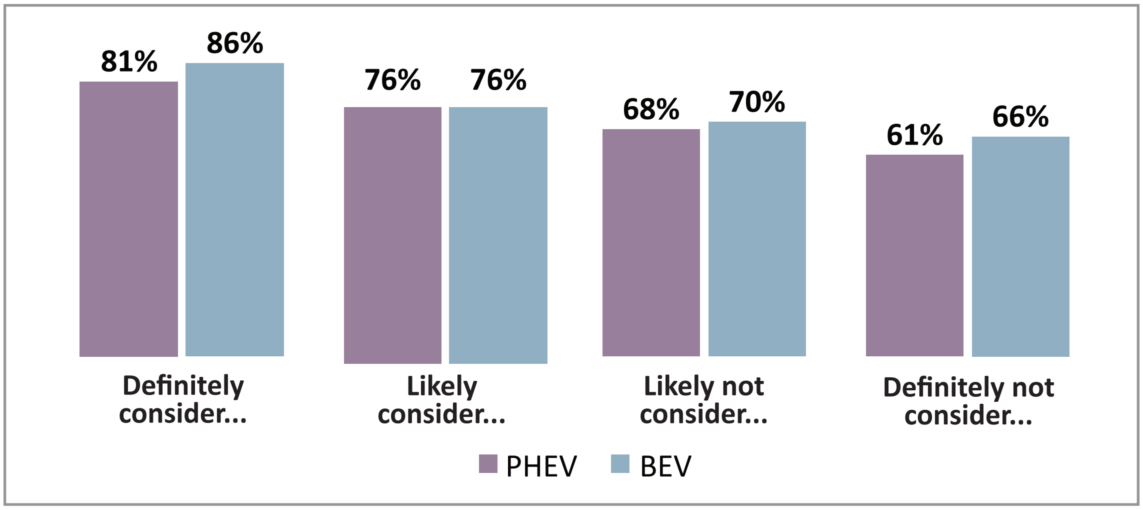
Figure 25: Interest in a Demand Response (DR) Program Provided That an Override Option Were Available



Validation of Preliminary Assumptions

Potential early adopters who said that they would definitely consider an EV expressed greater agreement with statements about ecological consciousness, interest in technology and consumptivity than those less likely to consider an EV. 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 ecological consciousness and interest in technology.

Figure 26: Responses to the Statement "I avoid using the services or products of companies that I consider to have a poor environmental record" by Likelihood of Considering a Plug-In Hybrid Electric Vehicle or a Battery Electric Vehicle



Each of the six early adopter segments was cross-referenced with the number of "definitely consider" responses about a potential PHEV or BEV 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 either a PHEV (Figure 27) or a BEV (Figure 28). The recalibrated maps detail the areas in the Cities of Markham, Richmond Hill and Vaughan where the adoption of PHEVs and BEVs will likely take place.

Figure 27: Strength of Interest in Purchasing a Plug-In Hybrid Electric Vehicle by Dissemination Area in the Cities of Markham, Richmond Hill and Vaughan

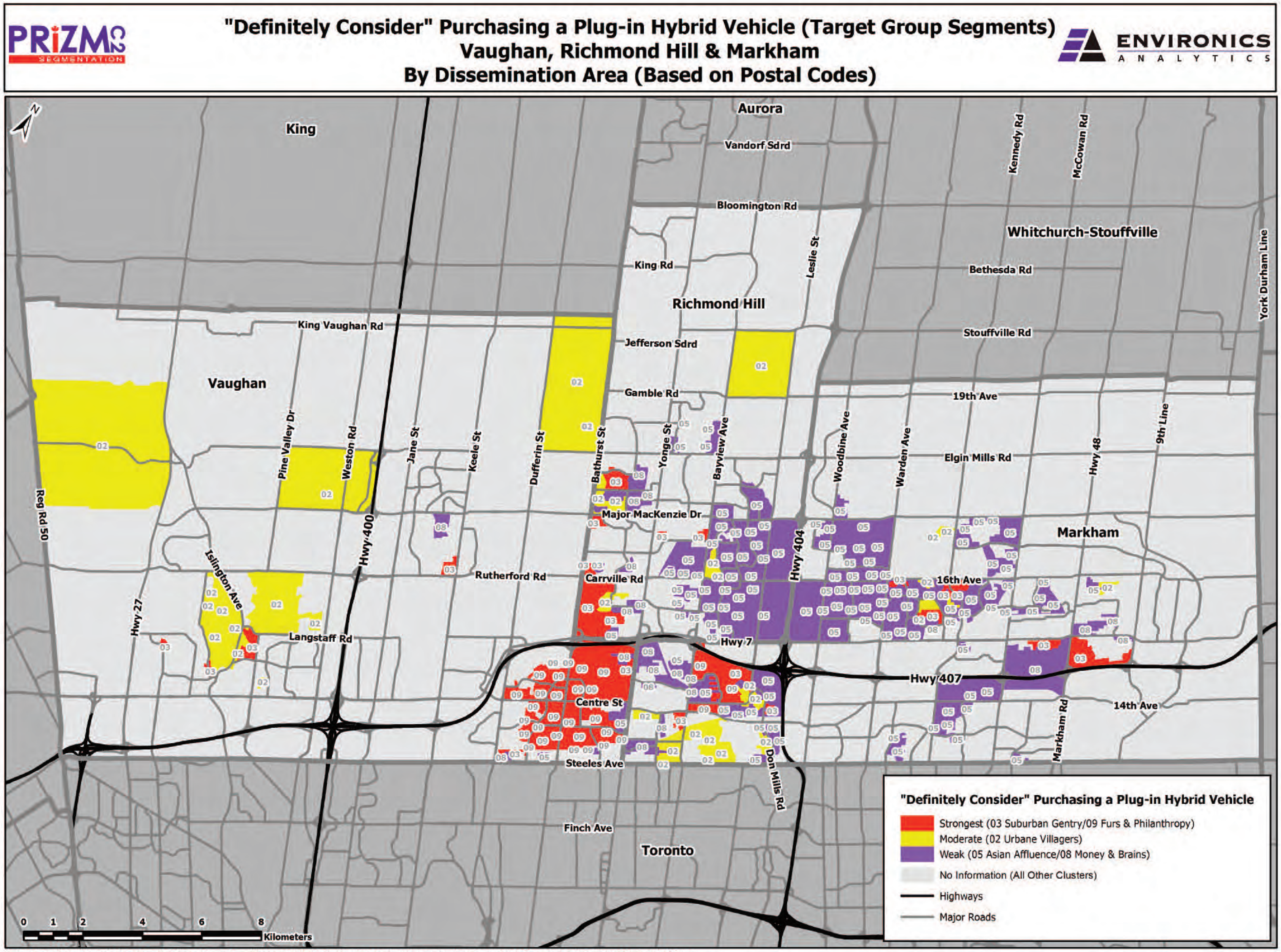
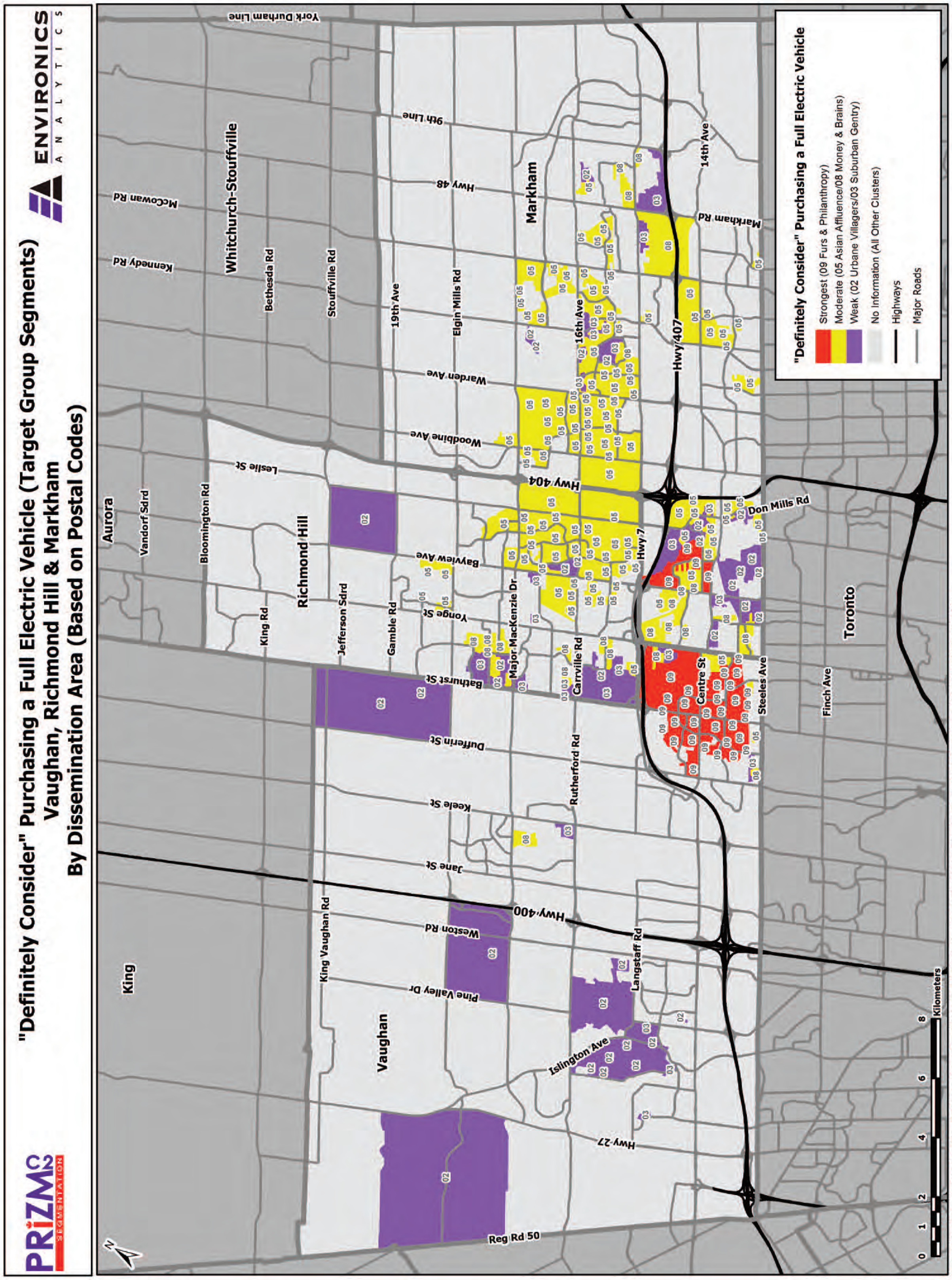


Figure 28: Strength of Interest in Purchasing a Battery Electric Vehicle by Dissemination Area in the Cities of Markham, Richmond Hill and Vaughan



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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 EVs. The findings from the household telephone survey provide a robust foundation for determining strategies to facilitate the successful uptake and integration of the technology in Markham, Richmond Hill and Vaughan.

Potential early adopters in Markham, Richmond Hill and Vaughan are more likely to be over the age of 45, more affluent and better educated than the general population. The survey results suggest that even among potential early adopters, purchasing or leasing an EV is not imminent, and few report having personal experience driving or riding in one. Concerns about the purchase price and current lack of infrastructure, as well as the potentially limiting range of the vehicle, are perceived as major barriers to the adoption of EVs. Vehicle range is the most mentioned barrier and, interestingly, even when it was pointed out to potential early adopters that a PHEV has the same driving range as a conventional, gasoline-powered vehicle, only a small minority were more inclined to purchase one. This suggests that much of the resistance to the technology may be related to a combination of factors, rather than to any one single barrier.

The survey results suggest that even among potential early adopters, purchasing or leasing an EV is not imminent, and few report having personal experience driving or riding in one.

The survey findings also identified important opportunities for the promotion of EV uptake. For example, the majority of potential early adopters felt that access to faster home charging would be very important. This points to an opportunity to promote technology that enables faster home charging as a means of overcoming a perceived barrier. In addition, potential early adopters may be open to participating in demand response programs, particularly if they have the option to override the program at their own discretion. These insights can help the LDC tailor its services to effectively allow existing distribution assets to reliably service EV charging.

The market research can be used to determine methods for advancing awareness of the value proposition of EV use among potential end-users, establishing a solid foundation for the growth of the EV industry.

The market research can be used to determine methods for advancing awareness of the value proposition of EV use among potential end-users, establishing a solid foundation for the growth of the EV industry. The results can inform a comprehensive understanding of the knowledge and information required to plan and prepare for the continued deployment of EVs in Markham, Richmond Hill and Vaughan. 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, thus decreasing the efficiency of these investments and increasing the cost of enabling EV use in Markham, Richmond Hill and Vaughan.

Section Two of the EMAP report has described the methodology and results of two separate but interrelated market research investigations. Section Three of the report describes the process of assessing the capacity of the electricity distribution system to accommodate the additional loading predicted as a result of the uptake of EVs.

SECTION THREE:
Electricity Distribution System Assessment

Purpose of Assessing the Electricity Distribution System

The electrical power generation and transmission systems serving the Cities of Markham, Richmond Hill and Vaughan are capable of supporting a robust market for EV charging and use. However, the capacity of the local distribution system to deliver power to EV end-users could be constrained under certain conditions. The EMAP market research showed that potential early adopters of EV technology may exhibit consumer values that are shared by others in their communities. This could lead to "clustering" of early EV adopters, which, in turn, could create conditions in which the electricity distribution system might be constrained in its capacity to support EV-related loads.

The EMAP market research survey generated a body of evidence that richly characterizes the market for EVs in Markham, Richmond Hill and Vaughan. It also provides a better understanding of the nature of the charging services required to support EV deployment (i.e., when vehicles would be plugged in, for how long, and the importance of fast charging to the end-user). The findings from the market research were the basis for an assessment of the capacity of the electricity distribution system to accommodate the predicted patterns of demand for power to charge EVs.

Understanding how EVs are likely to change the profile of power demand at the neighbourhood level is critical to making informed, strategic and effective investments in technology and infrastructure to maintain and improve quality of service.

Understanding how EVs are likely to change the profile of power demand at the neighbourhood level is critical to making informed, strategic and effective investments in technology and infrastructure to maintain and improve quality of service. The findings presented in this report provide a foundation upon which to base strategies for addressing the deployment of EVs within the PowerStream service area by ensuring that these strategies align with the needs of the early adopter market, defined by location, mobility patterns and attitudes toward EV charging and use.

Terms and Definitions

The following section provides an overview of a number of key terms related to the basic units of electricity as well as power system configurations, with examples drawn from Markham, Richmond Hill and Vaughan in particular and from the PowerStream service area as a whole. The definitions and descriptions are provided solely for the purpose of supporting the discussion of the EMAP electricity distribution system assessment and are not intended to reflect the intricacies of either the basic units of electricity or electrical power systems in general.

Basic Units of Electricity

The following basic units of electricity are used throughout this report in relation to potential constraints on the electricity distribution system:

Current (I) is the flow of electric charge through a conductor, such as a copper wire. Current is measured in amperes (A), often referred to as amps. Electrons are induced to move by electromagnetic forces, described as voltage.

Voltage (V) is a measure of electrical energy, or the work that an electromagnetic field can impart to a charged particle. Measured in volts (V), it is the energy that induces electrons to move in a conductor. Volts are also used to express the voltage applied to a circuit by an energy source, such as a battery or an electrical generator; in this context, voltage can also be referred to as **electromotive force**.

Resistance (R) is a measure of a material's tendency to oppose the flow of electrical current. Resistance is expressed as the ratio of voltage to current and is measured in ohms (Ω). The greater the resistance, the less electrical current flows through a conductor and the more the voltage (i.e., the electrical energy) applied to the conductor is converted to heat energy that dissipates into the immediate surroundings. Keeping current levels low in an electric wire is one way to minimize the amount of electrical energy that is converted and lost as heat. Such losses are known as **line losses**.

This report also makes frequent references to three other terms related to electricity: **power**, **load** and **energy**.

Power is the time rate at which energy (e.g., the energy of electrons carrying charge to a battery through a conducting wire) is transferred or converted. Power is expressed as the product of voltage and current, and is measured in watts (W). For example, a wire carrying a current of 15 A at 110 V is transferring energy at a rate of 1,650 W. A watt is a per-second measure of energy transfer or conversion. A kilowatt (kW) is equal to 1000 W and is one of the units typically used to express the maximum power characteristics of an electric motor or a transformer. For example, the charging systems built into new EVs (i.e., the on-board chargers) referenced in this report are rated in kilowatts. Power is also measured in kilovolt-amperes (kVA). The rated power capacities of the transformers investigated in this report are expressed in kilovolt-amperes, which include active power (the power consumed by the customer load) and reactive power (the energy exchanging within inductors and capacitors in the grid). All load profiles are expressed in kW because, at the customer level, reactive power is very small compared with active power.

A **load** is any device that uses electrical energy or changes it into other forms of energy (e.g., heat, light, mechanical energy). An EV plugged in to charge its battery is an example of an electrical load. If the EV is plugged into a socket that supplies electricity at 15 A and 110 V, power flows at 1,650 W – similar to a typical hair dryer.

What is the difference between a watt and a volt-ampere?

Both watts and volt-amperes can be used to express power when direct current (DC) circuits are being measured. In alternating current (AC) circuitry, which is a more common design in transmission and distribution systems, volt-amperes are used to accurately express more complex power characteristics.

Energy, measured in kilowatt-hours (kWh), is the product of the power (i.e., the rate at which energy is transferred) and the time over which it is supplied (Energy = Power x Time). A kWh is the basic unit of measurement used by LDCs to bill customers for energy delivery and use. An EV battery charging at 1,650 W for eight hours stores approximately 13 kWh of energy.

The Electrical Power System

The primary focus of the electricity distribution system assessment is the distribution system at the secondary, or neighbourhood, level. To better understand the implications of EV charging for the distribution system, it is important first to explore the functions of some of the electrical power system components. The following section provides a simplified description of these functions; it is not intended to reflect the intricacies of any particular system.

The purpose of the electrical power system is to connect the centres of demand for electricity (i.e., the end-users) with the sources of supply (i.e., the power plant). Because the capacity to store electricity once it is generated is limited, the balance of supply and demand in Ontario is delicately managed on an instant-by-instant basis by the Independent Electricity System Operator (IESO). If customers generated their own electricity to meet their own individual needs, no system of transmitting or distributing power would be needed. In reality, however, because the centres of demand are usually located far from the sources of supply, transmission and distribution are essential elements of today's power system.

In general, the power system involves electricity being generated at a power plant, where it is converted, or "stepped up," to very high voltages for transmission over long distances and then "stepped down" to lower voltages for distribution to end-users.

GENERATION

At the core of almost all generating stations is a series of turbines that are driven by water, steam or combustion gases. Connected by a driveshaft, the turbines cause an electromagnet inside the generator to rotate. The movement of the magnetic field induces a current in the surrounding coils of wire within the generator, producing a voltage that can feed the transmission system. The voltage and power levels generated are directly related to how quickly and with how much force the generator spins. Some generating stations in Ontario are privately owned and operated, while some are publicly owned. The largest power generator in the province is a Crown corporation, Ontario Power Generation.

TRANSMISSION

A **transmission substation** is located at or near the generating station. The transmission substation contains a large **step-up transformer**, which increases the voltage produced by the generator to the high levels required for long-distance transmission. Electrical power systems generally use a series of transformers to convert electricity to different voltage levels appropriate for each stage of the system.

Individual households are usually located far from the generation station. To reach the consumer, the electricity generated must be conducted by wires spanning long distances. High-voltage **transmission lines** are used for this purpose. A few high-voltage transmission lines can carry more electrical energy, more efficiently, than a larger number of lower-voltage lines. Also, the transmission of electrical power at high voltage keeps current levels low, and this minimizes resistance and line losses. While for the majority of end-users, these high voltages (500 kV, 230 kV and 115 kV in Ontario) need to be reduced (stepped down) to a lower level for household or small business use, some industrial facilities with high electrical loads (e.g., high-power motors) may be connected directly to the transmission system. The transmission company responsible for transmitting electricity to the Cities of Markham, Richmond Hill and Vaughan is Hydro One Networks, Inc. The transmission lines servicing these cities operate at voltages of 230 kV.

Step-down transformers are found at transmission stations located close to or within the cities. These transformers convert the high voltages from the transmission lines to lower voltages for distribution. These transmission stations and lower-voltage transmission lines are sometimes referred to as the **subtransmission system**.

How does a transformer "step down" or "step up" voltage?

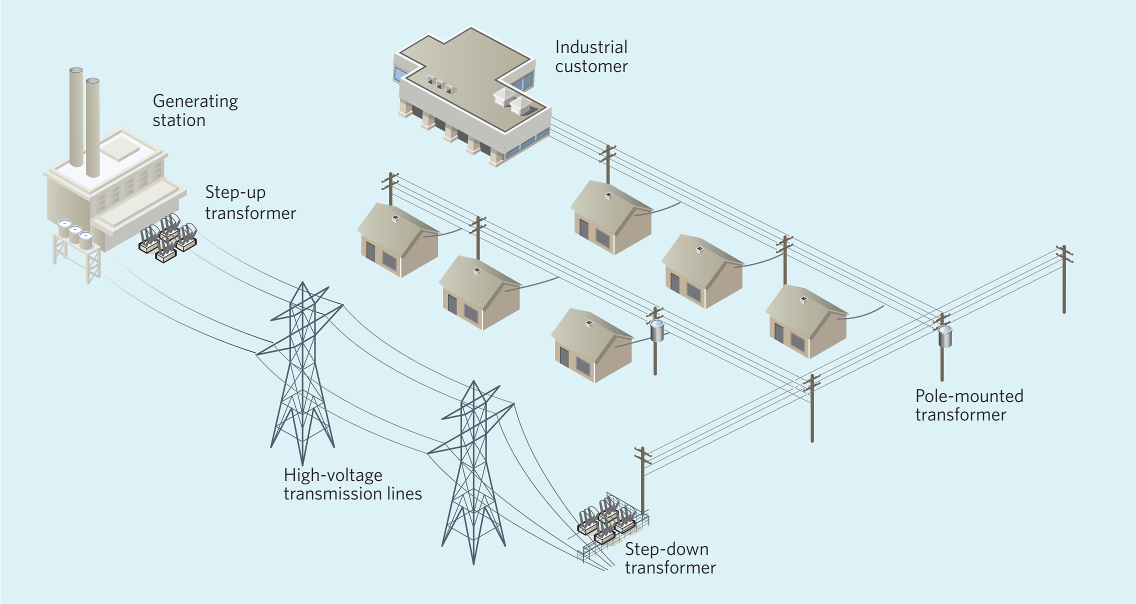
Transformers neither produce nor consume power or energy. But, by regulating power to the right levels, they make it possible for devices of all types and purposes to operate on just a few levels of power supply.

Transformers at their most essential level consist of parallel but separate coils of wire wound around a magnetic core. When voltage is applied to one coil (usually called the primary or input), it magnetizes the iron core, which induces a voltage in the other coil (usually called the secondary or output). If the secondary coil has fewer loops than the primary coil, less voltage and more current is induced in the secondary coil. This is the case with a "step-down" transformer. A "step-up" transformer works in the opposite way. With more loops in the secondary coil than in the primary coil, it increases voltage and reduces current. The turns ratio (the ratio of the number of turns on the primary coil of an electrical transformer to the number on the secondary) of the two sets of windings determines the amount of voltage transformation.

DISTRIBUTION

Electricity distribution is the final step in the delivery of electricity to end-users. The distribution system takes the electricity carried along the high-voltage transmission lines and, through a series of step-down transformers, lowers the voltage to levels appropriate for use by individual households and businesses. The distribution system is owned and operated by LDCs. As previously mentioned, PowerStream is the LDC for the Cities of Markham, Richmond Hill and Vaughan.

Figure 29: Electricity Generation, Transmission and Distribution System



The **distribution transformer station** is the point where the conversion from transmission to distribution occurs. In the PowerStream service area, these transformers step down power to one of three voltage levels – 27.6 kV, 13.8 kV and 8.32 kV, with 27.6 kV being the most common voltage level. **Distribution feeders** are electrical cables or conductors that distribute electric power from a distribution transformer station to one or more secondary transformers. The voltage level of these distribution feeders varies across the service area. Within PowerStream's service area, there are a total of 11 transformer stations that step down the voltage from 230 kV transmission lines to 27.6 kV feeders. These feeders then supply power directly to residential end-users through secondary transformers (pole-mounted or pad-mounted).

LOCAL TRANSFORMERS

Pole- or pad-mounted transformers provide the final voltage transformation in the electrical power system. These transformers step down the voltage from distribution feeders to the level appropriate for use by individual households (typically 120 V or 240 V).

When distribution feeders are located overhead, the transformer is usually mounted on a utility pole and is referred to as pole-mounted. When the distribution feeders run underground, the transformer is mounted on a concrete pad at ground level (pad-mounted).

SECONDARY CONNECTION SYSTEM

The secondary connection system supplies power from the local transformer to the end-user. The secondary connection system for a pole-mounted transformer consists of the following:

- The **secondary drop lead** is a conductor connecting the transformer to a secondary bus.
- The **secondary bus** is a common electrical connection point for the individual service cables running directly to each household serviced by the transformer.
- **Service cables** connect the secondary bus to the end-user. Service cables are the last stage of the distribution system.

Ground level, pad-mounted transformers typically supply power to residential end-users through buried service cables that run from the transformer to the individual customer. For the purposes of this report, the neighbourhood-level distribution system is defined as either the pole-or pad-mounted transformer and anything beyond it (i.e., the secondary connection system).

Methodology

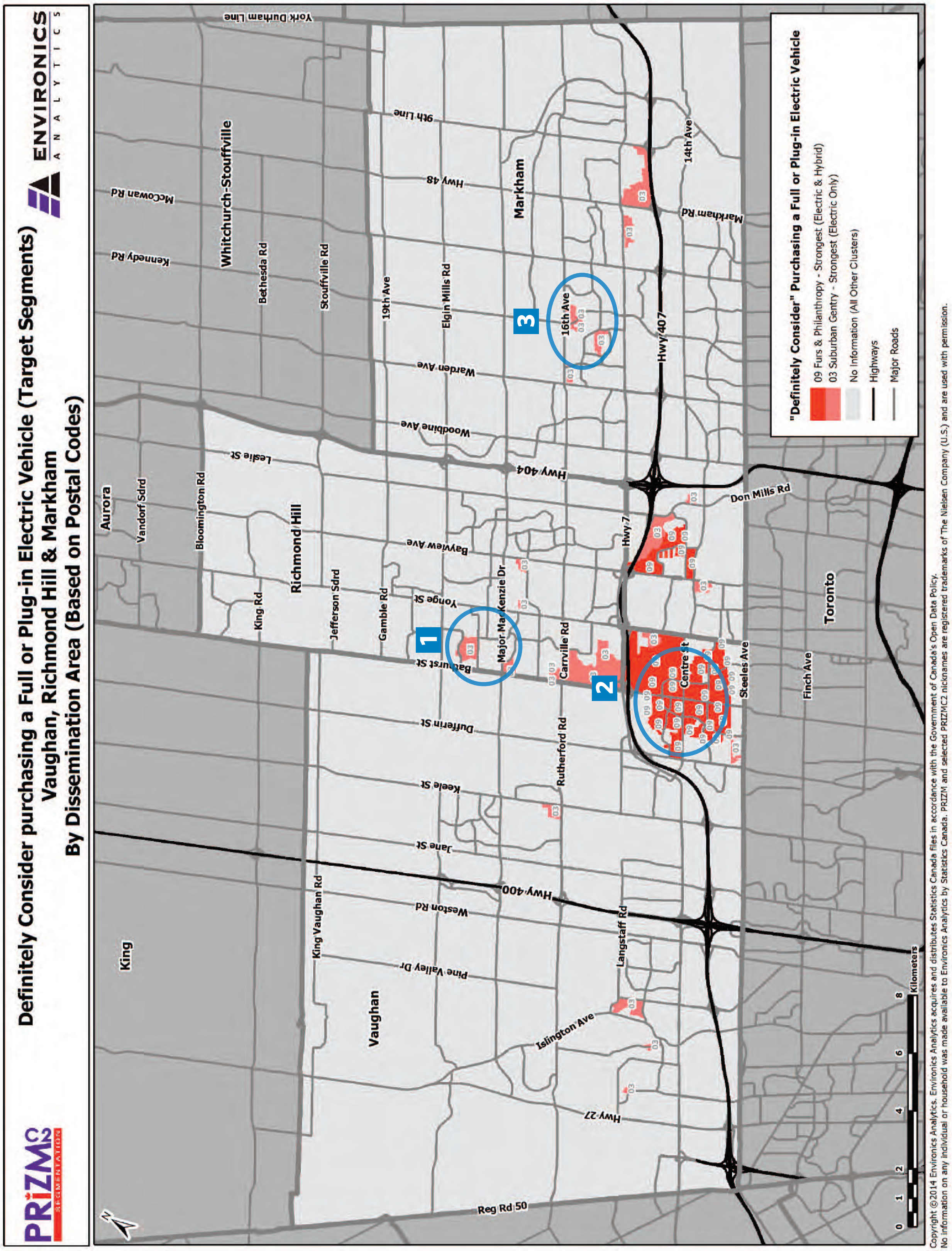
To better understand the implications of the anticipated uptake of EVs in the context of electricity demand in Markham, Richmond Hill and Vaughan, scenario development and simulation were undertaken to assess the electricity distribution system's capacity to support additional loading resulting from EV charging. The process involved a neighbourhood-level assessment of the pole- and pad-mounted transformers. The impacts of EV charging on the distribution system were simulated by Professor Warren Tracz of the School of Engineering Technology and Environmental Studies at Georgian College, using relevant feeder, transformer and load data provided by PowerStream.

The specific process, outputs and assumptions made in the development and application of the assessment are described below. Each of the scenarios modelled reflects a steady-state analysis as opposed to real-time dynamic simulations, which were beyond the scope of this study.

Assessment of the Electricity Distribution System at the Neighbourhood Level

Transformers in three residential areas were selected as test cases for the investigation of the neighbourhood-level distribution system; these residential areas correspond to neighbourhoods identified, based on responses to the market research survey, as having a high propensity for early adoption of EVs. To determine the areas to select, a new map was generated to capture the combined strength of interest in acquiring either a PHEV or a BEV, again based on responses to the market research survey (see Figures 27 and 28). The areas selected are primarily made up of single-family dwellings rather than multi-residential buildings, which is consistent with the profile of the early adopter. Figure 30 shows the three test case areas, Locations 1, 2 and 3, in Richmond Hill, Vaughan and Markham, respectively.

Figure 30: Location of Transformers Investigated in Markham, Richmond Hill and Vaughan



Relevant feeder and transformer data for the three locations were taken from CYME, an engineering software program, and used as inputs to Microsoft Excel to model the additional load on each transformer resulting from several variables associated with EV charging. Because of the large number of transformers in these three areas, three smaller sites were chosen within each location to focus the study in on transformers that could be the first to be impacted by EV charging. These sites were determined by identifying which transformers either exceeded or came within 25 per cent of their rated capacity at any point over a 24-hour period on July 17, 2013, the warmest day in the summer of the previous year (for the effects of ambient temperature on transformer capacity, see p. 55). A number of adjacent transformers were then selected to make up three sites (Sites A, B and C) within each location to demonstrate the impact of EV clustering.

The distribution system in the PowerStream service area is made up of a range of transformers with different capacities, each of which would experience the impacts related to EV penetration differently. The scenarios investigated look at various transformer capacities found within the PowerStream service area (25 kVA, 38 kVA, 50 kVA, 75 kVA and 100 kVA). Currently, the most common transformer size in the service area is 50 kVA; transformers of other sizes are likely to have been installed based on earlier practices and design standards. Table 1 provides further details specific to the transformers in each of the locations and sites investigated.

Table 1: Total Number of Transformers and Customers for Each Study Location and Site

Location and site	Number of transformers	Transformer rated capacities, kVA	Total number of customers connected
Location 1, Site A	10	50, 75	84
Location 1, Site B	8	50, 75, 100	61
Location 1, Site C	8	100	61
Location 2, Site A	5	50, 100	38
Location 2, Site B	8	50, 100	62
Location 2, Site C	8	25, 38, 50	61
Location 3, Site A	13	50	99
Location 3, Site B	7	50	65
Location 3, Site C	7	50	68
Totals	**74**	**25, 38, 50, 75, 100**	**599**

SCENARIO DEVELOPMENT AND RESULTS

By offering a means of investigating hypothetical situations, scenario development and simulation can inform the development of strategies to produce desired outcomes. A range of scenarios were investigated to better understand the extent to which key variables could impact the capacity of the electricity distribution system at the neighbourhood level to accommodate EV charging at home. In the interests of brevity, this report focuses on the findings for the transformers in Location 1, Site A. Each of the transformers in this site has a capacity of 50 kVA, with the exception of Transformer 3, which is rated at 75 kVA.

The following section outlines both the process and the key findings of the electricity distribution system assessment, including a discussion of the key variables predicted to have an effect on the capacity of the neighbourhood-level distribution system to support EV-related loads.

Investigating Key Variables

The following scenarios tested the capacity of the electricity distribution system at the neighbourhood level to accommodate the potential loading from EV charging. These scenarios were developed based on the predicted home charging patterns of early adopters of EV technology, three on-board charger capacities and the assumption that ambient temperature can create additional stress for the neighbourhood-level distribution system. While these conditions are not likely to occur simultaneously, this investigation allows for a better understanding of possible worst-case scenarios and key factors that could limit the number of EVs that can be accommodated by the electricity distribution system.

In any given scenario, if the sum of the household load and the EV-related load is less than the available capacity of the transformer, the system is deemed to be equipped to accommodate 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 specific household that is charging an EV is of little concern; it is the total load on the transformer that determines the available capacity to accommodate EV charging. Contingencies are usually built into the distribution system to accommodate high-impact but low-probability events, such as heat waves or cold snaps (when the demand for cooling or heating can cause spikes in the demand for power), equipment failures or planned work; the transformers investigated are assumed to have emergency capacities of 125 per cent of their rated capacity. For the purposes of this report, where the sum of the household load and the EV-related load is greater than the contingency or emergency rating (e.g., 62.5 kVA for a 50 kVA transformer), the transformer is assumed to be severely overloaded.

Scenarios were developed and tested based on key variables predicted to have the greatest potential for impacts on the capacity of the system to support EV-related loading. The variables tested were

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

The key variables investigated are described in greater detail below.

Electric Vehicle On-Board Charger Capacity

As previously noted, most EVs can be charged using a standard 120 V household outlet (Level 1 charging). If an EV is charging at Level 1, power flows through the on-board charger at a lower rate than it would if the vehicle were charging at 240 V (Level 2 charging). For example, the 2014 Nissan LEAF can charge at 6.6 kW at 240 V, but power flows at 1.2 kW when the vehicle is charging at 120 V.

A number of EVs on the market have 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. 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. Even more powerful chargers are also available, such as the charger rated at 20 kW on board the Tesla Model S.

Table 2 summarizes the specifications for three popular EV models used as examples of the charger capacities investigated in this section of this report. Looking at a range of charger capacities allows for a more in-depth analysis of the extent to which conditions such as ambient temperature or time of charge can affect the capacity of the electrical distribution system to meet the demand for power for EV charging. Level 1 charging is not investigated in this report because the load associated with charging an EV at Level 1 would have relatively little effect on the electricity distribution system and, moreover, the EMAP market research indicates that charging at Level 1 would take longer than the typical early adopter would likely be willing to wait.

Table 2: 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. For the purposes of this report, only 20 kW was investigated.

Ambient Temperature

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 the transformer. 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.

In the PowerStream service area, the demand for power is typically greater over the summer months than during the winter. As such, the scenarios investigating key variables examined the effects of EV penetration and different types of on-board chargers on the electricity distribution system for the warmest day from the previous year, July 17, 2013, with a high temperature of 33.2 °C, to represent the potential worst-case scenario.

Electric Vehicle Penetration Rate

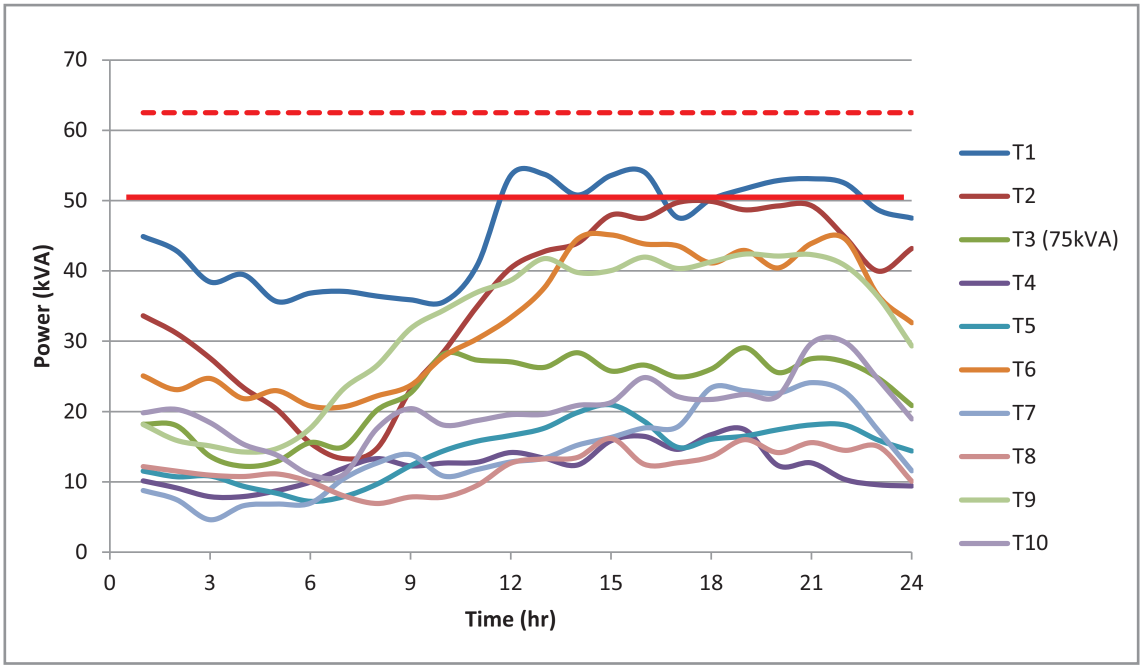
As the results of the market research show, the rate of EV penetration is influenced by several factors, including demographics, consumer attitudes and the availability of charging infrastructure. At the same time, the number of EVs that can be charged simultaneously is limited by the capacity of the transformer to meet the demand for power. The scenarios in this report explore the impact on the transformer resulting from the incremental load from each additional EV charging. Unless otherwise noted, the EV penetration rate is calculated by using the total load profile for the transformer and adding the additional load for one EV for each household served by the transformer.

Table 3: Total Number of Customers by Transformer for Location 1, Site A

Transformer	Transformer rated capacity, kVA	Transformer emergency capacity, kVA	Number of customers
1	50	62.5	9
2	50	62.5	8
3	75	93.75	8
4	50	62.5	6
5	50	62.5	5
6	50	62.5	15
7	50	62.5	9
8	50	62.5	7
9	50	62.5	8
10	50	62.5	9

Before any additional loading from EV charging was considered, the 24-hour load profiles for the warmest day in summer were generated for each of the ten transformers in Location 1, Site A. As Figure 31 shows, all the transformers were operating below their rated capacity (50 kVA or 75 kVA), even during times of peak demand, with the exception of Transformer 1. None of the transformers was operating above its emergency rated capacity (i.e., 62.5 kVA or 93.75 kVA).

Figure 31: Transformer Load Profile for the Ten Transformers in Location 1, Site A, by Hour for July 17, 2013



Electric Vehicle Charging with a 3.3 kW Charger

This set of scenarios explored the capacity of the distribution system at the neighbourhood level to accommodate EVs with a 3.3 kW charger. The total load was calculated by adding together the load profile for each household serviced by the transformer and the incremental EV load (i.e., 3.3 kW per EV). Figure 32 shows the results across a 24-hour period for each of the ten transformers if three EVs were charging simultaneously. While most of the transformers in this location could easily accommodate this demand for power, three of the transformers (2, 8 and 9) would be slightly overloaded (i.e., more than the rated capacity of the transformer but less than its emergency capacity), while Transformer 1 would be severely overloaded (i.e., more than 125% of its rated capacity).

Figure 33 shows that if eight EVs were charging simultaneously, all of the transformers that provide power to eight or more customers would exceed their rated capacity at least once throughout the course of the day, with the exception of Transformer 3, which has a rated capacity of 75 kVA rather than 50 kVA. In addition, four of the transformers (1, 2, 6 and 9) would exceed their emergency capacity.

Figure 32: Transformer Load Profile by Hour for Location 1, Site A, and Three 3.3 kW Chargers

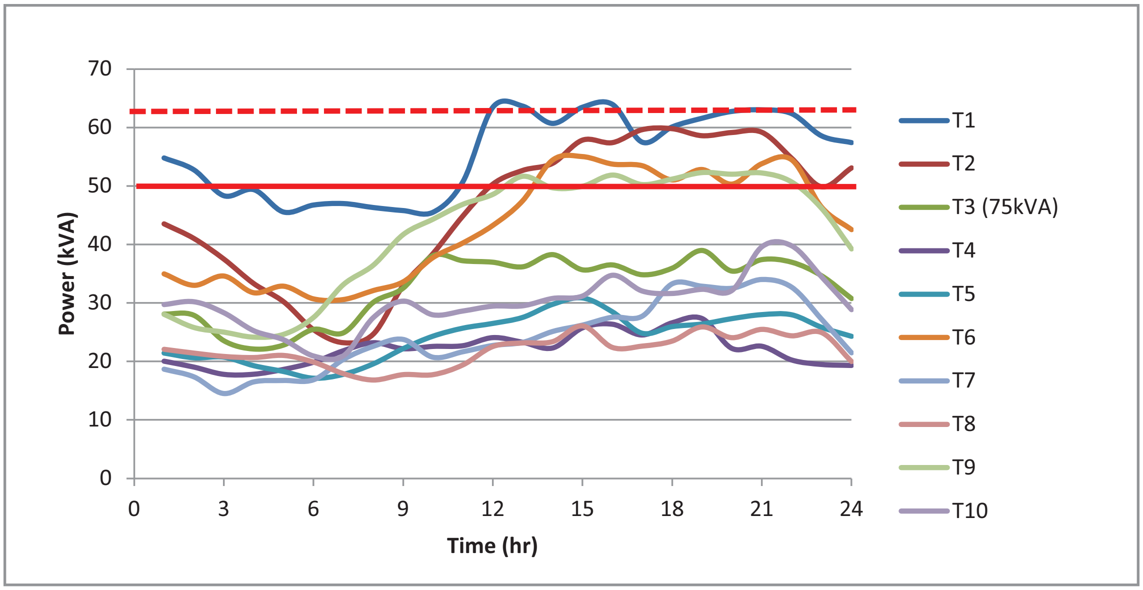
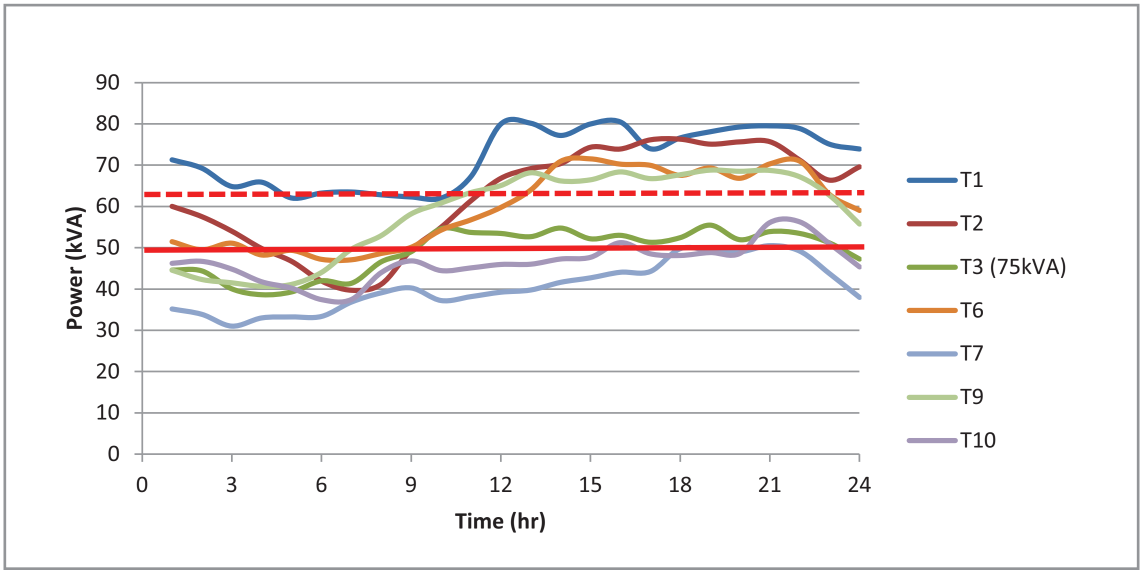


Figure 33: Transformer Load Profile by Hour for Location 1, Site A, and Eight 3.3 kW Chargers



Note: Transformers 4, 5 and 8 do not appear in this graph because they provide power to fewer than eight customers.

Electric Vehicle Charging with a 6.6 kW Charger

Figure 34 shows that if as few as two EVs with a 6.6 kW charger were charging simultaneously on the warmest day in summer, three of the transformers (Transformers 2, 6 and 9) would be slightly overloaded, and Transformer 1 would be severely overloaded. Figure 35 shows that all of the transformers that provide power to at least six households, with the exception of Transformer 3, would be overloaded at some point on the warmest day in summer if six EVs with a 6.6 kW charger were plugged in. In fact, five of the transformers would be severely overloaded, having exceeded their emergency capacity.

Figure 34: Transformer Load Profile by Hour for Location 1, Site A, and Two 6.6 kW Chargers

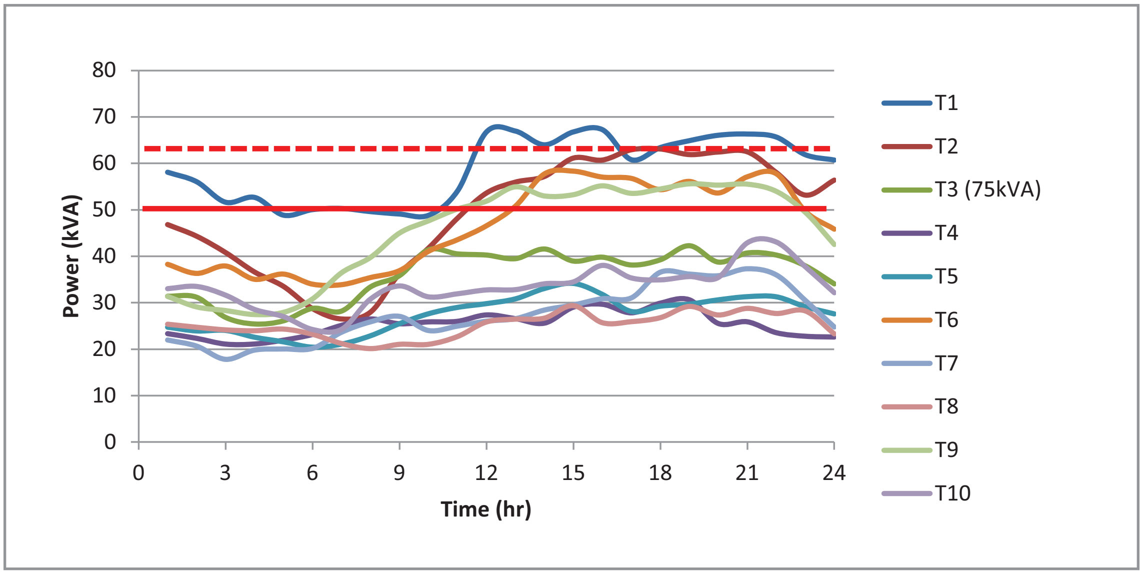
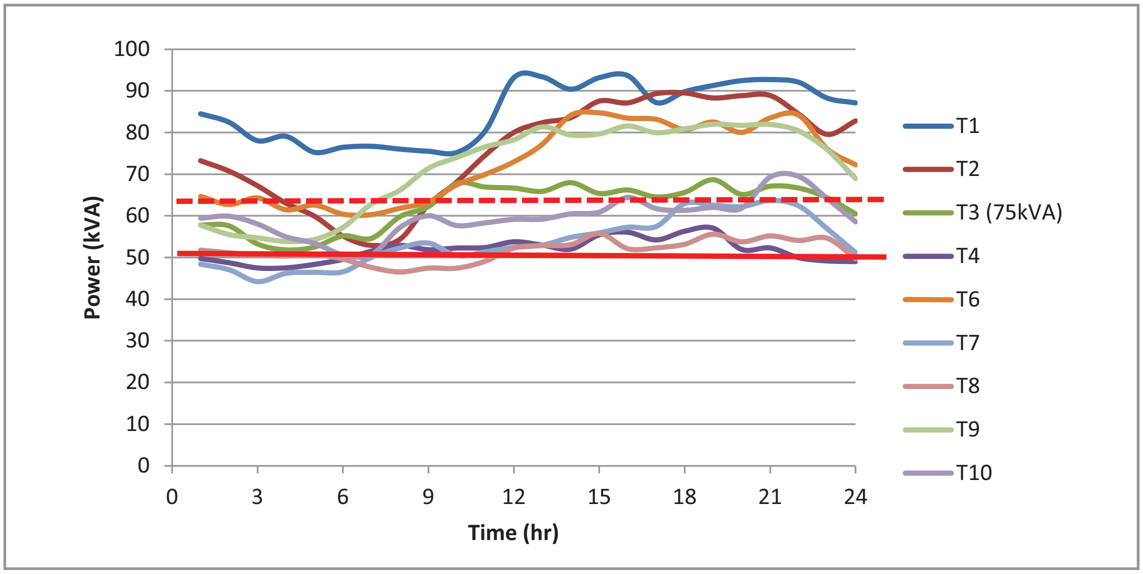


Figure 35: Transformer Load Profile by Hour for Location 1, Site A, and Six 6.6 kW Chargers

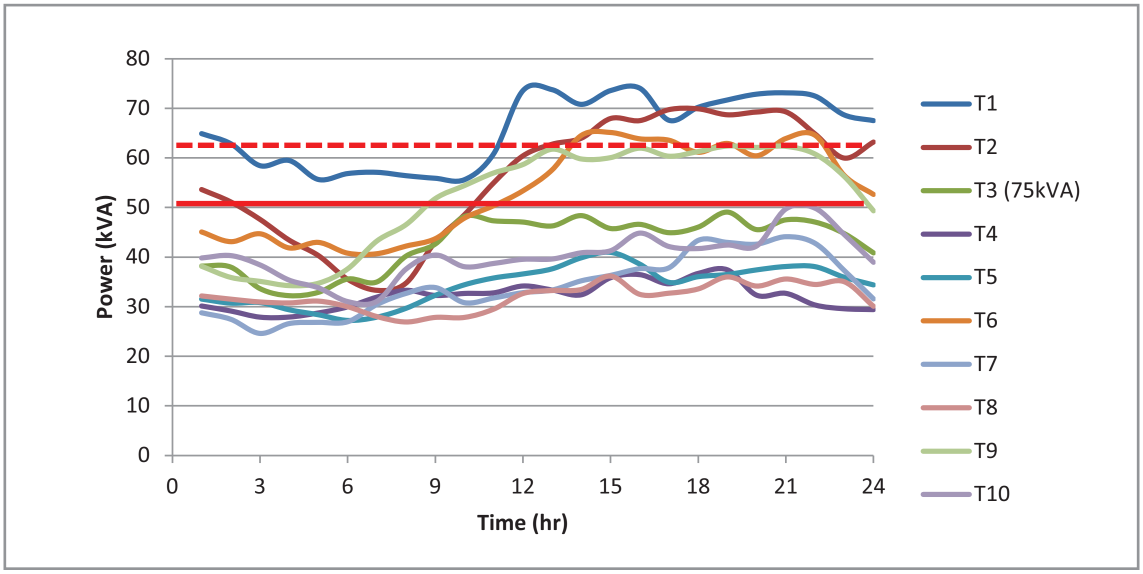


Note: Transformer 5 does not appear in this graph because it provides power to fewer than six customers.

Electric Vehicle Charging with a 20 kW Charger

Figure 36 shows that if even one EV with a 20 kW charger were plugged in on the warmest day in summer, four transformers (Transformers 1, 2, 6 and 9) would be overloaded for half the day. Three of these transformers (Transformers 1, 2 and 6) would be severely overloaded by just one EV with a 20 kW charger.

Figure 36: Transformer Load Profile by Hour for Location 1, Site A, and One 20 kW Charger



Maximum Number of Electric Vehicles Charging for Location 1, Site A

Table 4 shows the maximum number of EVs across a variety of charger sizes that could be accommodated by each of the transformers in Location 1, Site A, without exceeding the emergency capacity of the transformer (i.e., 125 per cent of its rated capacity). The results show that most of the transformers could accommodate 100 per cent penetration of EVs with a 3.3 kW charger without exceeding emergency capacity. However, this number is dramatically reduced for EVs with a 6.6 kW charger, with only two of the transformers capable of accommodating 100 per cent EV penetration. The maximum number of EVs with a 20 kW charger that could be accommodated by any of the ten transformers is two; however, some of the transformers would be severely overloaded with only one such vehicle charging. It should be noted that while the emergency capacity of the transformer might not be exceeded, in some cases the transformer could still be slightly overloaded (i.e., over its rated capacity), which could still have implications for it.

Table 4: Maximum Number of EVs Charging without Exceeding Transformer Emergency Capacity

Transformer	Transformer rated capacity, kVA	Transformer emergency capacity, kVA	Number of customers	Maximum number of chargers		
				3.3 kW	6.6 kW	20 kW
1	50	62.5	9	2	1	0
2	50	62.5	8	3	1	0
3	75	93.75	8	8	5	2
4	50	62.5	6	6	6	2
5	50	62.5	5	5	5	2
6	50	62.5	15	5	2	0
7	50	62.5	9	9	5	2
8	50	62.5	7	7	7	2
9	50	62.5	8	6	3	1
10	50	62.5	9	9	4	1

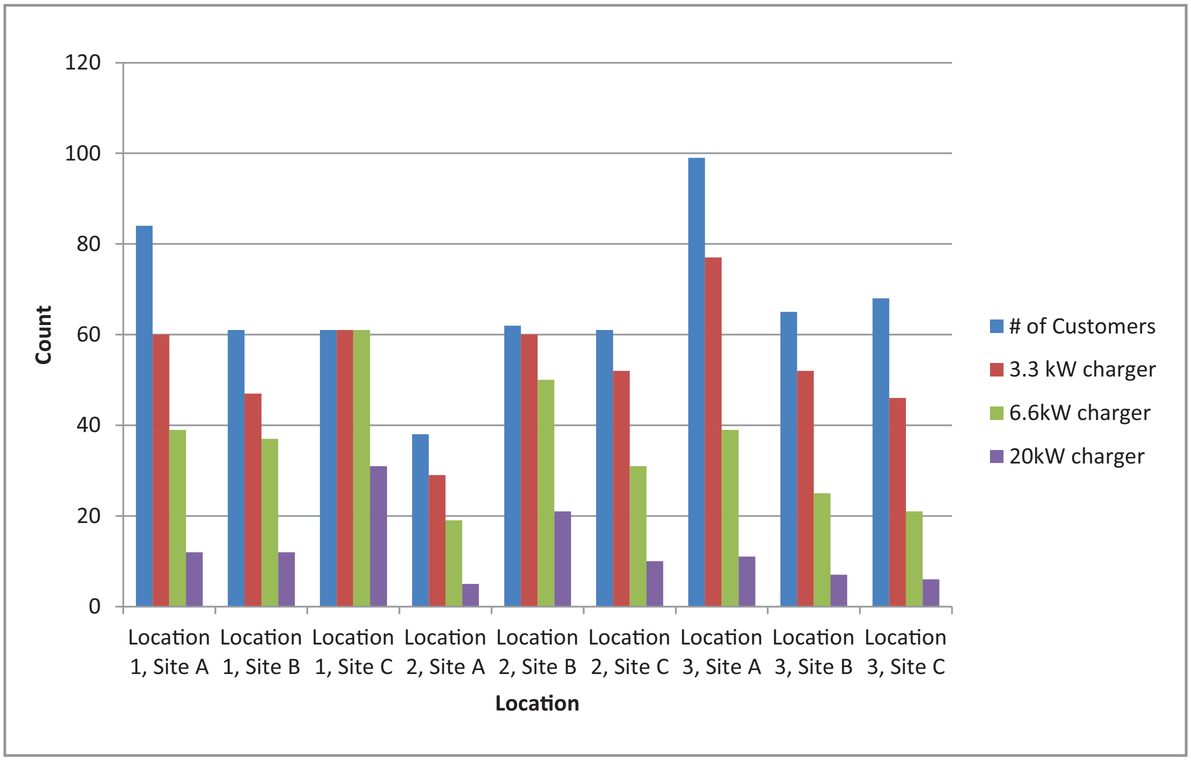
Maximum Number of Electric Vehicles Charging for the Study Area

This scenario assessed the capacity of all of the transformers in the study area to accommodate EV charging. The assessment looked at the available capacity on the warmest day of the previous year for EVs with a 3.3 kW, 6.6 kW or 20 kW charger. Table 5 shows that out of a total of 74 transformers providing power to 599 households, there is currently capacity to accommodate 484 EVs with a 3.3 kW charger, 322 with a 6.6 kW charger and 115 with a 20 kW charger. As previously noted, the rated capacities of the transformers in the study area range from 25 kVA to 100 kVA. Because of their varying sizes, each of these transformers would experience the effects of EV charging differently, which must be taken into account when looking at the results for a particular location. Figure 37 provides a visual representation of the results found in Table 5.

Table 5: Total Number of Electric Vehicles That Can Be Accommodated by Location and Site

Location	Number of transformers	Number of customers	3.3 kW	6.6 kW	20 kW
Location 1, Site A	10	84	60	39	12
Location 1, Site B	8	61	47	37	12
Location 1, Site C	8	61	61	61	31
Location 2, Site A	5	38	29	19	5
Location 2, Site B	8	62	60	50	21
Location 2, Site C	8	61	52	31	10
Location 3, Site A	13	99	77	39	11
Location 3, Site B	7	65	52	25	7
Location 3, Site C	7	68	46	21	6
Total	**74**	**599**	**484**	**322**	**115**

37: Total Number of Electric Vehicles That Can Be Accommodated by Location and Site



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. This scenario was developed with a view to understanding how to maximize the number of EVs charging while at the same time creating the least possible burden for the transformer. Whereas the previous scenarios looked at worst cases, this scenario explored the best case, assuming that key variables, such as time of charge, could be managed. This would involve some element of control, likely on the part of the LDC, to flow the electricity to charge an EV at those times when it would least impact the electricity distribution system.

This scenario assumed that each EV has a charger rated at 3.3 kW and that charging occurred on the warmest day in summer (i.e., July 17, 2013). Figure 38 shows the load profile for Transformer 1 in Location 1, Site A, with different numbers of EVs charging between 2 p.m. and 12 a.m., when the demand for power is high. The results illustrate that because the transformer is already heavily loaded during times of peak demand, the emergency capacity would quickly be exceeded if a few EVs were to charge simultaneously.

Figure 39 shows that if EV charging were to occur when demand on the transformer was at its lowest, a much greater number of EVs could be accommodated before any overloading of the transformer would occur. Seven EVs with a 3.3 kW charger could be accommodated for the majority of the off-peak time frame without exceeding the emergency capacity of the transformer. As such, an approach that encourages EV charging when demand for power is lowest would effectively allow existing distribution assets to reliably service any reasonable number of EVs.

Figure 38: Transformer Load Profile on the Warmest Day for Electric Vehicle Charging When the Demand for Power Is High

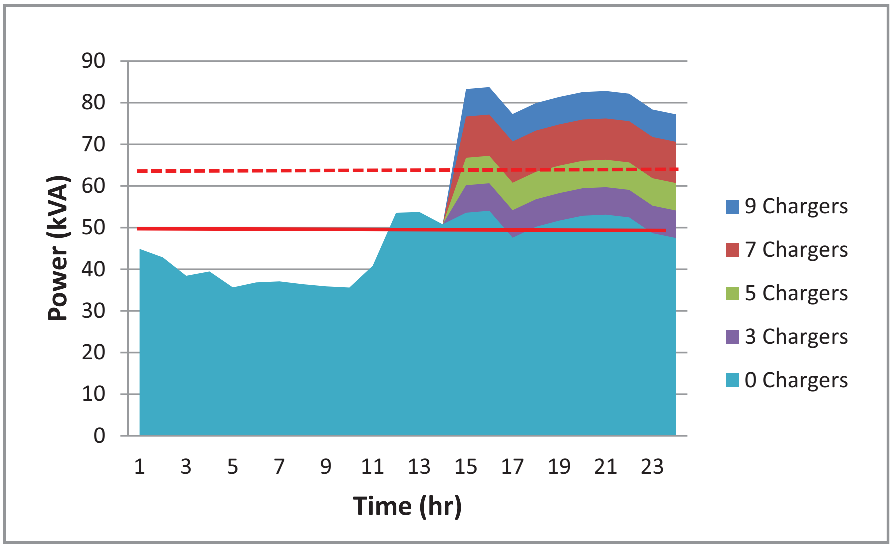
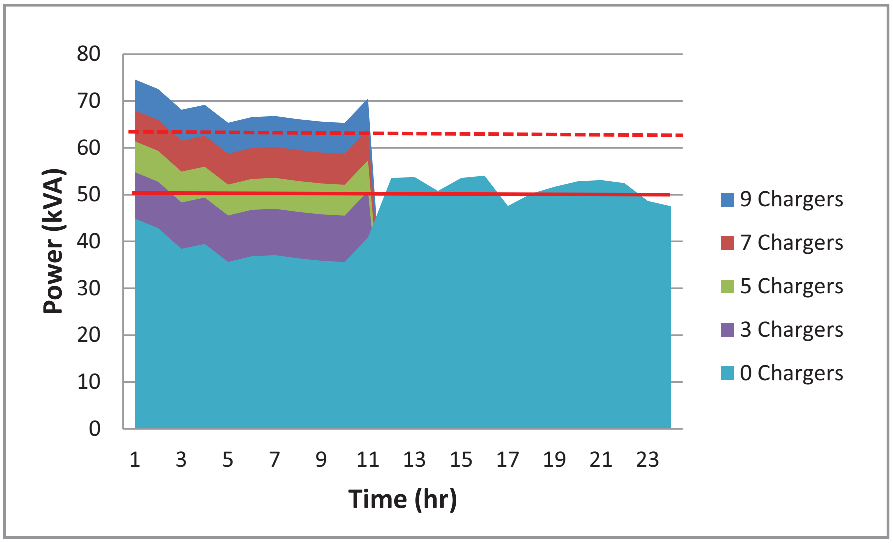


Figure 39: Transformer Load Profile on the Warmest Day for Electric Vehicle Charging When the Demand for Power Is Low



Summary

The assessment of the electricity distribution system provides a better understanding of some of the key factors that will contribute to the system's capacity to accommodate anticipated EV-related loads at the neighbourhood level. The majority of the scenarios investigated show that the system is currently able to support EV-related loading. Variables such as the capacity of the on-board charger, ambient temperature and time of charge all have the potential to impact the system under certain conditions. While the likelihood that the conditions simulated will occur, particularly in combination, is not high, planning and asset management will nonetheless require consideration of these factors.

The results of the electricity distribution system assessment demonstrate that, while there are no immediate issues related to the capacity of the distribution system to accommodate EV charging by early adopters, there are conditions under which overloading could occur. These risks can be mitigated and even substantial EV penetration levels accommodated, provided that charging occurs at optimal times. This will require EV strategies aimed at encouraging charging at those times when it will have the least effect on the electricity distribution system. Proactively managing EV charging will help to avoid unnecessary and expensive investment in new neighbourhood-level distribution infrastructure such as transformers.

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