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Supporting EV Adoption through EV Hotspots Analysis

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Executive Summary

This study presents a methodology developed for forecasting EV hotspots (i.e., areas with above average EV penetration) in urban areas using historical EV registration data, socio-economic data, and government EV sales targets. The methodology was applied to the City of Ottawa, Ontario, Canada, to forecast the number of EVs per household for each of its 200 census tract areas up to the year 2030. Decision-makers from local electricity distribution companies can use this methodology to prioritize grid updates to facilitate the charging of a fast-growing fleet of EVs in their cities.

Keywords: electric vehicle, modelling, demand, infrastructure, utility.

1 Introduction

The widespread adoption of electric vehicles (EVs) creates challenges for electricity distribution systems in Canadian cities because they have insufficient capacity to keep up with the charging demands of a fast-growing fleet of EVs. Grid upgrades are needed to prevent power outages due to overload caused by EV charging. To manage investment costs, these upgrades will need to be planned according to the growth of the EV fleet in each area of the city. Different areas will have different EV uptake rates due to various socio-economic factors such as income level and access to home charging.

Historical data of EV registrations in Ottawa, Ontario, Canada demonstrate differences in EV uptake between neighbourhoods with different income levels and for neighbourhoods with more limited access to home charging (for instance for apartment buildings, or downtown streets with on-road parking). In order to create a priority list and associated timelines for required grid upgrades, electric utilities need to get insight into where larger numbers of EVs are likely to appear first.

Sales of zero-emissions light-duty vehicles in Canada reached 9.4% in the third quarter of 2022 [1]. The Government of Canada has set a mandatory policy of having 100% zero-emission vehicle sales by 2035, with an interim target of 60% by 2030. This surge in EV adoption will significantly increase the need for EV charging infrastructure.

EV charging events can be categorized into home charging, workplace charging and public charging [2]. Multiple methodologies were developed in different studies to estimate future electric vehicle charging demand for the allocation of charging stations. A recent study performed a data-driven approach to optimize public EV charging [3]. The study utilized a Modified Geographical PageRank (MGPR) mode built on trip origin-destination, social dimension features, and mathematical modelling. The study results were fed into a Capacitated Maximal Coverage Location (CMCLP) model, which optimized the spatial distribution of the charging stations. A similar study for London, UK, provides a two-step approach for optimizing the location of EV charging points [4]. The study uses spatial statistics and maximal coverage location models for selecting locations of charging points. It also includes a process intensity scoring system for charging points allocation. The study results showed that EV charging demand is significantly associated with workspace population density, travel flows and densities of three points of interest categories (transport, retail and commercial). A different study developed a practical methodology to locate suitable charging infrastructure for local government authorities [2]. The methodology utilizes Geographic Information System (GIS) analysis of available census data to identify areas with residents more likely to use Plug-in Electric Vehicles (PEV) and to have residential on-street parking. The methodology was applied to Southampton, UK, where 128 streets were recommended as suitable locations for charging stations.

The methodologies provided in the literature studies discussed above do not include government-imposed EV sales mandates, which can significantly impact future EV uptake. To address the research gap, this study developed a new methodology that takes into consideration government EV sales mandates when forecasting EV uptake. This paper presents the results of a study which forecasts 'EV hotspots' (i.e., areas with above average EV uptake) for the City of Ottawa, Canada.

2 Methodology

To forecast the growth of the EV fleet in different parts of the City of Ottawa until 2030, a methodology was developed combining historical EV registration data, socio-economic data, and EV sales targets of the Government of Canada. Different census areas of the City of Ottawa were grouped together into five groups based on their median household income, because of the correlation between income and EV uptake. The EV sales targets were then adjusted for each income group and used to guide the forecasted EV demand for each census area.

2.1 EV Registrations per Household

Historical registration data of electric vehicles in Ottawa were obtained from Statistics Canada for the years 2017 to 2020 [5]. The data presents passenger vehicle EV registrations by geographical area according to the city's division into census tract areas. The EV category covers both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs).

Data on the number of households from the 2011 and 2016 Census of Canada [6], [7] were used to calculate the number of households per census tract area for the years 2017 to 2030 assuming a linear growth pattern. The EV registration numbers for each census area were then normalized by dividing them by the number of households for those census areas into the metric of the number of EVs per household (EV/hh).

Median household income levels for all census tract areas were also obtained from Statistics Canada [7] for the year 2015. A growth rate of 2% per year was applied to estimate median household incomes for the years 2016 to 2020. The 2% growth rate was calculated from the average growth rate in median household incomes between 2010 and 2015 for the City of Ottawa.

Figure 1 shows the number of EV/hh for all census areas with different average median household incomes for all years between 2017 and 2020. The graph shows a reasonable correlation between income and EV/hh rates.

2.2 Grouping Areas by Income Level

Ottawa has approximately 200 census tract areas, a number much too large to allow for an individual analysis of each area. Instead, census tract areas were grouped into five groups by income level, with income group 1 having the highest median annual income (CAD$173,056 per year) and group 5 representing the lowest income group (median income of CAD$26,432 per year). The forecast of EV uptake was then evaluated for the five income groups instead of for each of the 200 census tract areas individually.

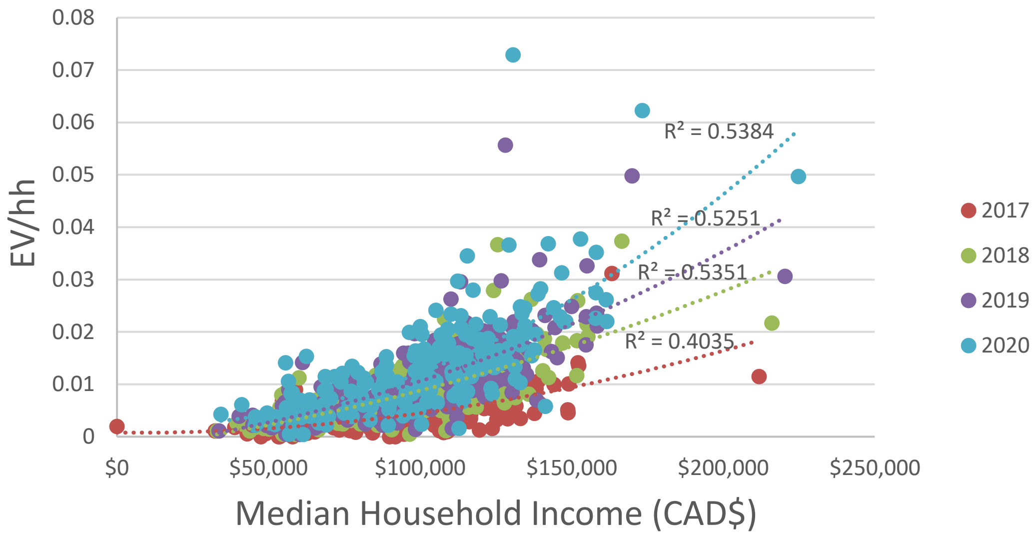

Figure 1: Average number of EVs per household compared to the corresponding median household income for each census area in Ottawa for 2017 to 2020.

2.3 Government of Canada ZEV Sales Targets

The Government of Canada has set a mandatory target of 100% zero-emission vehicle sales for all new light-duty cars and passenger trucks by 2035. This will require a huge increase in EV sales compared to the period for which historical data is available, rendering the trend displayed in the historical data invalid for forecasting EV uptake in later years. Instead, the profile of EV sales percentages required to reach 100% EV sales in 2035 was used for forecasting the EV uptake until 2030.

EV uptake in high-end neighbourhoods is expected to increase faster than this overall target, while low-income neighbourhoods are expected to trail behind. The EV sales profile for higher income groups was therefore adjusted to reach 100% EV sales a few years earlier. Similarly, the profiles for lower income groups were changed to reach the 100% sales target a bit later (see Figure 2). The EV sales rates for income groups 5 and 4 will reach 100% EV sales by 2030 and 2032, respectively. The EV sales rates for income groups 1 and 2 were adjusted to reach 100% EV sales by 2037 and 2036, respectively. The part of the EV sales profiles up to 2030 was used for forecasting EV adoption for each income group.

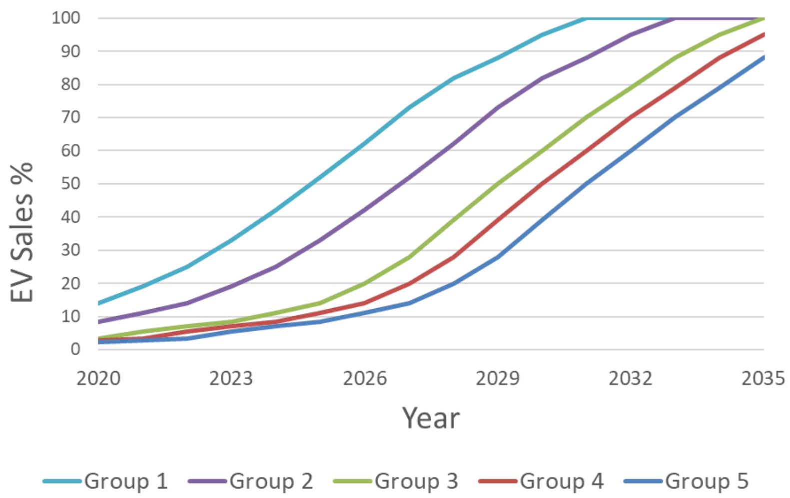

Figure 2: EV sales percentages for different income groups.

3 Results

3.1 Historical Data on the Number of EVs per Household

The average number of registered EVs per household for the period from 2017 to 2020 is presented in Figure 3 for each of the five groups of census tract areas characterized by their household income. While the number of EV registrations per household increased for all income groups, higher-income groups generally had significantly more EVs per household and a stronger growth over the years.

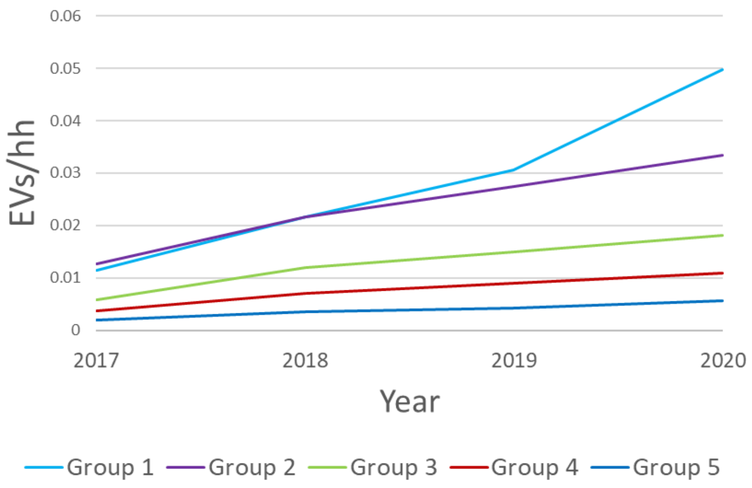

Figure 3: Historical trend in average number of EVs/hh per income group.

3.2 Forecasting Future EV Uptake

To forecast the increase in EV/hh for each census area, an assumption had to be made on the distribution of all new vehicles (EVs and conventional gasoline/diesel vehicles) over the city, because no data on this was available. It was assumed that areas belonging to the highest and lowest income groups would receive 30% more, respectively 30% fewer new vehicles than the average, while areas from the second highest and the second lowest groups would get 15% more/fewer new vehicles. After forecasting overall new vehicle registrations for each income group, the EV sales percentages (Figure 2) were applied to arrive at new EV sales. Finally, the new EV sales were added to the number of EVs from the year before to forecast the EV stock for that year and to calculate the average number of EVs per household. Figure 4 presents the forecast of the average number of EV registrations per household for the five groups of census tract area characterized by income until 2030. The number of EVs in high-income neighbourhoods is expected to increase drastically over this period, while a slower increase is foreseen in lower-income areas.

After forecasting the average penetration of EVs for each of the five income groups (as shown in Figure 4), the forecasted number of EV registrations were distributed among the census areas of each income group using the historical penetration rates for each census area. Initial differences in EV uptake were gradually reduced over the first five years of the forecast, after which all areas in a group were given the same EV penetration profile.

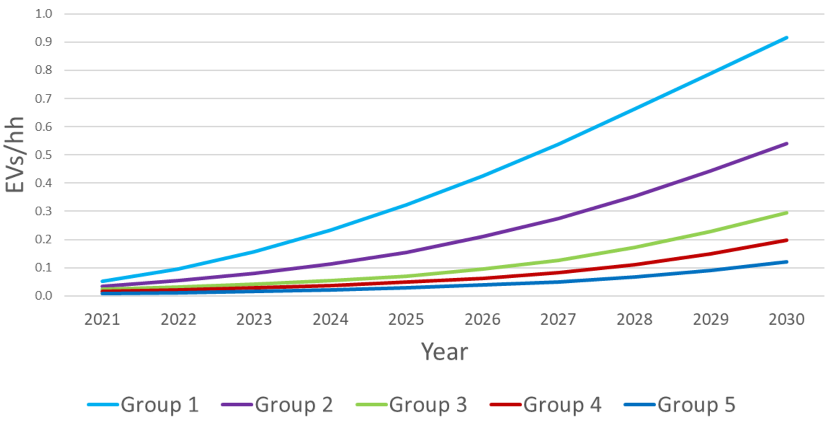

Figure 4: Forecasted average EVs/hh for different income groups.

3.3 Ottawa's EV Hotspots Areas for 2025 and 2030

The results of forecasting the number of EVs per household for the different census tract areas in Ottawa for 2025 and 2030 were then converted into a colour-coded maps as presented in Figure 6 and Figure 6 using Esri's ArcGIS software [8]. The sub-urban areas of the city showed more receptivity to EVs compared to urban areas, potentially due to more availability of home-charging possibilities in the suburbs. Electric utilities can use these maps to identify areas where grid upgrades may be needed.

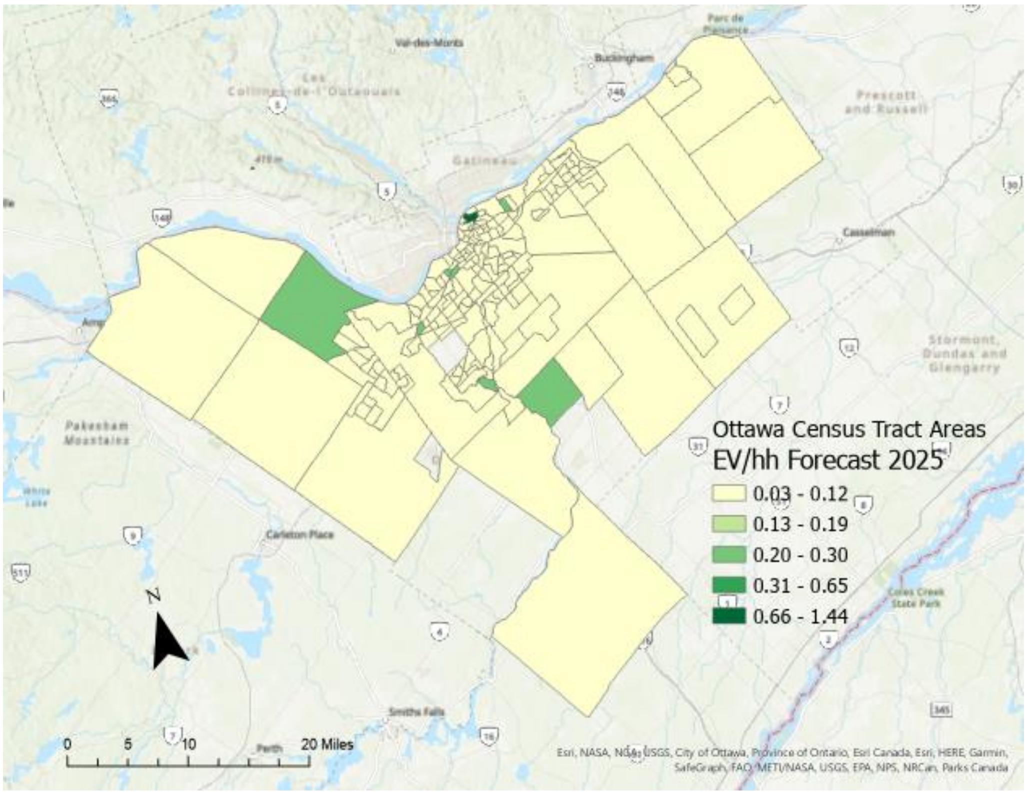

Figure 5: Ottawa's EV Hotspots for 2025, Basemap by Esri [8].

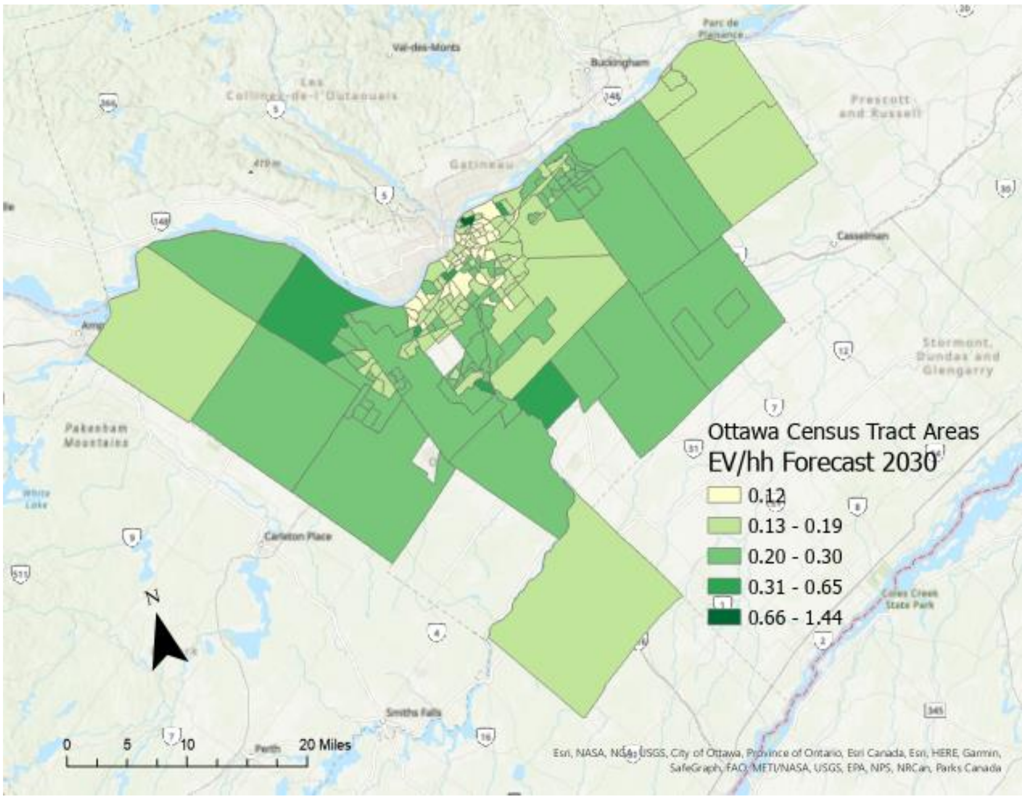

Figure 6: Ottawa's EV Hotspots for 2030, Basemap by Esri [8].

4 Conclusions

Canadian cities will be experiencing a fast transition from vehicles using gasoline and diesel to electric vehicles creating challenges to existing electricity distribution grids. In this study, a methodology was developed to forecast EV hotspots using historical EV penetration data, socio-economic data, and government EV sales targets. The methodology was applied to forecast EV hotspots in the City of Ottawa. The study's results can be utilized by electric utilities to prioritize electric grid updates.

5 Future Work

While the results of using this forecasting methodology with five income groups provide important first insights into where accelerated EV uptake can be expected, the methodology can be improved by including home charging accessibility as a second parameter in grouping census tract areas. Additionally, new EV registration data can be used to update the forecast each year. The same methodology can also be applied to different Canadian cities to forecast EV charging hotspots. This will be pursued in future work.

Acknowledgments

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Presenter Biography

Hajo Ribberink has a M.A.Sc. degree in Applied Physics from Delft University in the Netherlands. He has over 30 years of experience in using modelling and simulation to assess new and innovative technologies in the energy field. At Natural Resources Canada, he leads CanmetENERGY’s research on transportation electrification and advanced transportation technologies.