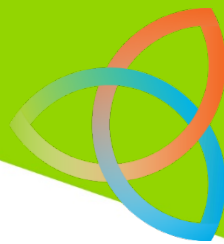# Guidehouse

# Additional Investigation of the Benefits of an Overnight Pricing Plan

**Evaluation of RPP Pilots and Development of Pricing Options**

**Prepared for:**

# ONTARIO ENERGY BOARD

**Ontario Energy Board**

**Submitted by:**

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# Disclaimers

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# 1. Introduction

The Ontario Energy Board (OEB) has administered the Regulated Price Plan (RPP) since 2005. In 2015, the OEB released the RPP Roadmap, which outlined a plan to review and update the RPP to better respond to policy objectives, improve system efficiency, and provide greater consumer control over bills[1]. The RPP Roadmap sought to test ways to improve pricing structures for residential customers. To this end, in 2017, the OEB commissioned pilots from a group of Ontario local distribution companies (LDCs) to test the effects of a variety of price and non-price treatments, and gain information required to advance the goals of the RPP.

Ultimately, 10 price and non-price treatments were implemented across four RPP pilots, involving approximately 15,000 customers. The four RPP pilot proponents were required to file interim and final reports evaluating the effectiveness of these pilots in achieving the RPP's goals. In 2019, the OEB contracted Guidehouse to conduct a review of these evaluation reports (the Meta-Analysis).[2] The goal of the meta-analysis was to provide evidence-based advice to the OEB regarding new or modified pricing plans and non-price tools that may be effective for further the objectives of the RPP.

One of the RPP pilots, Alectra Utilities' Overnight treatment, was in place between May 1, 2018, and April 30, 2019. This was an opt-in pilot; participants agreed to participate. In this pilot, participants accepted a higher On-Peak price (~18 cents/kWh) in exchange for a decreased price in the period from midnight to 6am (~2 cents/kWh, or approximately one third the status quo TOU Off-Peak price plan).

The evaluation of the Overnight price plan found consumption in the hours between midnight and 6am increased 45% in the summer and 73% in the winter, with a 15% increase in overall annual consumption for participants. Guidehouse hypothesized that the net increase in consumption may be due to behaviour changes that were not captured by the analysis of the meter data, such as shifting EV charging activities from public charging stations to the home or replacing gas heating with electric heat overnight (behavioural fuel switching).

In its meta-analysis, Guidehouse made a series of recommendations for next steps. Amongst these was the recommendation that additional analysis be applied to the Overnight pilot to better identify the source of the impacts reported in the evaluation of that pilot and assess whether the analysis conducted by the pilot's evaluator had captured all the benefits provided by the price plan. This report is intended to complete this recommendation and to provide the OEB with a more informed basis on which to determine next steps regarding an Overnight price plan.

This report investigates the behaviour changes responsible for the net increase in consumption associated with the Overnight price plan to test the hypotheses for the underlying causes of this change presented in the Meta-Analysis. This report also estimates the benefits (e.g., avoided energy, capacity, and carbon costs) associated with these changes in behaviour, benefits that cannot be assessed based only the customer meter data and so were not estimated as part of the pilot's original evaluation. The two primary goals of this report are:

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[1] Ontario Energy Board, **https://www.oeb.ca/sites/default/files/uploads/RPP_Roadmap_Report_of_the_Board_20151116.pdf**

[2] Ontario Energy Board, **https://www.oeb.ca/sites/default/files/report-RPP-Pilot-Meta-Analysis-20211110.pdf**

- **Goal 1:** Assess to what degree estimated pilot impacts can be attributed to EV-driving customers, and consequently identify whether the hypothesis of behavioural fuel switching can be rejected, and;

- **Goal 2:** Estimate the electricity system and avoided GHG benefits derived from EV-driving participants in the price plan pilot.

These goals are accomplished through three primary tasks, outlined in the following sections:

1. **Survey Analysis.** Guidehouse, with the assistance of an internet-based survey instrument, identified those program participants that owned an electric vehicle prior to and during the pilot period.

2. **Test Hypothesis of Behavioural Fuel Switching.** Guidehouse then re-estimated the impacts for the EV-owning group and the non-EV owning group to identify to what degree the overall average impact estimated by the pilot evaluation may have been driven by EV-based changes in behaviour.

3. **Estimate the Benefits of Price-Plan-Motivated EV Charging.** Guidehouse then used EV charging profiles and estimates of incremental EV electricity use to estimate the system and societal benefits (not captured in previous analyses) of different types of participant response to the price plan.

# 2. Survey Analysis

To determine whether the impacts of the treatment were driven by behavioural changes in electric vehicle drivers, or from other sources (e.g., behavioural fuel switching), Guidehouse needed to subset the group of pilot participants who operated electric vehicles. To do so, Guidehouse developed a survey to be delivered to all participants of the Overnight pilot.

The survey instrument was developed by Guidehouse and aimed to answer a few key questions:
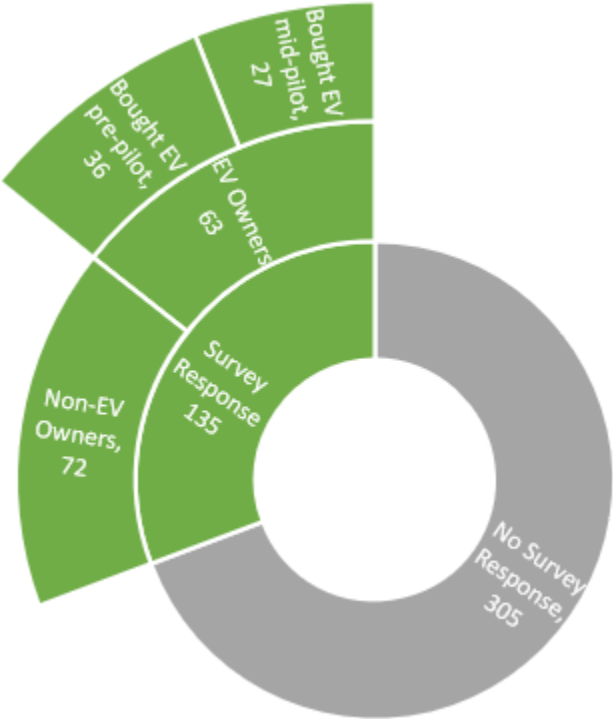
- Did the participant own/lease an EV during the pilot period (May 1, 2017, to April 30, 2018)?

- Whether, as a result of the pilot, the participant remembers altering their vehicle charging behaviour (e.g., shifting charging from workplace/public sources to home charging).

- Whether, as a result of the pilot, the participant remembers altering other behaviour (e.g., altering their use of home space heating).

The survey was administered by Alectra Utilities, sent to customers via email. Participants responding to the survey received a $10 Amazon gift card as an incentive to participate. In total, 135 participants responded to the survey, of 440 Overnight pilot participants. Of the 135 respondents, the survey identified 63 who owned/leased an electric vehicle during their participation in the treatment, and 72 who did not. Insights from the survey can be used support Guidehouse's evaluation of benefits not captured in the original evaluation.

Survey participants were asked, "Do you recall making any changes to your electric vehicle charging habits as a result of the time-of-use rate pilot that you [participated in]?" As anticipated, a majority of EV-owning respondents (92%) recalled shifting their home charging from on-peak to off-peak times. However, only a small portion (5%) of respondents indicated that they recalled shifting their charging from a workplace or public charging location to off-peak home charging. This indicates that while a small percentage of the pilot did shift their load as hypothesized (from a non-home to a home location), it likely does not account for the majority of increased load. This subset of participants contributes to the increase in consumption, but is not the primary driver of increase across the entire group.

Survey respondents were also asked to state the year/month that they purchased/leased their EV. This allows Guidehouse to determine whether they were operating their EV prior to pilot enrolment, after their participation in the pilot concluded, or most interestingly, whether they purchased the EV while they were subscribed to the pilot. A large percentage of these customers (43%) indicated that they first purchased/leased their EV while they were subscribed to the treatment. In other words, their pre- and post-pilot consumption patterns may vary significantly, as they are adding load from their vehicles. This hypothesis was not explored in the Meta-Analysis, but could help explain the increase in consumption examined as a result of the Overnight price plan. This hypothesis is explored further in this report.

**Figure 1. Survey Respondent Breakdown**



Bought EV mid-pilot, 27

Bought EV pre-pilot, 36

EV Owners, 63

Non-EV Owners, 72

Survey Response 135

No Survey Response, 305

# 3. Test Hypothesis of Behavioural Fuel Switching

In this task, Guidehouse used monthly usage data for participants and control customers and incremental survey data from participants to test the hypothesis that a material proportion of estimated winter demand impacts are a result of behavioural fuel switching.

## 3.1 Methodology

To test the hypothesis of behavioural fuel switching, in which customers are hypothesized to replace gas heating with electric heat overnight, Guidehouse estimated participants' behavioural response to the Overnight pilot for two subgroups: those who owned an electric vehicle during the pilot period, and those who didn't. This analysis leverages customer usage data and survey responses.

Guidehouse obtained the regression analysis dataset used by BEworks in that firm's evaluation of the Overnight pilot.[3] Some data manipulations were required to align the data with the regression model, including: 1) removing observations that fall outside the time period of analysis, 2) removing observations for customers who are neither pilot participants nor matched controls, 3) creating the dependent variable as the average difference in usage from the post- and pre-pilot periods, and 4) appending the price variable – which indicates whether a customer was a participant or control – found in the hourly dataset to the model dataset. The number of customers in the analysis data set exactly aligned with the numbers reported by BEworks. Guidehouse estimated two regression models to quantify impacts. The first model was an exact replica of the BEworks model, shown in Equation 1. The *price* variable indicates participation in the pilot and is the primary variable of interest. The coefficient for the price variable, $\beta_1$, is calculated in the regression analysis and is an estimate of the change in demand (kW) in each price period for pilot participants, as reported in Table 2.

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[3] Regulated Price Plan Pilot – Final Report. Prepared by BEworks and Alectra Utilities. Submitted to the Ontario Energy Board on August 31, 2020. Available at:
https://www.oeb.ca/sites/default/files/Alectra-RPP-roadmap-12-Month-Report-20200831.pdf

BEworks provided monthly datasets used for the regression analysis and hourly datasets used for load shape plots (post-period only). Guidehouse reconstructed the post-period monthly dataset, which consists of average usage per month and TOU period, from the hourly data and found a small discrepancy for the Off-peak period. Specifically, the values in the monthly dataset used for regression were 5.4% lower than the values recreated from the hourly dataset. Because this difference impacted usage for both the participant and comparison groups and was relatively small in magnitude, Guidehouse does not have concerns about this discrepancy biasing results.

**Equation 1. Primary Regression Model**

$$(PostTOUUsage_i - PreTOUUsage_i) = \alpha + \beta_1 \cdot Price_i + \epsilon_i$$

Where,

| | | |
|---|---|---|
| $PostTOUUsage_i$ | = | Average hourly TOU-period kW consumed during experimental period by household $i$ |
| $PreTOUUsage_i$ | = | Average hourly TOU-period kW consumed during pre-experiment period by household $i$ |
| $Price_i$ | = | Binary variable indicating presence of price manipulation for household $i$, taking a value of 1 for pilot participants and 0 for matched controls |
| $i$ | = | Indicates individual household |
| $\epsilon_i$ | = | Regression error term for household $i$ |

The second regression model used a lagged dependent variable (LDV) and is shown in Equation 2. The pre-period usage appears on the right side of the equation as an independent variable. The LDV model was estimated on a panel dataset, which includes monthly observations for each customer. The model includes a set of binary variables indicating the month. These monthly binary variables are included in isolation and interacted with pre-period usage. Guidehouse estimated this model as a robustness check on the results of the primary regression model.[4]

**Equation 2. Lagged Dependent Variable Model**

$$PostTOUUsage_{i,t} = \beta_1 \cdot Price_i + \beta_2 \cdot Month_t + \beta_3 \cdot Month_t \cdot PreTOUUsage_{i,t} + \epsilon_{i,t}$$

The t subscript indicates the month of the pilot period. The LDV model clusters standard errors at the household level. Guidehouse recommends clustering the standard error when working with panel data to account for household-level correlation. Both the primary and LDV models are estimated separately for the summer and winter seasons, and for each of the four TOU periods, in accordance with the prior study. In both models, the $\beta_1$ parameter represents the estimated average change in kW for the specified season and TOU period. Guidehouse estimated the primary and secondary regression models for the following groups of customers:

- **All**: All pilot participants and all matched controls

- **Survey**: Pilot participants who responded to the surveys and all matched controls[5]

- **No EV**: Pilot participants who responded to the surveys and indicated they did not own an electric vehicle during the study period and all matched controls

- **EV**: Pilot participants who responded to the surveys and indicated they owned an electric vehicle during the study period and all matched controls

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[4] If the two different regression models generate similar results, then we are confident that the results are not an artefact of the model specification, i.e., the impacts are robust to different specifications.

[5] We analyze the set of survey respondents to understand to what degree relying on survey data (and respondents) may bias the sample, compared to the full set of participants.

Table 1 shows the number of customers in each model group. The model data set incorporated responses from two surveys: the original survey implemented by BEworks and the survey implemented by Guidehouse for this study.[6] Guidehouse did not receive information to link matched control customers to participants, so was unable to subset the control group to match the changes in the participant sample. As a result, the full control group is used in all analysis groups, and may include a mix of customers with and without EVs.

**Table 1. Number of Customers by Analysis Group**

| | All Customers | Survey Respondents | No EV Group | EV Group |
|---|---|---|---|---|
| *Summer* | | | | |
| Participants | 340 | 145 | 74 | 71 |
| Controls | 361 | 361 | 361 | 361 |
| *Winter* | | | | |
| Participants | 302 | 124 | 83 | 41[7] |
| Controls | 430 | 430 | 430 | 430 |

## 3.2 Load Shapes

This section shows average load shapes by season for the pre-period and post-period, for each of the four analysis groups:

- All participants
- Survey respondents
- No EV
- EV

Pre-period usage is shown in the panels on the left, in Figure 2 through Figure 5 below, while post-period usage is shown in the panels on the right. The top row represents summer usage, while the bottom row represents winter usage.

The solid lines show average usage by TOU period, with the background shaded to indicate the TOU period. In cases where the TOU period is not contiguous, the solid line shows the average for the full TOU period, rather than a partial period. The dashed lines show the average hourly load that underlies the average usage by TOU period. The blue line represents average usage for customers in the matched control group, while the green line represents average usage for pilot participants. Hourly load is available only for the post-period.

The pre-period plots indicate how similar the matched control customer group's usage pattern is to that of the participant group.

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[6] Where responses disagreed, the response to the original survey was used, as it was closer to the analysis period in question.

[7] In alignment with the study conducted by BEworks, the set of customers differs for the summer and winter models. Of the survey respondents who reported having an EV, 38 were included in both the summer and winter models, 33 were in the summer model only, and 3 were in the winter model only.

Figure 2 shows average load shapes for all pilot participants and matched controls. The two groups have similar usage patterns in the pre-period in both summer and winter, but differences emerge in the post-period. The pilot participants have higher usage than the matched control group during the Overnight Off-Peak period. Differences exist during all TOU periods, but the overnight period has the largest impact and is the focus of this study.
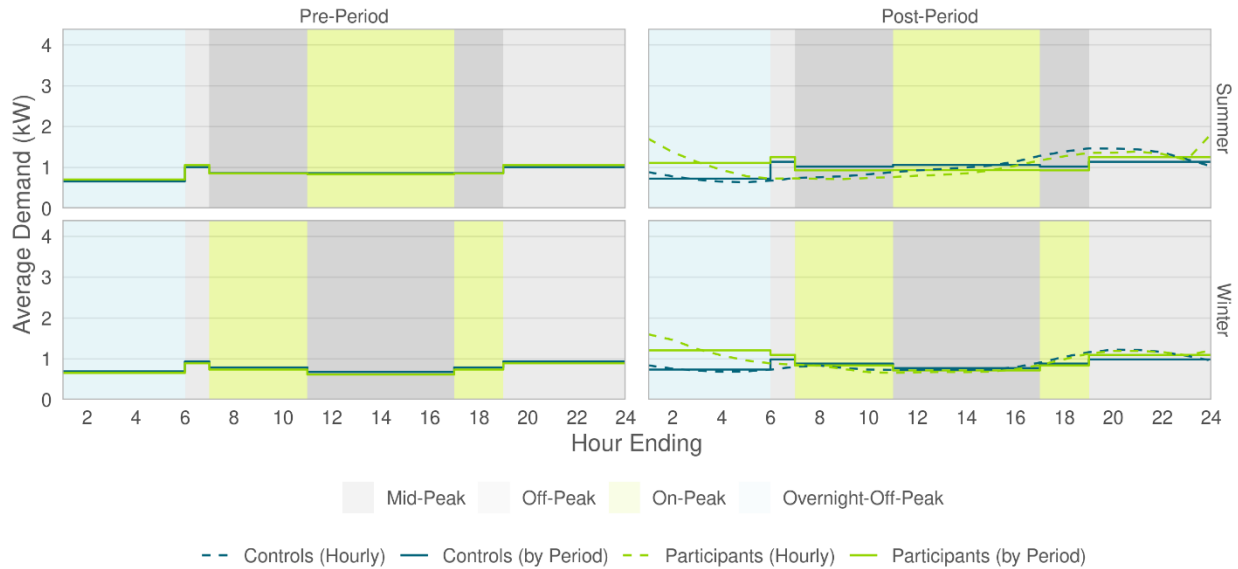
**Figure 2. Average Usage – All Customers**

Figure 3 shows average load shapes for pilot participants who responded to the survey and all matched controls. The two groups have similar usage patterns in the pre-period in both summer and winter, but slight differences emerge. These differences in pre-period usage may indicate the presence of selection bias in the sample of pilot participants that responded to the survey. **The pre-period differences are small and are unlikely to bias the results sufficiently to change the conclusions about impacts during the Overnight Off-Peak period**. As seen with the full study population, usage differs in the post-period for pilot participants and matched controls. The pilot participants have higher usage during the Overnight Off-Peak period compared to the matched control group, and the magnitude of the difference is larger for the survey respondents compared to the full study group.

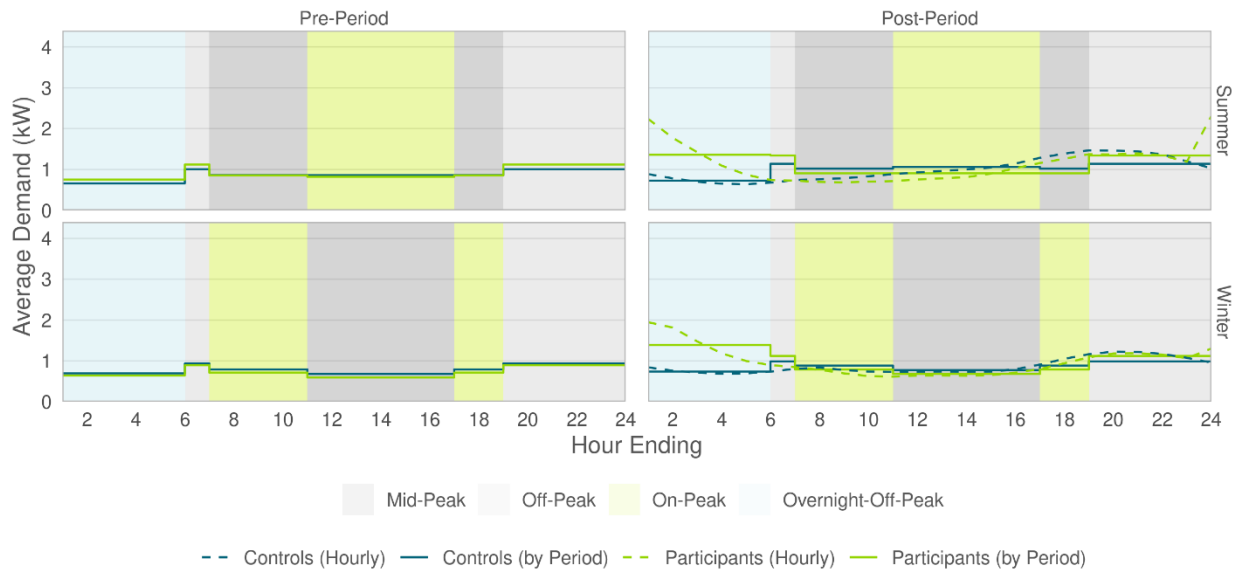**Figure 3. Average Usage - Survey Respondents**

Figure 4 shows average load shapes for pilot participants who responded to the survey and did not have an EV during the analysis period, and all matched controls.

The two groups have similar usage patterns in the pre-period in both summer and winter, but pilot participants have lower usage in all TOU periods in both the pre- and post-periods. These differences in pre-period usage likely result from the matched control group containing a mix of customers with and without EVs. The regression models use a difference-in-differences approach, which controls for observed differences in usage in the pre-period.

In contrast to the full set of survey respondents, pilot participants who do not have an EV during the analysis period exhibit only minor changes in energy usage during the Overnight Off-Peak period. Instead, impacts are largest during the Mid- and On-Peak periods, when pilot participants' usage decreases compared to the matched control group. Put another way, participants without EVs reduce their consumption during the most expensive parts of the day, but do not materially increase it overnight.

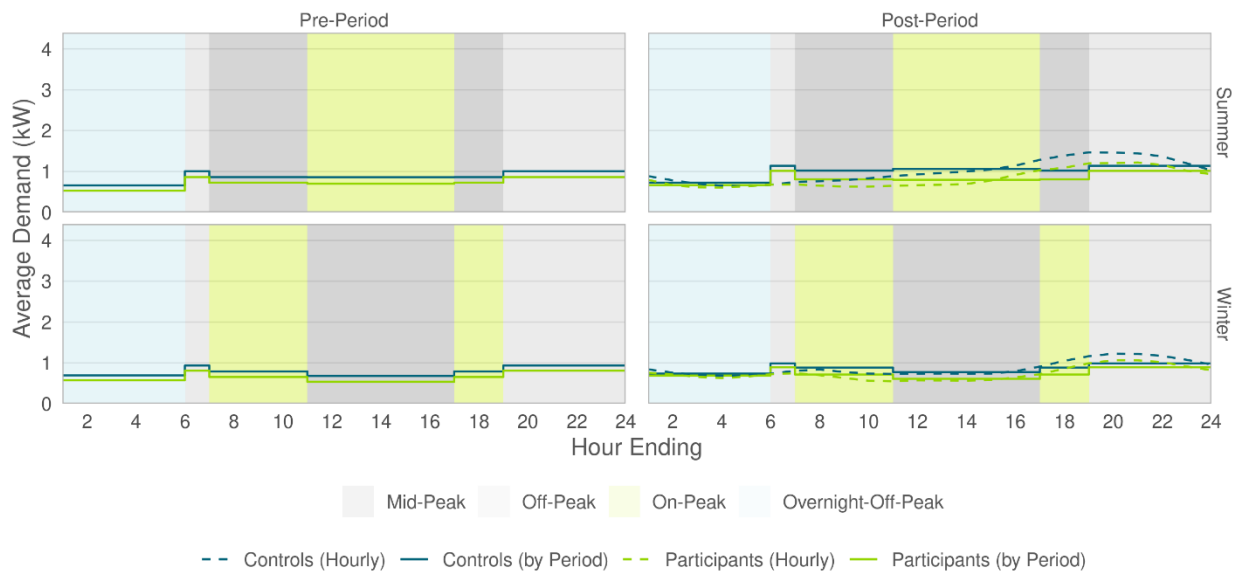**Figure 4. Average Usage – No EV Group**

Figure 5 shows average load shapes for pilot participants who responded to the survey and had an EV during the analysis period, and all matched controls.

The two groups have similar usage patterns in the pre-period in both summer and winter, but pilot participants have higher usage in all TOU periods, with notable differences in the Off-Peak and Overnight Off-Peak periods in the summer season. These differences likely result from the matched control group containing a mix of customers with and without EVs. The regression models use a difference-in-differences approach, which controls for observed differences in usage in the pre-period.

As seen with the full set of survey respondents, differences in usage between pilot participants and matched controls persist in the post-period but are larger than differences in the pre-period. In particular, the pilot participants have higher usage during the Off-Peak and Overnight Off-Peak periods compared to the matched control group, and the magnitude of the difference is 3 times larger in the summer and 4 times larger in the winter for the EV group than for the full set of survey respondents.

**Figure 5. Average Usage - EV Group**
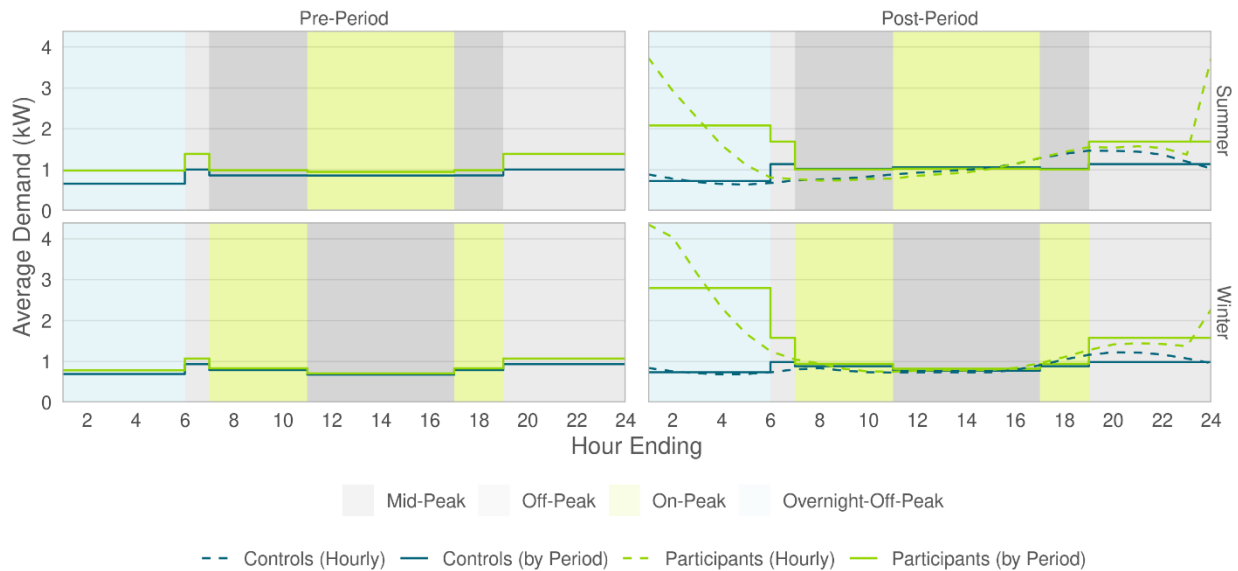


The large increase in Overnight Off-Peak usage for EV owners, compared to a small increase for customers who do not own EVs, indicates that the overnight impacts estimated in the prior study are driven largely by participants with EVs. The next section discusses the results of the regression analysis that quantifies the impacts for each analysis group.

## 3.3 Results

Guidehouse estimated the regression models defined in Equation 1 and Equation 2 for each season, TOU period, and analysis group. The full set of results appears in Table 2 below, which provides the estimates of the parameter on *price* in the model specifications. The values in the tables correspond to the average kW impact for each TOU period and analysis group, with positive values indicating a load increase and negative values indicating a load decrease.

The primary conclusion that can be drawn from these results is the net increase in consumption attributable to the Overnight pilot is primarily driven by EV participants. The average increase in consumption during the Overnight Off-Peak is approximately 20 (summer) to 40 (winter) times higher for EV participants than non-EV participants

Guidehouse successfully replicated BEworks' results for all pilot participants, as shown in the first column of Table 2. Additionally, the LDV model (column 2) generated similar results as the primary model for all pilot participants. While there are minor differences in the point estimates, the results of the primary and LDV models are not statistically significantly different from each other.

The third and fourth columns in Table 2 provide the results for the models estimated using survey respondents and all matched controls. While results are generally similar to those using all pilot participants, the Overnight Off-Peak impact increased substantially in both summer and winter seasons. This indicates the energy usage patterns for survey respondents differ from those for all pilot participants. In particular, the proportion of EV owners may differ between all pilot participants and the survey respondents. Similar to the results from the models using all pilot participants, the LDV model and primary model produced similar results.

Columns 5 through 8 in Table 2 provide results for the No EV and EV subgroups of survey respondents. Again, the primary and LDV models produced generally similar results for each subgroup. While both models lead to the same conclusions, the point estimates and statistical significance differ for some TOU periods, including the Overnight Off-Peak period. Guidehouse recommends using the results of the LDV model, which clusters the standard errors at the household level, but notes that both models lead to similar conclusions regarding the potential for behavioural fuel switching.

The results for the No EV and EV subgroups for the Overnight Off-Peak period are highlighted in green in Table 2 (columns 6 and 8). In the summer, customers who reported owning an EV during the study period more than doubled their Overnight Off-Peak usage (1.115 kW, 115% increase), while customers who reported no EV increased their usage by a moderate amount (0.045 kW, 7% increase). Similar impacts occurred during the winter. Customers who reported owning an EV during the study period more than tripled their Overnight Off-Peak usage (1.988 kW, 246% increase), while customers who reported no EV increased their usage by a moderate amount (0.051 kW, 8% increase). Furthermore, increased usage for the No EV group was not statistically significantly different from zero in either season.

## Table 2. Regression Results Summary (kW)

| Model | (1) Primary Model, Replication | (2) LDV Model | (3) Primary Model | (4) LDV Model | (5) Primary Model | (6) LDV Model | (7) Primary Model | (8) LDV Model |
|---|---|---|---|---|---|---|---|---|
| Analysis Group | All | All | Survey | Survey | No EV | No EV | EV | EV |
| *Summer* | | | | | | | | |
| Overnight Off-Peak | 0.346 *** | 0.352 *** | 0.547 *** | 0.559 *** | 0.073 . | 0.045 | 1.042 *** | 1.115 *** |
| Off-Peak | 0.058 * | 0.066 * | 0.088 * | 0.106 ** | 0.018 | 0 | 0.162 *** | 0.23 *** |
| Mid-Peak | -0.082 *** | -0.083 *** | -0.105 *** | -0.105 *** | -0.071 * | -0.071 * | -0.141 *** | -0.134 *** |
| On-Peak | -0.1 *** | -0.103 *** | -0.114 *** | -0.117 *** | -0.107 ** | -0.111 *** | -0.123 ** | -0.118 *** |
| *Winter* | | | | | | | | |
| Overnight Off-Peak | 0.511 *** | 0.505 *** | 0.701 *** | 0.693 *** | 0.074 | 0.051 | 1.971 *** | 1.988 *** |
| Off-Peak | 0.153 *** | 0.149 *** | 0.175 *** | 0.171 ** | 0.036 | 0.022 | 0.457 *** | 0.478 *** |
| Mid-Peak | 0.005 | 0 | -0.009 | -0.013 | -0.025 | -0.025 | 0.022 | 0.024 |
| On-Peak | 0.012 | 0.011 | -0.01 | -0.011 | -0.027 | -0.023 | 0.023 | 0.025 |

*Asterisks indicate statistical significance of the results, at the 5% (\*), 1% (\*\*), and 0.1% (\*\*\*) levels.*
*More asterisks indicate greater statistical significance.*

The regression results provide evidence to reject the hypothesis that a material proportion of estimated winter demand impacts are a result of behavioural fuel switching. The increase in usage during the Overnight Off-Peak period is driven by the EV participants.

# 4. Estimate Benefits of Price Plan-Motivated EV Charging

In the RPP Pilot Meta-Analysis, Guidehouse determined that the Overnight price plan yielded an avoided cost benefit peak demand and On-Peak and Mid-Peak energy reduction that was less than the incremental system costs of the additional overnight consumption. Guidehouse noted in its analysis the behaviours that resulted in the net increase in load might be the source of additional (untracked) system benefit that could not be assessed based solely on residential customer electricity meter data.

Guidehouse hypothesized that two most probable sources for the net additional Overnight Off-Peak and Off-Peak load were behavioural fuel switching or shifting of EV charging location. For example, participants with EVs shifting from paying a per-hourly charge for EV charging (at their workplace or a public charging station), to charging their EV at home overnight. The analysis conducted in Section 3 determined that the increased overnight consumption observed in the pilot could be attributed primarily to EV drivers. Due to the rejection of the hypothesis of behavioural fuel switching and survey findings regarding EV purchases during the pilot period (see Section 2) Guidehouse has refined its hypotheses; the increased consumption attributed to the piloted price plan could be derived from:

- Participants shifting their load from non-home charging (e.g., workplace charging, public charging) to home charging, or;

- Customers purchasing/leasing an EV while subscribed to the treatment plan, or shifting driving from an internal combustion engine vehicle (ICEV) to an EV[8]

The purpose of this task is to estimate benefits of the above hypotheses, which were not quantified in the Meta-Analysis. In the Meta-Analysis, analysis of price plan impacts was limited to the participants' home electricity consumption data. As such, Guidehouse hypothesized that the analysis understated the benefits of the plan.

First, an analysis only of participant advanced metering infrastructure (AMI) and billing data (and not of non-home charging) does not quantify the demand reductions during system peak of a shift from public charging at peak times to overnight charging at home. Secondly, the Meta-Analysis did not quantify the societal benefits associated with customer uptake of EVs, such as reductions in carbon footprint and impacts to customer's bills.

## 4.1 Benefits of Shifting Charging from Non-Home to Home

### 4.1.1 Benefit Stream Definition

This section estimates the benefits assuming increased loads overnight are a result of drivers shifting their charging from non-home (e.g., workplace or public) locations to home locations. The benefits of this shift which were not captured in the Meta-Analysis include reductions in peak period demand (Avoided Capacity costs) and reductions in energy consumed outside of the overnight off-peak period (Avoided Energy costs). In the survey analysis, it was found that few participants indicated they shifted their charging behaviour from a public to home location;

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[8] This explanation was previously unexplored in the Meta-Analysis. As the price plan had a limited duration, this was treated as an edge case, and not fully explored in the Meta-Analysis report.

however, the participants that did shift their charging contribute to the overall increase in consumption seen from the Overnight group.

## 4.1.2 Calculation Methodology

To estimate the incremental benefits (not captured in the meta-analysis) of participants shifting EV charging behaviour from day-time public charging to overnight public charging Guidehouse:

- Estimated the share of EV participants' net increased consumption that may be attributed to EV use

- Assumed that this incremental consumption had been shifted from public charging

- Applied this incremental consumption to day-time EV charging profiles to estimate the day-time impacts, by time of day

- Applied the avoided energy and capacity costs to these time of day impacts to estimate the system benefits of this shifting

Guidehouse compared regression impacts shown in Table 2 EV participants and non-EV participants to estimate the increase in consumption specific to EV charging. The average increase in consumption in each TOU period is calculated as the difference between impacts for the 'EV' group (column 7) and 'No EV' group (column 5). Only statistically significant impacts are considered (non-significant impacts assumed to be zero).[9] The total average daily increase in consumption is then calculated as the product of the number of hours in a given period and the average hourly impact attributable to EV charging.

This analysis estimated that the average EV participant had increased daily consumption by 6.3 kWh for the summer period, and 14.1 kWh in the winter period as a result of EV charging behaviours. In cases where this consumption increase is a result of shifting from non-home to home locations, the incremental benefits not captured in the Meta-Analysis are the system benefits reduced coincident peak, On-Peak and Mid-Peak EV charging load (at non-home locations).

To determine the profile of the EV charging assumed to have been shifted away from public charging, Guidehouse applied the estimated EV-related increase in consumption to the average vehicle charging profile of a group of EV drivers subject to the default standard RPP TOU price plan.[10]

For the purposes of this analysis, Guidehouse assumed that EV participants shifting consumption away from public charging to private charging were using public charging only between 6am and midnight (i.e., no public charging takes place during the Overnight Off-Peak

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[9] So, for example, the estimated average hourly impact due to EV charging during the summer On-Peak period is -0.123 kWh minus -0.107 kWh (both EV and non-EV impacts are statistically significant) whereas the estimated average hourly impact due to EV charging during the Overnight Off-Peak period is just 1.042 kWh since the corresponding non-EV participant impact is not statistically significant.

[10] The load profile for the control group were participants of Alectra's ongoing @Home pilot program. These participants have data loggers installed in their electric vehicles to track the location and magnitude of their charging behaviour. For more details on @Home, please see the Alectra website:
**https://www.alectra.com/sites/default/files/assets/pdf/Alectra_GREATCentre_AlectraDrive_Home_2020-01.pdf**

period). The hourly shape of this change in charging behaviour estimated using the process described above is illustrated in Figure 6, below.

**Figure 6. Variance in Load due to Locational Shifting**
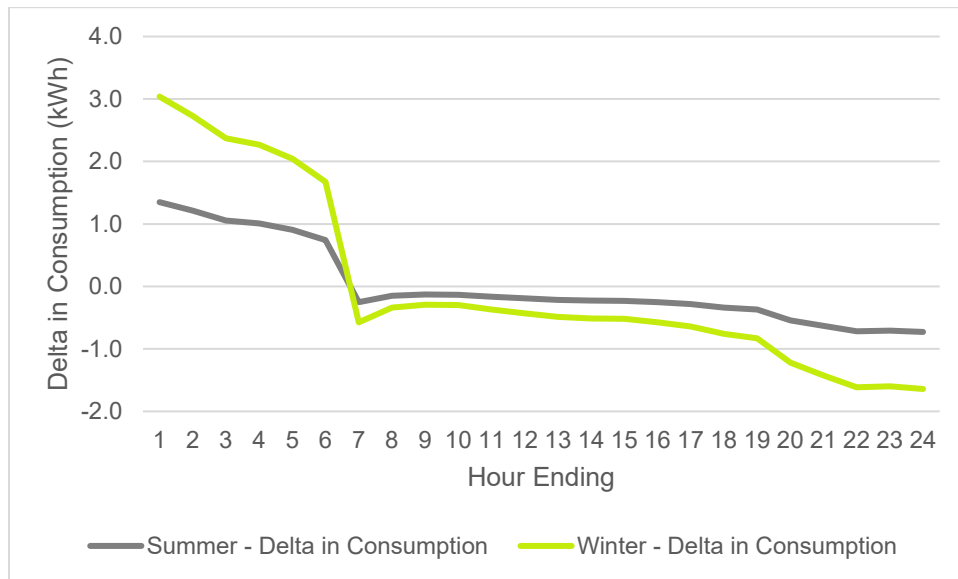


Guidehouse used the same IESO avoided energy cost values as for the Meta-Analysis, which are in 2020 dollars, and an avoided capacity cost of $135/kw-year for valuing coincident peak demand impacts. For the purposes of estimating the coincident peak demand impact, the system peak was assumed to be in the summer, between 4pm and 5pm, as the IESO reported this hour covered three out of the five system peaks in the period from May 1, 2020, to April 30, 2021.[11]

The benefits were calculated as:

- Avoided Energy Costs – the delta in consumption for each hour multiplied by the avoided energy cost for that time-of-use period and season.[12]

- Avoided Capacity Costs – the delta in consumption for the peak hour multiplied the stated capacity cost.

### 4.1.3 Results – Per Vehicle Benefits

The resulting estimated per-vehicle benefits of shifting load from non-home to home locations are shown in Table 3.

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[11] IESO. **https://www.ieso.ca/en/Sector-Participants/Settlements/Global-Adjustment-and-Peak-Demand-Factor**

[12] The avoided energy costs are only calculated for the periods which do not overlap with the overnight-off-peak period definition, as these benefits were already captured in the Meta-Analysis report.

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**Table 3. Per-vehicle Benefits of Locational Load Shifting**

|  | Summer Benefit | Winter Benefit | Annual Benefit |
|---|---|---|---|
| Avoided Energy Costs ($2020) | $30 | $60 | **$90** |
| Avoided Capacity Costs ($2020) | $41 | $0 | **$41** |

## 4.2 Benefits of EV Adoption

### 4.2.1 Benefit Stream Definition

This section calculates the benefits assuming the increased load is attributed to drivers shifting driving from an ICEV to an EV while subscribed to the treatment.[13] There are two primary benefit streams associated with increased EV uptake:

- **Societal Benefits** – carbon costs associated with the reduction of emissions resulting from driving an EV. The benefits to society of increased EV adoption are related to the decrease in greenhouse gas emissions resulting from vehicle ownership. ICEVs emit carbon while in operation. This carbon emission has an associated cost – removing those emissions are a net benefit to society. However, EVs are only as clean as the electricity they are powered by. EVs decrease fuel usage but increase electricity consumption; each electric grid has emissions related to the generation of electricity.

- **Individual Bill Benefits** – customer savings associated with decreased fuel prices from driving a zero-emission vehicle. The benefits to an individual of EV adoption on the Overnight treatment is a reduction in operation cost of the vehicle via reduced fuel costs. EVs generally have a lower operating cost than ICEVs due primarily to lower fuel costs; a decreased electricity price further increases savings to the customer.

### 4.2.2 Calculation Methodology

**Societal Benefits:**

To estimate the societal benefits (not captured in the meta-analysis) of participants shifting driving from an ICEV to an EV, Guidehouse:

- Calculated the average annual $CO_2$ emissions of an ICEV based on annual kilometers driven and the Environmental Protection Agency's average emissions per kilometer

- Calculated the average annual $CO_2$ emissions of an EV based on annual electricity consumption and the emissions per kWh of electricity generated in the Ontario electrical grid

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[13] This shift could either be a result of purchasing a new electric vehicle, or a result of two-or-more vehicle households shifting kilometers driven from one powertrain to another.

- Calculated the CO2 savings by switching powertrains

- Multiplied the CO2 savings by the Federal cost of carbon ($50/tonne in 2022)

For this benefit stream, Guidehouse calculated the difference in carbon emissions between an ICEV and an EV. For each powertrain, Guidehouse considered the annual mileage driven by the average driver in Ontario. Guidehouse's internal research arm, Guidehouse Insights, models this value at approximately 16,200 kilometers. For ICE vehicles, the EPA models an average emission of 404 grams of CO2 per mile driven (or 250 grams per kilometer). This equates to an annual CO2 emission of approximately 4 million grams.

For EVs, to calculate the emissions associated with increased grid generation, the annual electricity consumption of a vehicle must be determined. Guidehouse considered the average electric fuel efficiency modeled by Guidehouse Insights of 5.3 kilometers per kWh, resulting in an average consumption of 3,059 kWh. The Ontario grid has an emissions intensity factor of 31 grams of CO2/kWh.[14] This equates to an annual CO2 emission of approximately 95,000 grams.

Thus, the CO2 emissions reduction from switching an ICEV to an EV is 3.97 million grams, or 3.97 tonnes. In 2022, under the Federal government's carbon pricing system, carbon emissions are priced at $50/tonne.[15] The resulting societal benefit, per vehicle adopted, is $198.6.

| | Annual Benefit |
|---|---|
| Societal Benefits | $199 |

In the Meta-Analysis, Guidehouse found the response to the Overnight price yielded a negative system benefit. The avoided cost benefit of the peak demand and On-Peak and Mid-Peak energy reductions were less than the incremental system costs of the additional overnight consumption, with a net present value of a lifetime avoided cost benefit of -$14. The benefits output above were not captured in the Meta-Analysis.

The societal benefits calculated above (nearly $200 per participant) only apply to a subset of the entire Overnight pilot group (as ~47% of survey respondents indicated they owned/leased an EV, and of that group, 43% purchased the vehicle while subscribed to the treatment). Thus, the benefits obtained are applicable to roughly one-fifth of the treatment population. However, the benefit captured above is an **annual** benefit, while the -$14 value in the Meta-Analysis is a net present value of **lifetime** costs[16]. For this reason, due to the magnitude and lifetime of this benefit, were this to have been captured in the Meta-Analysis, the Overnight treatment would yield a positive societal benefit.

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[14] "A Clearer View on Ontario's Emissions", Toronto Atmospheric Fund. 2019. **https://taf.ca/wp-content/uploads/2019/06/A-Clearer-View-on-Ontarios-Emissions-June-2019.pdf**

[15] Government of Canada, **https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information.html**

[16] Lifetime defined as 14 years in the Meta-Analysis.

**Individual Bill Benefits:**

To estimate the individual bill benefits (not captured in the Meta-Analysis) of participants shifting driving from an ICEV to an EV, Guidehouse:

- Calculated the annual fuel cost of operating an ICEV based on average annual kilometers driven, average fuel efficiency and gasoline prices in Ontario

- Calculated the annual fuel cost of operating an EV based on average annual kilometers driven, average fuel efficiency and electricity prices on the Overnight price for an ICEV based on average annual mileage, average gasoline prices in Ontario

- Calculated the difference in fuel costs across the powertrains

For this calculation, the same annual mileage is assumed (16,200 km). To calculate fuel consumption for an ICEV, a fuel efficiency of 27.7 miles per gallon is assumed, per Guidehouse Insights. At 16,200 kilometers driven per year (or 10,000 miles), this results in an annual fuel consumption of 364 gallons, or 1,650 liters. The Government of Ontario reported an average gasoline price of $1.57 per litre in 2021, resulting in a fuel cost of $2,600. For an EV, an annual electricity consumption of 3,059 kWh was previously calculated.

Assuming the entirety of this electricity is consumed during the overnight off-peak period ($0.02 per kWh) results in a fuel cost of $61, for an annual bill savings of $2,539. If instead, the average consumption profile of EV drivers on the Overnight pilot is used, an average electricity price of $0.09 per kWh is realized, resulting in a fuel cost of $260, for an annual bill savings of $2,340.[17]

|  | Annual Benefit |
|---|---|
| Individual Bill Benefits | $2,340 |

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[17] Were a customer to adopt identical charging behaviour (e.g., same load shape) on the standard time-of-use rate (as the rates were set during the Overnight pilot), the customer would realize an annual bill savings of $2,344. In other words, customers could receive an additional savings of $194 per year by shifting their charging entirely to the overnight off-peak period.

# 5. Findings and Conclusions

In its Meta-Analysis of RPP Pilots, Guidehouse hypothesized that the entirety of benefits associated with the Overnight price plan were not captured. This report set out to estimate the incremental benefits of the pilot, and to test the hypotheses of sources of additional consumption. Through this analysis, Guidehouse can conclude:

1. **The estimated net increase in consumption due to the Overnight price plan does not appear to be the result of behavioural fuel-switching.** Participants that did not report owning or leasing an EV during the pilot period did not exhibit any statistically significant increase in consumption during the Overnight Off-Peak period. EV participants in contrast increased their average summer Overnight Off-Peak demand by more than 1 kW and their average winter Overnight Off-Peak demand by nearly 2kW.

2. **A very high proportion of EV participants acquired their vehicles during the pilot.** Of the 135 participants that responded to Guidehouse's survey, 63 indicated that they owned or leased an EV during the pilot period, and, of these, 27 (43% of EV participants) indicated that they acquired the vehicle during the pilot.

3. **The majority of the estimated increase in consumption as a result of the Overnight price plan is likely attributable to participants using EVs more, and ICEVs less.** Only 5% of EV participants that responded to the survey indicated that they had shifted their consumption from public to private charging. As noted above, all increases in Overnight Off-Peak consumption are attributable to EV participants, and nearly half of these identified that they had acquired their EV during the pilot.

4. **Where the average increase in consumption may be attributable to a shift from ICEV to EV use, the societal benefits are considerable.** Using average vehicle efficiencies to convert the incremental electricity consumption attributable to EVs (on a per vehicle basis) to an estimated reduction in gasoline use, and applying the federal carbon price as a proxy for the societal benefit of these reductions Guidehouse has estimated an average annual societal benefit of approximately $200.

5. **The individual customer bill savings of converting from ICEV to EV driving when subject to the Overnight price plan may be more than $2,000 per year**. One of the most significant costs of operating a vehicle are fuel costs. As the Overnight price plan greatly reduces the fuel cost for electric vehicles (which already have a lower per-mile cost than internal combustion engine vehicles), the realized benefits are significant.