Hydro Ottawa Smart Thermostat Evaluation Report

FINAL REPORT

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SUBMITTED TO:
Independent Electricity System Operator

SUBMITTED BY:
NMR Group, Inc. in partnership with Resource Innovations

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Finally, the NMR team would like to thank Alice Herrera, Nam Nguyen, and Jimmy Lu at the Independent Electricity System Operator (IESO) for their assistance in coordinating this evaluation effort. With their support and guidance, the NMR team was able to complete their activities as efficiently and successfully as possible.

Acronyms

Acronym	Definition
CPUC	California Public Utility Commission
CPP	Critical peak pricing
CE	Cost-effectiveness
EM&V	Evaluated Measurement and Verification
GHG	Greenhouse Gas
IDI	In-depth Interview
IESO	Independent Electricity System Operator
IF	Interim Framework
IOUs	Investor-Owned Utilities
kW	Kilowatt
kWh	Kilowatt-hours
LDC	Local Distribution Company
MSE	Mean squared error
MW	Megawatt
MWh	Megawatt-hour
NTG	Net-to-Gross
POS	Point-of-sale
PRISM	Princeton Scorekeeping Method
RR	Realization Rate
SMUD	Sacramento Municipal Utility District
TOU rate	Time-of-use

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Executive Summary

NMR Group, Inc. (NMR), in partnership with subcontractor, Resource Innovations, Inc., (collectively, “the NMR team”) and under contract to the Independent Electricity System Operator (the IESO), performed an evaluation of the Hydro Ottawa Limited (referred to as Hydro Ottawa”) Smart Thermostat Program.

Program Description

The Smart Thermostat Program was a locally delivered program that was offered by local distribution company (LDC), Hydro Ottawa. It was delivered in partnership with an Enbridge Gas smart thermostat program to eligible customers from residential, single-family homes in pre-specified areas. Customers could receive a total of $219 (pre-tax) between the Enbridge Gas and Hydro Ottawa programs. The first $75 was applied as an Enbridge Gas cash rebate for purchasing a new smart thermostat online or at various retail locations at the point-of-sale (POS), and the remaining amount was applied as a credit, with a maximum of $144 (pre-tax), on customers’ Hydro Ottawa bills.

Evaluation Objectives

The evaluation sought to address several evaluation objectives, including the following:

- Verify energy and demand savings
- Estimate realization rates (RR)
- Conduct cost-effectiveness (CE) analyses
- Estimate the avoided greenhouse gas (GHG) emissions
- Perform a limited process evaluation

Summary of Results

The impact evaluation results for the Smart Thermostat Program are displayed in Table 1 for the customers who were always on the time-of-use (TOU) rate, Table 2 for the customers who switched from the TOU to the tiered rate, and Table 3 for all participants. The overall gross RRs were 129%, 93%, and 136%, respectively.[1] The values displayed in Table 1, Table 2, and Table 3 represent an increase in energy usage.

Table 1: Smart Thermostat Program Results

Metric	Units	Evaluated
Participation	Homes	1,048
Gross Verified Energy Change	MWh	300.3

[1] Demand savings (kW) were not calculated as a part of this evaluation. Given the negative energy savings, the NMR team and IESO program staff determined it was not worth the extra cost and effort to compute demand savings.

Metric	Units	Evaluated
Gross Energy RR	-	1.29
Net Verified Annual Energy Change	MWh	300.3
Net-to-Gross (NTG) Ratio	-	1

Table 2: Hydro Ottawa Smart Thermostat Program Results – TOU to Tiered Rate Switch

Metric	Units	Evaluated
Participation	Homes	583
Gross Verified Energy Change	MWh	216.6
Gross Energy RR	-	0.93
Net Verified Annual Energy Change	MWh	216.6
NTG Ratio	-	1

Table 3: Hydro Ottawa Smart Thermostat Program Results – All Participants

Metric	Units	Evaluated
Participation	Homes	1,631
Gross Verified Energy Change	MWh	516.0
Gross Energy RR	-	1.36
Net Verified Annual Energy Change	MWh	516.0
NTG Ratio	-	1

Key Findings and Recommendations

The following section summarizes the Smart Thermostat Program evaluation's key findings and recommendations. Section 5 presents these key findings and recommendations in greater detail.

Finding 1: Rebating a new smart thermostat does not guarantee energy savings. Participants in the Smart Thermostat Program had a statistically significant change in average monthly consumption of 26.4 kWh. There are some evaluations from other jurisdictions that have also reported change in consumption.

- **Recommendation 1.** Providing participants with education about how to use the features of a smart thermostat could help the program achieve energy savings. In a review of comparable evaluations, the NMR team found that an educational component was included as a part of program implementation in half of the evaluations reviewed. The evaluations that included education all showed statistically significant energy savings, while the evaluations without an educational component had, at least partially, statistically significant increases in usage. After installing the smart thermostat, participants could receive support on the best way to use their thermostat to save energy. These tips could be provided via bill inserts or flyers mailed directly to the customers who received incentives for installing a smart thermostat. Additionally, participants could receive further education about their thermostats including ways to optimize their settings after installation. Also, the information should be tailored to the participant's specific smart thermostat since the interface and features vary across manufacturers. See Appendix B for more information about smart thermostat programs in other jurisdictions.

Finding 2: Smart thermostat manufacturers have different features that can impact electrical usage. While reviewing other smart thermostat evaluations, the NMR team found not all smart thermostats can be expected to deliver equal energy savings. The expected savings can vary based on the default settings built into the smart thermostat. For example, the smart thermostat from one manufacturer might automatically adjust its setpoint back to an energy-saving level after a manual change by a customer, whereas a different thermostat will stay at the manually adjusted level.[2]

- **Recommendation 2.** When implementing smart thermostat programs in the future, consider designing the program to enable a comparison of savings from different manufacturers. This methodology can provide insight into the strengths and weaknesses of various smart thermostats and which thermostat features should be required for program eligibility in the future. Another option is to set an eligibility requirement around features that are present in smart thermostat programs with demonstrated savings. Additionally, including participant surveys in future evaluations could shed light on how customers are engaging with their smart thermostats.

Finding 3: The effects of the COVID-19 pandemic on program results are unknown. The evaluation period for the Smart Thermostat Program, June 2019 – December 2021, directly coincides with the pandemic. Various stay-at-home orders and a shift to remote work and school rapidly changed how much energy people consume at home. Given this large societal shift in electricity usage patterns in addition to economic pressures due to interruptions of work and school, it is not known whether participants would have used their smart thermostats differently during this time if the pandemic had not occurred. Significant changes in home occupancy patterns during the pandemic also likely diminished the potential for the thermostats to change setpoints during periods of no occupancy.

- **Recommendation 3.** The NMR team recommends future smart thermostat evaluations use a within-subjects methodology instead of a matched control group analysis. A within-subjects evaluation compares each participant's usage before and after the installation of a smart thermostat. Although there are pros and cons to each methodology, a within-subjects design eliminates the concern over selection bias in the treatment group. The original scope for this evaluation called for a within-subjects design but had to be abandoned due to the effects of COVID-19 on electric usage. In instances when a within-subjects methodology cannot be utilized, like in this evaluation, the NRM team recommends that a matched control group methodology be adopted.

Finding 4: Daily electric usage for participants increased during the COVID-19 pandemic. The average daily usage for participants before the installation of a smart thermostat, from June 2019 – May 2020, was 21.0 kWh. This metric increased to 26.1 kWh after the smart thermostats were installed, from January 2021 – December 2021. The pre- and post-installation periods overlap with the beginning of the pandemic in April 2020. The increase in usage is likely related to people spending more time in their homes due to the pandemic.

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[2] Xcel Energy Colorado Smart Thermostat Pilot – Evaluation Report. Schellenberg, J., Lemarchand, A., & Wein, A. (2017).

- **Recommendation 4.** While a within-subjects approach is suitable for smart thermostat evaluations when electric usage is relatively stable, when there are huge shifts in usage caused by external forces then a matched control group is preferred. In this evaluation, a matched control group was utilized to account for changes in usage related to the pandemic. The NMR team recommends that IESO and the LDCs be prepared to change an evaluation's approach to a matched control group when a within-subjects methodology is not feasible. Specifically, a matched-control group methodology requires providing potentially a large amount of additional data for customers not participating in a smart thermostat program. At the outset of the program's implementation, the IESO and implementing LDC should have a contingency plan covering the case that non-participant data is needed for the impact evaluation. Additionally, funding should be provided for participant and non-participant surveys to help detect and correct for self-selection bias and spillover.

Finding 5: LDC program staff reported the Smart Thermostat Program was easy to participate in and administer but fell far short of its participation target. The Smart Thermostat Program reached approximately 20% of its participation target, which LDC program staff attributed to the COVID-19 pandemic and its related effects on program marketing and program duration. Program staff felt the program was relatively easy to participate in from the customer perspective, that it was relatively straightforward to administer, and that the collaboration with the Enbridge Gas was successful.

- **Recommendation 5.** If the Smart Thermostat Program were to run again in the future, run it for a longer duration, perform in-person marketing in addition to online and direct mail outreach, and consider collaborations with Enbridge Gas or other LDCs running similar programs.

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Section 1 Introduction

The Independent Electricity System Operator (the IESO) retained NMR Group, Inc. (NMR), in partnership with subcontractor, Resource Innovations, Inc. (collectively, "the NMR team"), to conduct an evaluation of its Low Income, First Nations, and Residential Local programs and pilots offered under the Interim Framework (IF). This report includes results, findings, and recommendations for the NMR team's evaluation of the Smart Thermostat Program offered by local distribution company (LDC), Hydro Ottawa Limited (referred to ask "Hydro Ottawa").

1.1 Program Description

Hydro Ottawa offered the Smart Thermostat Program to eligible residential customers in pre-specified areas of their service territory between June 2020 to December 2020. The program encouraged more residents to adopt smart thermostats in grid-constrained areas. It was offered in partnership with Enbridge Gas' province-wide Instant Rebate Smart Thermostat Program, which had been in-market prior to the launch of the Hydro Ottawa program.

1.1.1 Program Design

Customers could receive a total of $219 (pre-tax) between the Enbridge Gas and Hydro Ottawa programs. The first $75 was applied as an Enbridge Gas cash rebate for purchasing a new smart thermostat online or at various retail locations at the point-of-sale (POS), and the remaining amount was applied as a credit, with a maximum of $144 (pre-tax), on customers' Hydro Ottawa bills.

1.1.2 Delivery

Hydro Ottawa administered and delivered the program. It carried out a limited marketing and promotional campaigns through e-mail, online, and postal mail engagements. In person-outreach was curtailed due to the pandemic.

1.1.3 Eligibility

To be eligible for the program, customers were required to live in one of the identified areas in Kanata, be active Hydro Ottawa residential customers, and live in a single-family home (detached, semi, or townhouse) with central air conditioning. If the applicant did not own the residence, they were required to supply a letter confirming the landlord's approval to install the smart thermostat. They were also required to be an Enbridge Gas customer and have applied for the initial $75 rebate through Enbridge Gas at the Points of Sale (POS). Customers could not live at the location of a previous participant who installed a smart thermostat using funding from a previously in-market program.

1.2 Evaluation Objectives

The evaluation sought to address several evaluation objectives, including the following:

- Verify energy and demand savings with a 90% level of confidence at 10% precision for the program;
- Estimate realization rates (RRs);
- Conduct cost-effectiveness (CE) analyses;
- Estimate the avoided greenhouse gas (GHG) emissions from electricity savings using the IESO *Cost Effectiveness Tool*; and
- Perform a limited process evaluation by addressing key research questions of interest to the program.

Section 2 Methodology

This section presents a summary of the impact estimation methodology. Detailed descriptions of the methodologies used are provided in Appendix A.

2.1 Impact Evaluation Methodology

The evaluation plan for the Smart Thermostat Program originally specified estimating energy savings using a within-subjects framework. In a within-subjects impact evaluation, a counterfactual for each participant would be estimated using their monthly electricity consumption before the installation of the smart thermostat. However, this method had to be abandoned given the effect of the COVID-19 pandemic on residential electric usage. If a within-subjects research design had been utilized, distinguishing between the changes in usage in the post-treatment period attributable to the pandemic and the smart thermostats would not be possible.

Instead, this evaluation uses a matched control group framework along with a difference-in-difference estimation methodology to obtain energy savings for program participants ("treatment customers") for each month in 2021. Using a matched control group, participants are matched to similar non-participating customers ("control customers") based on usage before the installation of a smart thermostat. The effects of the COVID-19 pandemic on electricity usage equally influence the treatment and matched control customers. Thus, the changes in usage associated with the pandemic are netted out between the two groups.

The following subsections provide context about data management, control group selection, and impact estimation.

2.1.1 Data Sources and Management

To develop estimates of the energy savings attributable to the Smart Thermostat Program, the NMR team requested and received the following information from Hydro Ottawa:

1. **Participation records** which included a list of program participants and smart thermostat purchase date.
2. **Billed electric consumption** for each participant and a large pool of non-participants. The NMR team received the available billed usage for these customers covering the period June 2019 to December 2021. Hydro Ottawa randomly selected the control customers from their entire population of residential customers that are not participating in the Smart Thermostat Program.

The NMR team performed a thorough cleaning and validation of all data to ensure the impact estimates were calculated using only reliable observations. The data were checked for completeness, missing or duplicate values, and outliers. Through the data cleaning process, 354 treatment and 30 potential control customers were dropped, including those with incomplete data based on the timing of account open and close dates. Table 4 shows the number of treatment and potential control customers included in the billing data along with the number of customers excluded from the analysis after data cleaning.

Table 4: Availability of Monthly Billing Data

Data Completeness Status	Treatment Customers (Participants)	Potential Control Customers
Complete Data	1,277	23,510
Incomplete Data	354	30
Total	**1,631**	**23,540**

The date ranges provided in each customer's billing data were specific to their billing period. For example, a customer's June billing period might be May 15 to June 14. The NMR team calendarized billed electric consumption into monthly usage values. This was done by calculating the average daily usage values for each calendar month in each billing period and then calculating the weighted average daily consumption for each calendar month.

The NMR team found customers who switched electric rates during the analysis period. This is attributed to a provincial regulatory change effective November 1, 2020, whereby customers were given the option to take a tiered electricity rate. Prior to November 2020, residential customers in Ontario were required to take a time-of-use (TOU) electricity rate.

Table 5 shows the customer counts for all participants and those with complete billing data by rate. Approximately half of the customers who received a smart thermostat, 821 out of 1,631, had complete data and were on the TOU rate for the entire analysis period. Additionally, 450 customers opted to move from the TOU to the tiered rate. The customers who were always on the tiered rate and those who switched from the tiered to TOU rate were not included in the analysis due to low sample sizes.[3]

Table 5: Summary of Participant Rate Switching

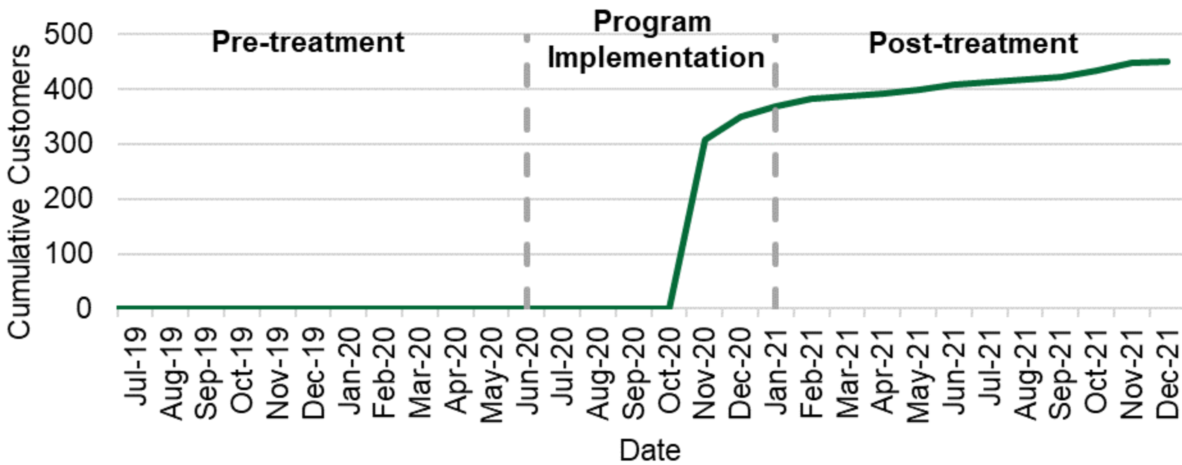
Electric Rate Structure	All Participants	Participants with Complete Data
Always on TOU	1,045	821
Always on Tiered	10	3
TOU to Tiered	573	450
Tiered to TOU	3	3
Total	**1,631**	**1,277**

Figure 1 presents the number of participants who switched from the TOU to the tiered rate each month. The largest number of customers changed rates in November 2020, which was the first month customers were allowed to switch rates. Figure 1 also shows the analysis periods in effect for this evaluation. These periods include the pre-treatment, program implementation, and post-

[3] To calculate program aggregate energy savings (MWh), the always-on-tiered customers were included in the TOU-to-tiered group and the tiered-to-TOU participants were included with the always-on-TOU group.

treatments periods, which represent the time before, during, and after smart thermostat installation, respectively.

Figure 1: Treatment Customers who Switch from the TOU to the Tiered Rate by Month



2.1.2 Control Group Validation

The NMR team conducted a statistical matching process of the treatment and control customers to estimate the reference load or counterfactual. The reference load is an estimate of monthly electricity usage in absence of the Smart Thermostat Program and was compared to the load of the treatment customers to estimate the impacts of the program. A multivariate-distance matching technique was used to obtain a set of matched control customers that had similar usage patterns as the treatment customers during the pre-treatment period, June 2019 to May 2020. Control customers were allowed to match to multiple treatment customers.

The NMR team conducted matching separately for customers who were always on the TOU rate and those that switched from TOU to the tiered rate. Participants always on the TOU rate were matched to control customers also always on a TOU rate. For the customers who switched from TOU to tiered rates, the matching for any given program participant was performed exclusively to a non-participant that also switched to the tiered rate in the same month. This was done to account for potential changes in usage attributable to the rate change, which are unrelated to the installation of a smart thermostat. The checks to determine equivalence included t-tests, a fixed-effects regression, and visual inspection with boxplots and graphs. The details of the matching model and checks are presented in Appendix A.1.

2.1.3 Energy Savings

To calculate energy savings, the NMR team used calendarized billing data for treatment and control customers to compare their usage during the pre- and post-treatment periods. The analysis approach used a difference-in-difference estimation – i.e., the difference in usage between treatment and control customers that already existed before the thermostats were installed is accounted for in the impacts. The difference between the two groups during the pre-treatment period is subtracted from the difference between groups during the post-treatment period. This methodology is commonly used when comparing groups and accounts for any differences that might exist between the groups during the pre-treatment period. Appendix A.1 presents more information on the estimation of energy savings.

2.2 Cost-Effectiveness Evaluation

Since the impact evaluation found no savings, a cost effectiveness assessment of the program would not yield meaningful results. Therefore, the NMR team did not conduct a cost-effectiveness analysis on this program. Additionally, the team also did not perform an avoided GHG emissions estimation due to the lack of program savings.

2.3 Limited Process Evaluation

Table 6 shows details about the primary data source used to support the limited process evaluation methodology. The process evaluation focused on program design and delivery. The NMR team evaluated program processes through an in-depth interview (IDI) with the local distribution company (LDC) program staff from Hydro Ottawa. The NMR team developed a customized interview guide that was reviewed and approved by the IESO Evaluated Measurement and Verification (EM&V) staff. The NMR team completed the IDI in June 2021 with LDC program staff who were responsible for administering the program. The purpose of this IDI was to learn about the LDC's experiences with program administration and to identify any successes, barriers, and program improvement opportunities should a similar program continue in future years.

Table 6: Limited Process Evaluation Primary Data Sources

Respondent Type	Methodology	Completed	Population	90% CI Error Margin
LDC Program Staff	Phone In-depth Interviews (IDIs)	1	1	0%

Section 3 Impact Evaluation

The following subsections outline the impact evaluation results. Details regarding the impact methodology can be found in Section 2 and Appendix A.1.

3.1 Energy Change

Based on the methodology presented in Section 2.1, the NMR team estimated energy change as a result of the Smart Thermostat Program. The results are presented separately for the customers who stayed on the TOU rate throughout the evaluation period and for the customers who switched rates from the TOU to tiered structure, in addition to a combined result across all participants.

In the tables below, the rows labeled "Total for 2021" are a summation of each month of the calendar year 2021. The column labeled "Total Gross Change" represents the entire change attributable to each month or year when accounting for all customers included in the analysis.

3.1.1 Energy Change – Always TOU

Table 7 shows the overall average monthly energy change during the evaluation period, January 2021 – December 2021, for customers always on the TOU rate. Overall, there was a statistically significant 3.3%, or 23.9 kWh, change in usage by treatment customers over matched control customers, after considering pre-treatment differences in usage between the treatment and control customers.

Table 7: Overall Average Monthly Energy Change – Always TOU

Treatment Customers	Average Monthly Change (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Average Gross Monthly Change (MWh)
1,048	23.9*	11.2	36.6	3.3%	25.0*

*Statistically significant at the 90% level of confidence.

The monthly energy change for the TOU-only customers are presented in Table 8. Like the overall average seen in Table 7, none of the months showed savings. The treatment customers show a change in consumption of 286.5 kWh due to the smart thermostat over the calendar year. Changes in monthly energy usage ranged from 2.2 kWh, or 0.4%, higher in April 2021 to 44.5 kWh, or 5.0%, higher in July 2021. Additionally, nine out of the 12 months showed statistically significant change in usage due to the smart thermostats.

Table 8: Average Monthly Energy Change - Always TOU

Month	Treatment Customers	Average Monthly Change (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Total Gross Change (MWh)
Jan-21	1,048	8.6	-11.6	28.9	1.2%	9.0
Feb-21	1,048	19.1	-5.2	43.4	2.7%	20.0
Mar-21	1,048	18.9*	1.8	35.9	2.9%	19.8*
Apr-21	1,048	2.2	-10.3	14.8	0.4%	2.3
May-21	1,048	18.5*	4.1	32.9	2.6%	19.4*
Jun-21	1,048	29.5*	8.1	50.8	3.5%	30.9*
Jul-21	1,048	44.5*	22.8	66.2	5.0%	46.6*
Aug-21	1,048	29.4*	7.5	51.2	3.1%	30.8*
Sep-21	1,048	36.2*	18.2	54.2	4.9%	37.9*
Oct-21	1,048	30.0*	13.5	46.4	4.8%	31.4*
Nov-21	1,048	24.8*	7.8	41.9	3.9%	26.0*
Dec-21	1,048	24.9*	4.6	45.1	3.5%	26.1*
Total for 2021		**286.5***	**134.1**	**438.9**	**3.3%**	**300.3***

*Statistically significant at the 90% level of confidence.

3.1.2 Energy Change – TOU to Tiered Rate Switch

Table 9 shows the average monthly energy change in 2021 for customers who switched from the TOU to the tiered rate, which was 31.0 kWh or 3.7% higher. The average monthly impact is statistically significant at the 90% confidence level.

Table 9: Overall Average Monthly Energy Change - TOU to Tiered Rate Switch

Treatment Customers	Average Monthly Change (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Average Gross Monthly Change (MWh)
583	31.0*	4.2	57.8	3.7%	18.1*

*Statistically significant at the 90% level of confidence.

Table 10 shows the average energy change each month in 2021 for the customers who switch their rates from the TOU to tiered rate. December 2021 reflects nonsignificant savings of -11.6 kWh. However, all the other months show an increase in consumption. The monthly energy change are only statistically significant in January and June through August, but the annual energy change is statistically significant for the entire year. The treatment customers had a higher consumption of 3.7%, or 371.6 kWh due to the smart thermostat over the calendar year.

Table 10: Average Monthly Energy Change - TOU to Tiered Rate Switch

Month	Treatment Customers	Average Monthly Impact (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Total Gross Savings (MWh)
Jan-21	583	46.9*	6.8	87	5.1%	27.3*
Feb-21	583	31.6	-5.7	68.9	3.9%	18.4
Mar-21	583	24.1	-13.6	61.8	3.2%	14.0
Apr-21	583	12.6	-21.4	46.7	1.8%	7.4
May-21	583	26.4	-10.1	62.9	3.3%	15.4
Jun-21	583	50.1*	6.2	93.9	5.7%	29.2*
Jul-21	583	67.4*	21.5	113.3	7.2%	39.3*
Aug-21	583	80.5*	30.1	131	8.2%	47.0*
Sep-21	583	35.1	-9.4	79.6	4.4%	20.5
Oct-21	583	5.1	-37.4	47.6	0.7%	3.0
Nov-21	583	3.3	-38.1	44.7	0.4%	1.9
Dec-21	583	-11.6	-56.1	33	-1.3%	-6.7
Total for 2021		**371.6***	**49.9**	**693.5**	**3.7%**	**216.6***

*Statistically significant at the 90% level of confidence.

3.1.3 Energy Savings – All Participants

Table 11 shows the average monthly energy change in 2021 for all the participants in the program, which was 26.4 kWh or 3.4% higher. The average monthly change is statistically significant at the 90% confidence level.

Table 11: Overall Average Monthly Energy Change – All Participants

Treatment Customers	Average Monthly Impact (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Average Gross Monthly Impact (MWh)
1,631	26.4*	12.1	40.6	3.4%	43.0*

*Statistically significant at the 90% level of confidence.

Table 12 displays the average energy change each month in 2021 for all the participants in the program. The monthly changes in consumption are statistically significant each month besides April, November, and December. Overall, the treatment customers showed a change in usage by 3.4%, or 316.4 kWh, over the calendar year.

Table 12: Average Monthly Energy Change – All Participants

Month	Treatment Customers	Average Monthly Change (kWh)	Lower Bound (90%)	Upper Bound (90%)	Percent Impact	Gross Monthly Change (MWh)
Jan-21	1,631	22.2*	0.7	43.7	2.8%	36.2
Feb-21	1,631	23.4*	2.1	44.8	3.2%	38.2
Mar-21	1,631	20.7*	2.5	38.9	3.0%	33.8
Apr-21	1,631	5.9	-9.8	21.6	0.9%	9.6
May-21	1,631	21.3*	4	38.7	2.9%	34.8
Jun-21	1,631	36.8*	15.3	58.2	4.3%	59.9
Jul-21	1,631	52.6*	29.8	75.4	5.8%	85.8
Aug-21	1,631	47.5*	23.6	71.4	5.0%	77.5
Sep-21	1,631	35.8*	15.4	56.2	4.7%	58.4
Oct-21	1,631	21.1*	1.5	40.6	3.2%	34.4
Nov-21	1,631	17.2	-2.4	36.8	2.5%	28.0
Dec-21	1,631	12.0	-9.8	33.7	1.6%	19.5
Total for 2021		**316.4***	**145.4**	**487.5**	**3.4%**	**516.0**

*Statistically significant at the 90% level of confidence.

While it is not known for certain why participants changed their electrical usage compared to control customers after the installation of a smart thermostat, both groups increased their electricity consumption after the onset of the COVID-19 pandemic. As displayed in Table 13, the average daily consumption for both treatment and control customers increased during the post-smart thermostat period, which begins in January 2021. This is likely related to people spending more time in their homes due to pandemic restrictions. When comparing the two groups, the treatment customers had a greater increase than the control customers during the post-smart thermostat period.

This change in electricity consumption due to the pandemic necessitated the adoption of a matched control group methodology. A within-subjects (or pre-post methodology as it is also called) would not be able to distinguish changes in electricity consumption due to the pandemic and those due to the thermostat. Further, the difference-in-difference impact estimation approach using the matched control group (rather than a simple difference) used in this evaluation also accounts for any differences in usage between treatment and control customers before the installation of a smart thermostat.

Table 13: Average Daily Usage Before and After Smart Thermostat Installation

Period	Date Range	Treatment Customers (kWh)	Control Customers (kWh)	Difference in Usage (kWh)
Pre-Smart Thermostat	June 2019 - May 2020	21.01	20.96	0.05
Post-Smart Thermostat	January 2021 - December 2021	26.14	25.23	0.91

An important consideration to remember is the Smart Thermostat Program did not employ direct load control of the thermostat or additional educational messaging for participants, including energy savings tips and how to best program the thermostat. In a review of comparable smart thermostat evaluations, the NMR team found an educational component was a part of the program implementation in half of the evaluations. Although smart thermostats are generally user friendly, there is no guarantee people use them in a manner that reduces their home's energy usage. For example, people could use it in the same manner as they use a regular manual thermostat. Additionally, different smart thermostat manufacturers have features and settings unique to their thermostat. One manufacturer's thermostat might return to a pre-planned energy-saving schedule after a manual adjustment, whereas another thermostat could stay at the adjusted temperature. See Appendix B for additional information about other smart thermostat programs.

Another factor contributing to the results could be the effect of the COVID-19 pandemic on the participants' use or engagement of the thermostats. It is unknown if program participants would have used their thermostat differently in 2021 if the pandemic had not occurred. We do know that participants' electricity usage overall did change during the pandemic, and that change has been considered, but what is unknown is how the impact of the thermostat's presence itself may have changed due to the pandemic.

Further, the learning algorithms in the smart thermostats did not respond efficiently or as desired from a conservation standpoint to the unexpected and significant change in home occupancy during the pandemic. Learning algorithms in smart thermostats at least partly rely on home occupants' trips in and out of the home to drive energy savings by reducing cooling and heating when no one is in the house. The opportunity for that kind of setpoint optimization was significantly curtailed during pandemic lockdowns.

Lastly, matched control group impact analysis suffers from the inability to definitively rule out self-selection bias due to an unobserved difference between the program participants and matched control customers that is correlated with energy usage and occurs at the same time of the program's implementation. Participant and non-participant surveys can help assess the potential for and provide information that can help account for the potential for self-selection bias in the impact estimate. Additionally, surveys can provide data on whether customers in the matched control group also installed smart thermostats at the same time as the program participants. Budget for participant and non-participant surveys was not available for this evaluation.

A hypothesis on the causes of treatment customers increasing usage after receiving a smart thermostat could be the presence of a new and exciting technology in their homes. Participants in the program went through the process of signing up for a rebate and installing the thermostat themselves, so they were likely curious to try their new thermostat. This could have led participants to think about their household temperature more often and towards the end of increasing comfort rather than reducing energy consumption. The new technology in their home may have made them want to engage with it (i.e., adjust setpoints to feel more comfortable) more than their old thermostat, resulting in more cooling and/or heating usage.

Section 4 Limited Process Evaluation

This section presents the limited process evaluation results. Details regarding the limited process methodology can be found in Section 2.3.

4.1 LDC Program Staff Perspectives

The following subsections highlight the feedback received from the LDC program staff about the design and delivery of the program.

4.1.1 High-Level Results

High-level results from the LDC program staff IDI include the following:

- LDC program staff indicated that the program had met expectations in line with the challenges and restraints that the COVID-19 pandemic presented.
- The program achieved approximately 20% of its participation target, largely due to the pandemic, which delayed the program and limited planned marketing campaigns.
- LDC program staff indicated that the Enbridge Gas program's participation increased significantly once the Hydro Ottawa program came to market, likely driven by the fact that the rebates covered nearly the entire cost of the smart thermostat.
- LDC staff appreciated the opportunity to collaborate with Enbridge Gas' program, noting that they communicated effectively, sharing their promotion plans and manufacturing contacts when needed.
- Barriers mentioned by LDC program staff included pandemic-related marketing limitations, the initial difficulty of managing the in-bill rebate system, and the two-step rebate process.
- LDC program staff identified opportunities to consider in future, including collaborating with additional utilities on future programming and potentially utilizing smart thermostats for local demand response initiatives.

4.1.2 Program Design and Delivery

LDC program staff cited the pandemic as a major obstacle to program delivery, especially pertaining to customer enrollments and marketing efforts. The program had an initial target of 8,000 participants and a much longer program delivery timeline. Due to the pandemic, the program was only in-market for five and a half months and reached only 20% of its participation target. LDC program staff indicated this participation rate was reasonable given the challenges of the pandemic.

The pandemic limited marketing campaigns by eliminating the ability to drive participation through in-person outreach. Hydro Ottawa had initially planned to hire college students to make door-to-door visits to promote the program. They also were planning to schedule multiple in-person marketing campaigns at major home-improvement retail stores. Without in-person outreach, the program staff relied on e-mail, online, and postal mail engagements. Despite this more limited outreach, once Hydro Ottawa's marketing began, Enbridge Gas informed them that participation in the program increased by three to four times its initial rate.

According to the LDC program staff, both LDCs communicated with each other frequently, keeping each other up to date on promotions and other program aspects. LDC program staff appreciated the opportunity to collaborate with Enbridge, noting that by working together, they were more quicky able to enter the field given Enbridge's existing relationships with manufacturers.

To ensure quality control, the LDC program staff only targeted eligible Hydro Ottawa customers with their outreach efforts. Prior to issuing customers rebates, the LDC program staff verified eligibility by reviewing all customer account information and proof of installation details.

4.1.3 Customer Participation

LDC program staff indicated that the application process worked well, requiring minimal information from customers. However, they noted that the two-step rebate process increased the points of contact for customers, with customers first submitting requests for credit through Enbridge Gas and then again through Hydro Ottawa. Ideally, customers could have received the rebates from one source, but Enbridge Gas was not able to issue the rebates on Hydro Ottawa's behalf given that they could not determine the geographical eligibility of Hydro Ottawa's customer base. LDC staff reported that the two-step process may have led to reduced free-ridership given that the extra step required might have discouraged customers that did not really need the rebates from participating. In addition, this process allowed customers to receive rebates from both their electric utility and their gas utility rather than having to decide on participating with one over the other.

4.1.4 Barriers and Opportunities

LDC program staff mentioned that it was initially difficult to manage the two-step rebate process but noted that they were able to adapt to the process quickly. In addition, the LDC program staff developed a system to help them issue the rebates in batches, which allowed them to automate the on-bill processes. They indicated this will serve them well if they were to offer similar programs in the future. Future opportunities as reported by LDC program staff included potentially collaborating with additional utilities on future programming, or the possibility of utilizing smart thermostats for local demand response initiatives.

Section 5 Key Findings and Recommendations

The following section presents detailed key findings and recommendations for the Smart Thermostat Program.

Finding 1: Rebating a new smart thermostat does not guarantee energy savings. Participants in the Smart Thermostat Program who were always on the TOU rate had a statistically significant increase in average monthly consumption of -23.9 kWh, and participants who switched from the TOU to the tiered rate had an increase in usage of -31.0 kWh. Overall, all participants had a statistically significant average increase in monthly electricity consumption of -26.4 kWh. Although smart thermostat programs often produce energy savings, there are some evaluations from other jurisdictions that have also generated negative results. Furthermore, there is evidence that greater savings can be achieved when customers receive additional training about how to properly use their smart thermostat. Refer to Appendix B for a literature review of other smart thermostat program impact evaluations.

- **Recommendation 1.** Providing participants with education about how to use the features of a smart thermostat could help the program achieve energy savings. In a review of comparable evaluations, the NMR team found that an educational component was included as a part of program implementation in half of the evaluations reviewed. The evaluations that included education all showed statistically significant energy savings, while the evaluations without an educational component had, at least partially, statistically significant increases in usage. After installing the smart thermostat, participants could receive support on the best way to use their thermostat. These tips could be provided via bill inserts or flyers mailed directly to the customers who received incentives for installing a smart thermostat. Additionally, participants could receive further education about their thermostats including ways to optimize their settings after installation. Also, the information should be tailored to the participant's specific smart thermostat since the interface and features vary across manufacturers.

Finding 2: Smart thermostat manufacturers have different features than can impact electrical usage. While reviewing other smart thermostat evaluations, the NMR team found that not all smart thermostats can be expected to deliver equal energy savings. The expected savings can vary based on the default settings built into the smart thermostat. For example, the smart thermostat from one manufacturer might automatically adjust its setpoint back to an energy-saving level after a manual change by a customer, whereas a different thermostat will stay at the manually adjusted level.[4] The NMR team discovered one past evaluation that estimated impacts separately for three different smart thermostat manufactures. The impacts from this evaluation varied widely based on the smart thermostat. The first manufacturer produced statistically

[4] Xcel Energy Colorado Smart Thermostat Pilot – Evaluation Report. Schellenberg, J., Lemarchand, A., & Wein, A. (2017).

significant negative impacts, the second did not have significant results, and the final had significant positive energy savings.

- **Recommendation 2.** When implementing smart thermostat programs in the future, consider designing the program to enable a comparison of savings from different manufacturers. This methodology can provide insight into the strengths and weaknesses of various smart thermostats and which thermostat features should be required for program eligibility in the future. Another option is to set an eligibility requirement around features that are present in smart thermostat programs with demonstrated savings. Additionally, including participant surveys in future evaluations could shed light on how customers are engaging with their smart thermostats.

Finding 3: The effects of the COVID-19 pandemic on program results are unknown. The evaluation period for the Smart Thermostat Program, June 2019 to December 2021, directly coincides with the COVID-19 pandemic. Various stay-at-home orders and a shift to remote work and school rapidly changed how much energy people consume at home. Given this large societal shift in electricity usage patterns, in addition to economic pressures due to interruptions of work and school, it is not known whether participants would have used their smart thermostats differently if the pandemic had not occurred, or if the thermostats' learning algorithms efficiently responded to the significant and unforeseen change in occupancy patterns. The thermostats' algorithms may also have lost the opportunity to drive savings by adjusting setpoints during times of no occupancy – pandemic lockdowns kept individuals at home for much of the evaluation period during times of day when occupancy normally fluctuates over the course of the day, providing opportunity for savings.

- **Recommendation 3.** In the case of interventions such as a smart thermostat rebate program, the NMR team recommends the use a within-subjects methodology instead of a matched control group analysis. A within-subjects evaluation compares each participant's usage before and after the installation of a smart thermostat. There are pros and cons to all impact estimation methodologies, but a within-subjects design eliminates the concern of selection bias in the treatment group – customers who sign up to receive a smart thermostat rebate could be inherently different from the matched control customers. Within-subjects impact estimation also skirts the issue how whether and how to estimate how many customers in the matched control group also installed smart thermostats at the same time as the treatment group. The original scope for this evaluation called for a within-subjects design but had to be abandoned due to the strong effects of the COVID-19 pandemic on electric usage. In instances when a within-subjects methodology cannot be utilized, like in this evaluation, the NRM team recommends that a matched control group methodology be adopted.

Finding 4: Daily electric usage for participants increased during the COVID-19 pandemic. The average daily usage for participants and control customers increased after the beginning of the pandemic. Average daily usage for participants before the installation of a smart thermostat, from June 2019 – May 2020, was 21.0 kWh. This metric increased to 26.1 kWh after the smart thermostats were installed, from January 2021 – December 2021. The same pre- and post-installation metrics for control customers were 20.9 kWh and 25.2 kWh, respectively. The increase in usage is likely related to people spending more time in their homes due to the pandemic, which started in April 2020.

- **Recommendation 4.** While a within-subjects approach is suitable for smart thermostat evaluations when electric usage is relatively stable, when there are huge shifts in usage caused by external forces then a matched control group is preferred. In this evaluation, a matched control group was utilized to account for changes in usage related to the pandemic. The NMR team recommends that IESO and the LDCs be prepared to change an evaluation's approach to a matched control group when a within-subjects methodology is not feasible. Specifically, a matched-control group methodology requires providing potentially a large amount of additional data for customers not participating in a smart thermostat program. Upon program launch, LDCs should prepare a contingency plan for providing non-participant data to the IESO for the impact evaluation should conditions warrant that evaluation approach. Additionally, in that case funding should be provided for participant and non-participant surveys to help detect and correct for self-selection bias and spillover.

Finding 5: LDC program staff reported the Smart Thermostat Program was easy to participate in and administer but fell far short of its participation target. The Smart Thermostat Program reached approximately 20% of its participation target, which LDC program staff attributed to the COVID-19 pandemic and its related effects on program marketing and program duration. Program staff felt the program was relatively easy to participate in from the customer perspective, that it was relatively straightforward to administer, and that the collaboration with the Enbridge Gas was successful.

- **Recommendation 5.** If the Smart Thermostat Program were to run again in the future, run it for a longer duration, perform in-person marketing in addition to online and direct mail outreach, and consider collaborations with Enbridge Gas or other LDCs running similar programs.

A

Appendix A Impact Evaluation Methodology

This appendix presents additional details about the impact evaluation methodology. A summary of the methodology was provided in Section 2.1.

A.1 Control Group Selection and Validation

To select matched control customers who had similar usage as Smart Thermostat program participants, nine different models were evaluated to find the one that produced the closest match. Table 14 shows the usage variables and different combinations of variables that were tested for matching.

Table 14: Models Tested for Matching

Variables	M1	M2	M3	M4	M5	M6	M7	M8	M9
Avg Daily Usage for January	X	X	X	X	X	X		X	
Avg Daily Usage for February	X	X	X	X	X	X		X	
Avg Daily Usage for March	X	X	X	X	X	X		X	
Avg Daily Usage for April	X	X	X	X	X	X	X		
Avg Daily Usage for May	X	X	X	X	X	X	X		
Avg Daily Usage for June	X	X	X	X	X		X	X	
Avg Daily Usage for July	X	X	X	X	X		X	X	
Avg Daily Usage for August	X	X	X	X	X		X	X	
Avg Daily Usage for September	X	X	X	X	X		X	X	
Avg Daily Usage for October	X	X	X	X	X	X	X		
Avg Daily Usage for November	X	X	X	X	X	X		X	
Avg Daily Usage for December	X	X	X	X	X	X		X	
Avg Daily Usage for Summer Months		X			X	X			X
Avg Daily Usage for Winter Months			X		X		X		X
Avg Daily Usage Shoulder Months				X	X			X	X

The best model selected had the lowest mean squared error (MSE) in terms of usage between treatment and control usage during the pre-treatment months, June 2019 – May 2020. Table 15 shows an example of the ranking procedure.

Table 15: Example of Model Ranking

Model	MSE	Rank
7	0.0045	1
4	0.0093	2
1	0.0094	3
5	0.0097	4
3	0.0101	5
2	0.0101	6
8	0.0208	7
9	0.0217	8
6	0.0478	9

For the customers who were always on the TOU rate, Model 7 produced the closest matches. Model 7 used the combination of average daily usage for April through October and daily average of winter usage (November through March). For customers who switched their rates from TOU to tiered, Model 2 produced the closest match results. Model 2 used the combination of average daily usage for January through December and the average daily usage of summer months (June through September).

The NMR team validated these matches by conducting t-tests on the differences in mean daily consumption by month between the treatment and control groups. Table 16 presents the validation results for the customers who were on the TOU rate throughout the evaluation period. The differences between average daily electricity consumption between treatment and control were not statistically different for any month. The absolute percent difference between the electric usage of the matched control and the treatment groups was no more than 0.87%. Given the low percentage difference in usage between the two groups, the matches are sufficiently comparable. Additionally, Figure 2 presents the daily average usage for treatment and matched control customers graphically.

Table 16: Treatment and Control Group Equivalence – Always TOU

Month	Avg. Daily Control Usage (kWh)	Avg. Daily Treatment Usage (kWh)	Difference	Percent Difference	Lower Bound (90%)	Upper Bound (90%)	P-value
1	21.38	21.45	0.07	0.33%	-0.87	1.01	0.90
2	20.69	20.70	0.01	0.05%	-0.91	0.93	0.99
3	20.70	20.52	-0.18	-0.87%	-1.04	0.68	0.73
4	20.81	20.84	0.03	0.13%	-0.84	0.89	0.96
5	23.01	23.06	0.05	0.21%	-0.94	1.04	0.94
6	23.74	23.65	-0.09	-0.40%	-1.16	0.97	0.88
7	30.24	30.30	0.06	0.20%	-1.22	1.34	0.94
8	25.90	25.96	0.07	0.25%	-1.11	1.24	0.93
9	20.32	20.37	0.05	0.27%	-0.90	1.01	0.92
10	18.88	18.86	-0.02	-0.13%	-0.82	0.77	0.96
11	20.02	19.93	-0.09	-0.43%	-0.94	0.77	0.87
12	21.54	21.54	0.00	0.01%	-0.95	0.95	1.00

Figure 2: Treatment and Control Pre-Treatment Average Daily Consumption – Always TOU

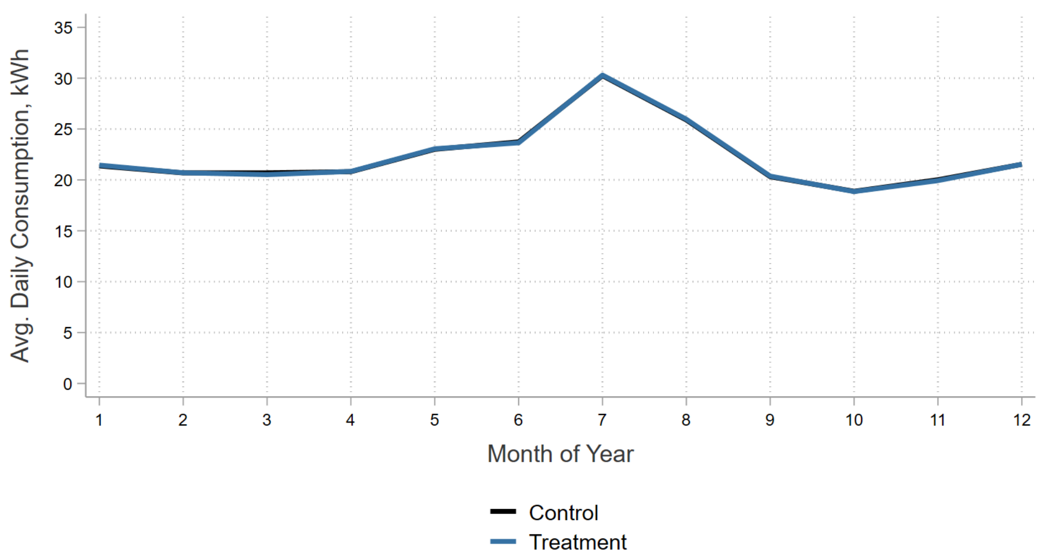


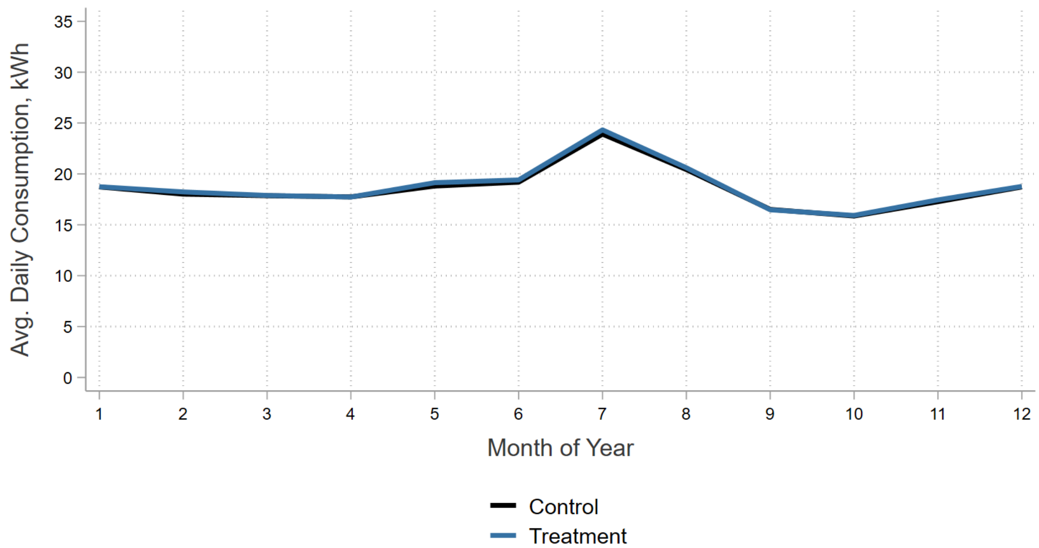
Table 17 and Figure 3 present the matching results for the customers who switch from the TOU to the tiered rate. The differences each month between average daily electricity consumption between treatment and control groups are not significantly different. The largest percent difference in usage for any month is 1.74%.

An interesting finding to note in the figures above is customers who switched from the TOU to the tiered rate have lower usage each month compared to the customers always on TOU. Average summer (June-September) daily consumption is 25.1 kWh for the always-TOU group, while the switched-to-tiered group's consumption is 20.2 kWh. For any given pretreatment month, the difference in usage between always-TOU and switched-to-tiered is statistically significant.

Table 17: Treatment and Control Group Equivalence – TOU to Tiered Rate Switch

Month	Avg. Daily Control Usage (kWh)	Avg. Daily Treatment Usage (kWh)	Difference	Percent Difference	Lower Bound (90%)	Upper Bound (90%)	P-value
1	18.72	18.75	0.02	0.11%	-0.96	1.01	0.97
2	18.01	18.23	0.22	1.21%	-0.74	1.18	0.71
3	17.86	17.89	0.03	0.15%	-0.90	0.95	0.96
4	17.74	17.73	-0.01	-0.05%	-0.93	0.91	0.99
5	18.81	19.14	0.33	1.74%	-0.72	1.37	0.61
6	19.19	19.41	0.22	1.14%	-1.01	1.44	0.77
7	23.91	24.33	0.42	1.75%	-1.09	1.92	0.65
8	20.43	20.60	0.17	0.85%	-1.12	1.46	0.83
9	16.52	16.48	-0.04	-0.25%	-1.02	0.94	0.94
10	15.87	15.92	0.06	0.36%	-0.79	0.90	0.91
11	17.28	17.45	0.17	1.01%	-0.73	1.08	0.75
12	18.72	18.78	0.05	0.29%	-0.96	1.07	0.93

Figure 3: Treatment and Control Pre-Treatment Average Daily Consumption – TOU to Tiered Rate Switch



A.2 ENERGY SAVINGS METHODOLOGY

The difference-in-differences model used to calculate energy savings includes customer and day fixed effects to obtain the most statistically precise estimate possible given the availability of data for the pre- and post-treatment periods. Fixed effects are used to account for constant, unobserved differences for each subject. Customer fixed effects account for differences in usage between customers that are fixed across time. For example, some customers live in larger houses and use more electricity than the customers in smaller homes. Time fixed effects account for differences in usage between periods that are fixed across all customers. For example, time effects account for customers using more electricity during hotter summer months than cooler summer months. The NMR team only included customers with complete data in the analysis.

Equation 1 shows the model specification used to estimate energy savings; Table 18 presents the definition of terms in the model.

Equation 1: Energy Savings Model Specification

$$kW_{i,t} = \delta \text{treat}_i + \gamma \text{post}_t + \beta (\text{treatpost})_{i,t} + \ v_i + \ \varepsilon_{i,t}$$

Table 18: Energy Savings Regression Model Definition of Terms

Variable	Definition
kWh_{it}	Usage during the event, where i each customer and t refers to the time period of interest
$treat_i$	Binary variable equal to 1 for program participants and 0 for control customers
$post_t$	Binary variable equal to 1 for the post-treatment period and 0 for the pre-treatment period
$treatpost_{i,t}$	Interaction term for treat and post. The coefficient β is the difference-in-difference estimator
v_i	Mean usage for each customer. This is the fixed-effects variable that controls for unobserved factors
$\varepsilon_{i,t}$	The error term.

To calculate the estimated monthly savings in kWh, the NMR team multiplied the average daily treatment effect (β) for each month by the number of days in the month. The NMR team summed the monthly savings impacts over the study horizon to produce the total change in energy consumption in treated homes.

Appendix B Prior Smart Thermostat Impact Evaluation Studies

This appendix presents a summary of smart thermostat impact evaluations previously conducted by North American utilities and system operators other than the IESO. The NMR team has benchmarked these studies using key metrics such as program implementation approach, energy savings, number of customers enrolled, evaluation period, and impact estimation methodology. It is important to note that some of the studies are not directly comparable to Hydro Ottawa's Smart Thermostat program due to the different implementation strategies between utilities and analysis methodologies used by evaluators. Overall, the savings attributable to smart thermostat programs from other utilities covers a broad range.

Table 19 presents a summary of findings for the studies highlighted in this review. The table shows if each evaluation estimated positive or negative impacts. Positive impacts represent an increase in energy usage attributable to the thermostat and negative impacts correspond energy savings. Since many of the evaluations tested multiple smart thermostats separately, it is possible an evaluation estimated both positive and negative impacts. Additionally, the last column indicates if the program included thermostat training or education for participants.

Table 19: Summary of Prior Smart Thermostat Evaluations

Utility	Evaluation Period	Sector	Statistically Significant Negative Impacts	Statistically Significant Positive Impacts	Smart Thermostat Training Included
Xcel Energy	Jun 2015 - Dec 2016	Residential	Y	Y	N
Vectren Corporation	Nov 2013 - Sep 2014	Residential	Y	N	Y
Sacramento Municipal Utility District (SMUD)	Feb 2013 - Jan 2014	Residential	Y	N	Y
California Public Utility Commission (CPUC)	Jan 2019 - Dec - 2019	Residential	Y	Y	N

B.1 Smart Thermostat Pilot Evaluation – Xcel Energy Colorado

Table 20: Xcel Program Summary

Utility	Thermostat Type	Sector	Thermostat Cost	Evaluator	Evaluation Period	Length of Installation before Evaluation
Xcel Energy	Smart Commun-icating Thermostats	Residential	$50 Rebate	Nexant	Jun 2015 - Dec 2016	<4 Months
Type of Thermostat	**Rebate Channel**	**% Impact**	**Annual kWh Impact**	**Annual kWh Lower Bound**	**Annual kWh Upper Bound**	**# Of Treatment Customers**
Vendor 1	Mail	4.3*	401.78*	NA	NA	144
Vendor 1	Store	3.1	288.55	NA	NA	252
Vendor 1	Both	3.5*	325.07*	NA	NA	708
Vendor 2	Mail	0.1	14.61	NA	NA	1104
Vendor 2	Store	-2	-178.97	NA	NA	327
Vendor 2	Both	-1	-94.97	NA	NA	325
Vendor 3	Mail	-0.8	-80.36	NA	NA	837
Vendor 3	Store	-3.6*	-357.95*	NA	NA	1498
Vendor 3	Both	-2.4*	-237.41*	NA	NA	471
All	Mail	0.1	7.31	NA	NA	577
All	Store	-1.9*	-182.63*	NA	NA	1545
All	Both	-1.1	-105.92	NA	NA	2593

*Statistically significant at the 90% level of confidence.

Program overview: Xcel offered $50 rebates with the option to choose from three different smart thermostats. Participants could purchase the thermostat from Xcel Energy's online store or request a rebate by mail with proof of qualifying purchases made from other retailers.

Methodology: Difference-in-difference impact estimation using a matched control group. Nexant also performed an adjustment for free-ridership based on the participant and non-participant surveys.

Smart thermostat training: The evaluation report did not note any education around smart thermostats for participants.

Comparison to Hydro Ottawa: Xcel Energy's program implementation and impact estimation methodology are similar to Hydro Ottawa's. A matched control group with a difference-in-difference impact estimate is utilized in both evaluations. Also, neither program directly installed the thermostat nor taught participants how to use their smart thermostat. Out of the three manufacturers, Vendor 3 was the only one that displayed statistically significant energy savings, while Vendor 1 had a significant increase in usage.

One main takeaway from this pilot was not all smart thermostats deliver the same amount of energy savings. Each thermostat has unique settings and features that can influence energy usage. For instance, some smart thermostats do not automatically return to a pre-programmed energy-saving schedule after a manual adjustment.

B.2 Programmable and Smart Thermostat Program – Vectren (Indiana)

Table 21: Vectren Program Summary

Utility	Thermostat Type	Sector	Thermostat Cost	Evaluator	Evaluation Period	Length of Installation before Evaluation
Vectren Corporation	Programmable and smart thermostats	Residential	Free with direct install	Cadmus Group	Nov 2013 - Sep 2014	<4 Months
Type of Thermostat	**% Impact**	**Monthly kWh Impact**	**Annual kWh Impact**	**Annual kWh Lower Bound**	**Annual kWh Upper Bound**	**# Of Treatment Customers**
Smart (Nest)	-3.3*	N/A	-429*	270	589	191
Programmable	-3.0*	N/A	-332*	181	483	205

*Statistically significant at the 90% level of confidence

Program overview: Vectren offered either a free smart or programable thermostat to customers who had manual thermostats.

Methodology: Variable degree-day Princeton Scorekeeping Method (PRISM) along with difference-in-difference impact estimation using a matched control group.

Smart thermostat training: Customers received training on the proper operation of their new thermostats. Additionally, participants received professionally installed smart thermostats.

Comparison to Hydro Ottawa: In contrast to Hydro Ottawa, the Vectren thermostat program offered direct installation and training on how to use the thermostats. It is possible these two additional aspects of the Vectren program contributed to the savings displayed in Table 21. Furthermore, one interesting finding included in Vectren's report is only 47% of programmable thermostats are actually set up in an energy-saving manner and many consumers use programmable thermostats in the same way as a manual thermostat. While similar statistics were not presented for smart thermostats, this highlights the need for education and training for customers when they install a new thermostat.

B.3 Sacramento Municipal Utility District's (SMUD) Smart Thermostat Pilot – Load Impact Evaluation

Table 22: SMUD Program Summary

Utility	Thermostat Type	Sector	Thermostat Cost	Evaluator	Evaluation Period	Length of Installation before Evaluation
SMUD	Smart thermostats	Residential	Free with direct install	Herter Energy Research Solutions	Feb 2013 - Jan 2014	<4 Months
Type of Thermostat	**Rate**	**% Impact**	**Annual kWh Impact**	**Annual kWh Lower Bound**	**Annual kWh Upper Bound**	**# Of Treatment Customers**
Nest	TOU/CPP	-3.3*	-320*	N/A	N/A	175
	Standard 2-tiered	-1.6*	-150*	N/A	N/A	194
Ecofactor	TOU/CPP	-3.3*	-340*	N/A	N/A	147
	Standard 2-tiered	-3.2*	-310*	N/A	N/A	180

*Statistically significant at the 95% level of confidence.

Program overview: SMUD's Smart Thermostat Pilot evaluated two smart thermostat systems, Nest and Ecofactor, and two different rates, TOU/CPP and two-tiered. Those customers on the TOU rate also experience critical peak pricing (CPP) event days throughout the evaluation period.

Methodology: Difference-in-difference impact estimation using a matched control group.

Smart thermostat training: Participants received additional information about their thermostat in the form of a welcome packet, which included a user guide and other rate information. During installation, participants watched a video designed to educate them on the smart thermostat. Additionally, the program's website included energy savings tips and an FAQ section.

Comparison to Hydro Ottawa: Among the four smart thermostats and rates evaluated, the standard two-tiered rates are the most comparable to the Hydro Ottawa evaluation. The TOU/CPP rates include impacts from demand response event days, so they are not directly equivalent. SMUD's program implementation included extensive smart thermostat training for participants. It is possible this was a contributing factor in the energy savings shown in the four groups.

NMR Group, Inc.

B.4 Impact Evaluation of Smart Thermostats – California Public Utility Commission (CPUC) (California Investor-Owned Utilities (IOUs))

Table 23: CPUC Program Summary

Utility	Thermostat Type	Sector	Thermostat Cost	Evaluator	Evaluation Period	Length of Installation before Evaluation
California IOUs	Smart Thermostats	Residential	Combination of $50 - $75 rebates and free with direct install	DNV GL	Jan 2019 - Dec 2019	12 Months
Utility	**Climate Zone**	**% Impact**	**Lower/Upper Bound**	**Annual kWh Adjusted Impact**	**Annual kWh Unadjusted Impact**	**# Of Treatment Customers**
PG&E	2	NA	NA	-43.10	74.30	1,250
PG&E	3	NA	NA	14.70	80.70*	5,186
PG&E	4	NA	NA	-54.20	149.10*	4,767
PG&E	5	NA	NA	6.30	107.10	255
PG&E	11	NA	NA	-194.50	153.00	3,026
PG&E	12	NA	NA	-81.40	193.30*	13,374
PG&E	13	NA	NA	-166.50	75.20	7,531
PG&E	16	NA	NA	-300.40	-193.90	79
SCE	6	NA	NA	-74.60	100.80	7,568
SCE	8	NA	NA	-20.20	169.30*	12,285
SCE	9	NA	NA	-55.60	155.80*	9,189
SCE	10	NA	NA	-72.80	122.00*	36,557
SCE	13	NA	NA	-278.60	170.50	1,406
SCE	14	NA	NA	-205.60	167.30	2,587
SCE	15	NA	NA	-166.40	85.70	5,935
SCE	16	NA	NA	-164.90	192.30	1,395
SDG&E	6	NA	NA	14.70	41.90	854
SDG&E	7	NA	NA	19.50	22.70	4,797
SDG&E	8	NA	NA	-99.50	174.20	308
SDG&E	10	NA	NA	-81.10	92.90*	5,947

*Statistically significant (confidence level was not specified)

Program overview: The evaluation of the CPUC's Smart Thermostat program was a complex study that estimated energy savings from the smart thermostats installed throughout the state of California, including service territories of PG&E, SCE, and SDG&E. The program was a component of 18 energy-efficiency programs implemented by the utilities. Each program had a different implementation strategy and program objectives.

Methodology: Difference-in-difference impact estimation using a matched control group with three different post-regression adjustments. Table 23 presents the impact results before and after the adjustment. Note that the CPUC report included stakeholder comments, many of which were critical of the application of adjustments to the estimates, the NMR team does not find the adjustments to be appropriate to the evaluation.

Smart thermostat training: The evaluation report did not note any education around smart thermostats for participants.

Comparison to Hydro Ottawa: Given the complexities of this evaluation, direct comparisons to the Hydro Ottawa program are difficult. The most interesting finding of note is the unadjusted results presented in Table 23 are calculated using the same methodology as the Hydro Ottawa evaluation. Using these results, seven out of the 20 different climate zones have statistically significant increases in usage. But when the three ad hoc adjustments are applied, most of the climate zones have energy savings. The NMR team does not recommend applying any ad hoc adjustment to the difference-in-difference impact estimates.

Finally, Figure 4, Figure 5, and Figure 6 show the matching, installation, and post-treatment periods for the CPUC and Hydro Ottawa evaluations. Customers always on the TOU rate and those that switch from the TOU to the tiered rate have separate graphs. The graphs for the two evaluations are surprisingly similar, with the treatment customers using more electricity after the installation of a smart thermostat. This provides further evidence that providing smart thermostats to residential customers does not guarantee energy savings.

Figure 4: CPUC Average Unadjusted Usage for Treatment and Control Customers

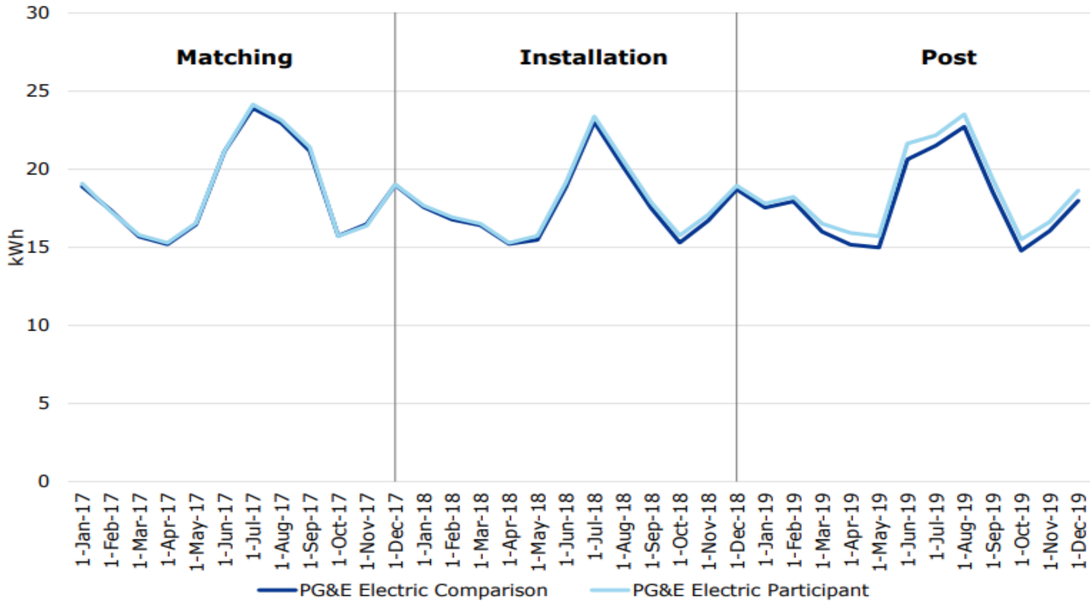


Figure 5: Hydro Ottawa Average Usage Treatment and Control Customers - Always TOU

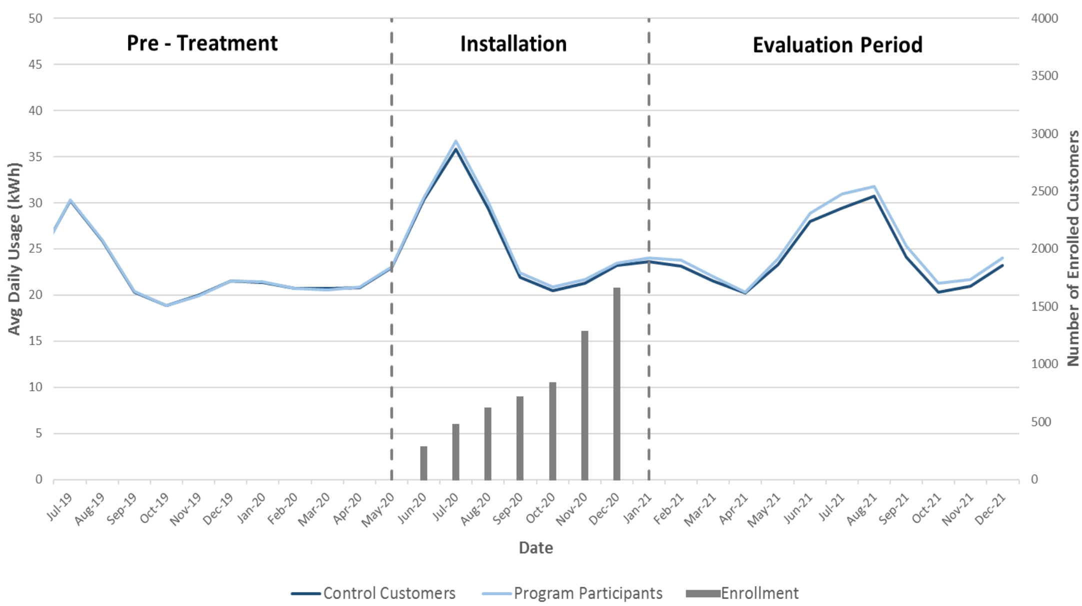


Figure 6: Hydro Ottawa Average Usage Treatment and Control Customers - TOU to Tiered Switch