

Regulated Price Plan Roadmap Pilot Program Interim Impact Evaluation: Summer 2018

Evaluation Report
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Prepared for:



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Additional Appendices provided as separate documents:

- 1. Appendix B: OEB Required Pilot Metrics.** A spreadsheet file containing the data required by the OEB as an output from this analysis.
- 2. Appendix C: General Outputs.** A spreadsheet file containing the data associated with the figures presented in Chapter 3.
- 3. Appendix D: Energy Impact Outputs.** A spreadsheet file containing the data associated with the figures (excluding load profiles) presented in Section 4.1
- 4. Appendix E: CPP Event Demand Impacts.** A spreadsheet file containing the data associated with the figures (excluding load profiles) presented in Section 4.2
- 5. Appendix F: Seasonal Load Profiles.** A PDF file containing the full set of load profiles referenced in Section 4.1.
- 6. Appendix G: CPP Event Load Profiles.** A PDF file containing the full set of average event load profiles referenced in Section 4.2
- 7. Appendix H: Alternative Control Group Approach.** An MS Word document outlining the alternative control group developed, but not, in the end, used, for this evaluation.
- 8. Appendix I: Participant Engagement Tools and Strategy.** An MS Word document providing additional detail about the Trickl app, the customer engagement strategy used by London Hydro, and customer disconnections.

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1. EXECUTIVE SUMMARY

This executive summary provides a high-level overview of the London Hydro Regulated Price Plan (RPP) pilot program, a brief summary of the data and methods used for quantifying impacts, the key evaluation findings, and the conclusions about the program motivated by those findings.

1.1 Introduction & Program Description

London Hydro's RPP pilot is an experiment funded by the Ontario Energy Board (OEB) as part of its ongoing RPP Roadmap, and is a test of two experimental treatments, and of their interaction.

This pilot is an experiment designed to test the impacts of these two treatments across three distinct groups of participants, specifically:

- **Real-Time Information (RT).** The impact on participant consumption patterns of the provision of real-time information (the RT treatment) via a mobile application: "Trickl" provides real-time consumption data, energy saving tips, and notifications when overall energy consumption exceeds that of peer households.

Approximately 1,000 London Hydro customers were enrolled in this stream.

- **Critical Peak Pricing (CPP).** The impact on participant consumption patterns (and demand during critical peak events) of providing customers with a slightly discounted Off-Peak time-of-use (TOU) rate in exchange for being subjected to 18 one-hour critical peak pricing periods over the course of the summer. The critical peak price was set at 59.5 cents per kWh by the OEB.

All CPP participants are provided with one "smart plug" and a load control switch installed at the participant's electrical panel. Each switch is capable of controlling up to three 30 amp circuits. These enabling technologies respond to a control signal dispatched by London Hydro and are intended to automate some CPP event demand reductions.

Approximately 300 participants were enrolled in this stream

- **Combined Effects (CPP/RT).** The impact on participant consumption patterns (and demand during critical peak events) of combining both treatments (CPP and RT together).

Approximately 300 participants were enrolled in this stream

In addition to the approximately 1,700 participants enrolled in the three groups, approximately 450 customers were enrolled as control customers.¹ These customers applied to participate in the pilot program but were not enrolled by London Hydro. This "recruit-and-deny" strategy enabled the pilot to be evaluated as a randomized control trial (RCT). For the purposes of the impact analysis, these RCT control customers act in a manner analogous to that of the placebo group in a pharmaceutical trial. RCTs are generally considered the "gold standard" for program evaluation.

Enabling technology (see below) deployment and participant enrollment took place over the course of the period beginning at scale in July of 2017 through until May 1 of 2018, at which time the pilot became live. From this point on, the participants subject to the CPP rate were liable for the all charges they incurred under the new rate.

¹ Specific participant counts may be found in Section 3.1

As part of its efforts to support the success of the pilot, and to provide participants with the knowledge and ability to take advantage of the tools offered by the pilot (both informational and price-related), London Hydro maintained an active customer engagement strategy over the summer of 2018. A summary of this is presented in Section 2.1, and a detailed timeline and description of this strategy may be found in Appendix I, under a separate cover.

1.2 Approach, Data, and Sampling

London Hydro provided Navigant with hourly electricity consumption data for all participants and RCT controls, from May 2016 through to the end of October 2018. When estimating impacts, only the program period (May through October of 2018) data were used. Consumption in pre-program periods was used to develop regression variables for the impact estimation intended to improve the precision² and accuracy of the estimation, and Navigant used consumption in these prior periods as a contrast to consumption in the program period to better understand the program impacts.

Both energy impacts and CPP event day impacts were estimated using regression analysis. The daily average energy impacts were estimated using all summer consumption data, aggregated to a daily series, by TOU period. CPP event impacts were estimated using only the days on which CPP events occurred.

In addition to participant consumption data, Navigant leveraged connectivity data collected by London Hydro as part of the CPP event demand analysis. These data track which CPP participants' enabling technologies were connected and able to receive the curtailment signal during CPP events. These data enabled Navigant to differentiate between purely behavioural CPP event impacts (i.e., impacts from the group whose enabling technologies were not connected) and impacts that were a combination of behaviour and automation.

1.3 Key Findings

There are two components of Navigant's impact analysis: the energy impact analysis, and the CPP event demand impact analysis.

1.3.1 Energy Impact Key Findings

Navigant's key findings from the energy impact analysis include:

- **CPP participants delivered On-Peak and Mid-Peak energy savings with a reasonably high degree of certainty.** CPP and CPP/RT participants reduced their daily:
 - On-Peak consumption by approximately 5% on average
 - Mid-Peak consumption by approximately 3% on average
- **RT-Only participants delivered modest On-Peak energy savings, although these results are less certain.** RT participants reduced their On-Peak consumption by just over 2%, although these results are less certain than those of the CPP group.

² In statistics, "precision" refers to the measure of uncertainty around estimated values, quantified in regression analysis by the estimated parameter's standard error.

- **CPP participants also equipped with the RT technology are saving the same as CPP-only participants.** Navigant found no statistically significant difference between the energy savings achieved by CPP and CPP/RT participants. This suggests that savings are being driven by a combination of the price-effect (attempting to reduce risk by limiting consumption during periods more likely to observe a critical peak price) and the educational component provided by London Hydro.
- **Energy savings appear to be driven by a variety of end-uses.** Based on the regression-estimated parameters, approximately a third (On-Peak) and 40% (Mid-Peak) of CPP participant savings are insensitive to temperature, with the balance of savings being temperature driven. This suggests that participants did not rely solely on reducing A/C use (typically the largest single discretionary load in a home) to achieve savings. For RT participants approximately 60% of savings appear to be temperature-insensitive.

1.3.2 CPP Event Demand Impact Key Findings

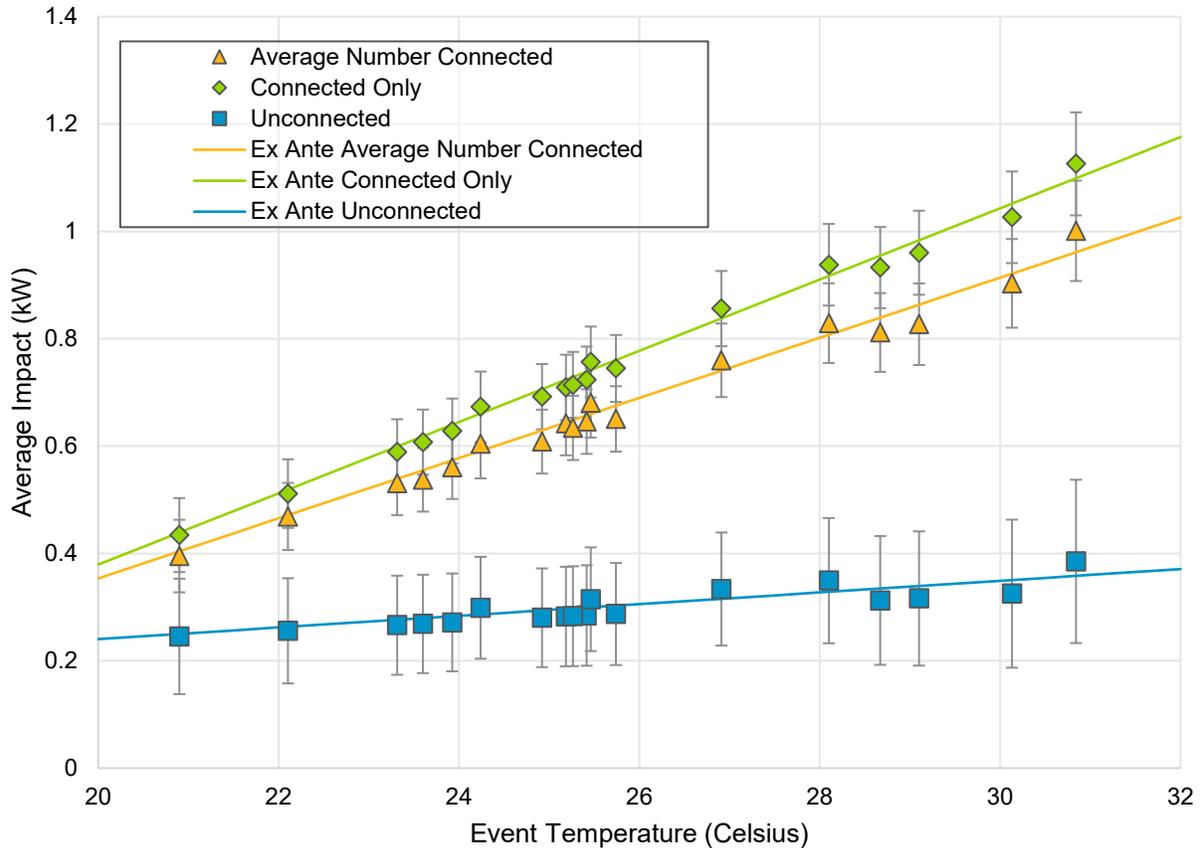
Figure 1, below, shows a scatterplot of CPP event impact and temperature pairs. This plot contains three series of CPP event impact/temperature pairs:

- The **yellow triangles** indicate average program impact, per participant for each event.
- The **green diamonds** indicate the average program impact when only including participants whose enabling technologies were *connected* at the time of the CPP event, per participant for each event.
- The **blue squares** indicate the average program impact when only including participants whose enabling technologies were *disconnected* at the time of the CPP event, per participant for each event. Note that since all these participants are not connected, all impacts shown below are behavioural, rather than automated via signal from London Hydro.

The whiskers surrounding each marker provide the 90% confidence interval in the impact, and the solid lines that run through the markers indicate the average relationship between CPP event program impacts and contemporaneous outdoor temperature. These are the ex-ante estimates of program capability under a range of different temperatures.

This chart illustrates the estimated relationship between the average demand response capability of the program under a range of outdoor temperatures – a key output of this study.

Figure 1: Ex-Ante and Ex-Post Impact Scatter Plot



Navigant’s other key findings from the demand impact analysis include:

- **CPP event demand reductions were substantial.** On average, CPP participants delivered 0.67 kW of demand reductions (approximately a third of baseline demand) during CPP events and delivered 1 kW of reductions per participant during the hottest event, on July 4th.
- **There is a behavioural element to CPP event impacts.** CPP participants are equipped with enabling technologies (a switch at the panel, and one or two smart plugs) that respond automatically to London Hydro’s price signal. Even though participants receive approximately 15 minutes’ notification of an event, there are clear behavioural elements to their response over and above the automated response delivered by the switches and smart plugs.
 - *Participants reduced consumption during hours in which CPP events were likely to occur.* CPP participants reduce their exposure to the CPP rate by making changes to their consumption habits in anticipation of CPP events – substantial savings are achieved in hours of the CPP event day leading up to the CPP event, despite participants not having any knowledge of when the event will occur until 15 minutes before it does.
 - *Disconnected participants still delivered demand response.* For any given event, approximately 20% of participants’ devices could not receive, or respond to, London Hydro’s curtailment signal. These participants were still able to, on average, with only 15

minutes' notice, to reduce demand by 0.2 kW each without the program-deployed enabling technologies.³

Some additional context may be helpful in understanding how remarkable this is: an evaluation of San Diego Gas and Electric's voluntary CPP rate⁴ (notification provided no later than 3pm on the day *prior* to the event) found the average response (at an average temperature of 99 degrees Fahrenheit, or approximately 37 degrees Celsius) was only 0.14 kW.

- **Demand reductions appear to be largely, but not overwhelmingly, driven by changes in space-cooling.** An examination of the estimated relationships between impacts and temperature is strongly suggestive of the fact that approximately a third of the average CPP event impact (approximately 0.2 to 0.3 kW) is driven by an end-use, or end-uses, other than space-cooling.
- **Real-time information on consumption did not affect demand reductions.** The impacts of the CPP and CPP/RT group were not statistically significantly different from one another – the availability of the energy tracking app did not impact participants' ability to deliver demand reductions

1.4 Conclusions

Navigant has drawn three main conclusions from this interim evaluation of the London Hydro RPP Pilot:

- **The available evidence suggests that education and customer engagement are key factors in enabling participant response.** Education and engagement are key elements of *all* programs and pilots that seek to motivate a behavioural response from participants. The question may be asked, why does Navigant single this as a key factor rather than attributing impacts *only* to the pricing and informational/technological treatment? This hypothesis is driven by two findings:
 - *The RT treatment motivates no incremental energy or demand impact from CPP/RT participants, but delivers energy savings for RT-only participants.* For both energy impacts and CPP event demand impacts, Navigant found that the combined CPP/RT treatment did not deliver any incremental statistically significant impacts, indicating that the RT treatment provided no additional benefit to participants already subject to CPP. Yet, the RT-only treatment *did* deliver material energy savings. These two findings seem at odds – if the RT treatment on its own delivers savings, and the CPP treatment on its own delivers savings, why would the two treatments combined not deliver more savings than one of the treatments alone?

³ Participants' whose enabling technologies were not connected to London Hydro's dispatch system continued to receive event notification via the Trickl app.

⁴ Christensen Associates Energy Consulting, *2016 Load Impact Evaluation of San Diego Gas and Electric's Voluntary Residential Critical Peak Pricing (CPP) and Time-of-Use (TOU) Rates*, CALMAC Study ID SDGE0304, April 2017 http://www.calmac.org/publications/PY16_TOU_and_CPP_Ex_Post_and_Ex_Ante_Report.pdf

Navigant believes that the most likely explanation is that in fact the RT technology –the app – isn't what's responsible for the energy savings.⁵ Rather, these offerings are the shiny object that entices customers to participate in the program, and savings are delivered through the concerted effort of the utility to educate participants in effective, practical strategies that deliver modest energy savings.

- *The price-only treatment (CPP) motivates a change in behaviour even when there is no direct price signal to do so.* The majority of the energy savings achieved by the CPP-only group were achieved in non-event periods.⁶

Certainly, this behaviour may be explained through the lens of expected value – participants assessing when peak prices will occur and making behavioural adjustments on this basis. The problem with this hypothesis is that it cannot explain why impacts were greatest in the On-Peak period, and yet, *by design*, the CPP price can only occur in the final hour of that period (from 4pm to 5pm).

A rational economic actor responding purely to price might adjust their behaviour in the window from 4pm to 5pm, but otherwise has no motivation to adjust their behaviour in the On-Peak period.

It is on the basis of these two observations regarding the estimated impacts that Navigant infers that the customer engagement strategy used by London Hydro to support the deployment of the pilot design was a critical factor in empowering customer decision-making, and ultimately delivering the final reported results.

- **Critical peak pricing can be a tool for energy conservation as well as demand reduction.** CPP participants are provided with 15 minutes or less of notice when a CPP event occurs. This limits the scope of what actions participants can take in the short term when they receive event notification. In response to this challenge, it appears that participants have worked to limit their exposure to the critical peak rate by reducing consumption in hours in which events are likely to occur.

Participants have been educated to understand that CPP events are driven by system needs, and that system needs are driven (in the summer) by weather. And so, daily energy impacts (even when no event takes place) are correlated with temperature. Participants undertake actions that reduce their risk exposure even as the risk of a CPP event climbs (i.e., temperature increases). Put another way, participants are provided with a qualitative understanding of the factors that drive the prices they will face and develop rules of thumb for responding to those prices.⁷

⁵ Evaluations of real-time information pilots often yield savings estimates that are very low, or are statistically insignificant, suggesting that simply providing customers with data is insufficient for motivating real savings. Participants require an intermediary, such as the utility or some third-party home energy report provider to translate those data into *information*.

For a summary of real-time information studies and the associated impacts, see for example Table 13 on PDF page 41/95 of:

Navigant, prepared for Newfoundland Labrador Hydro, *Real Time Monitor Pilot Program: Impact and Process Evaluation*, March 2016

https://www.exec.gov.nl.ca/exec/occ/publications/RTM_Complete_Rpt_F_Mar31_2016.pdf

⁶ CPP events only account for 18 hours off the summer.

⁷ It has previously been noted that when participants are provided with prices that change too frequently to allow a true “real-time” response (e.g., real-time pricing), they develop a set of rules for behaviour changes that reflect their average expectations of price changes. See for example:

- **Participants can be remarkably nimble in responding to very short-term changes in price.** Navigant did not expect to find that disconnected participants delivered *any* demand response. It was Navigant's hypothesis that the very short notification period would mean that "DR only" response (as opposed to the more general response in anticipation of a potential event) would be limited to those participants whose enabling technologies were connected to London Hydro's systems and able to respond automatically to London Hydro's curtailment signal.

The findings of this analysis require a rejection of this initial hypothesis. On average, it appears that disconnected participants were able to contribute approximately 0.2 kW of "pure" demand response during the CPP events. That is, on average, participants were able, with 15 minutes' notice, to reduce demand on average by 0.2 kW without the program-deployed enabling technologies.

Recommendations for ongoing research motivated by these conclusions can be found in section 5.3 of the main body of the report below.

2. INTRODUCTION AND PILOT OVERVIEW

Navigant's interim evaluation of London Hydro's (LH) Regulated Price Plan (RPP) pilot covers all evaluation activities for the summer (May through October) of 2018. It is divided into four chapters.

1. **Introduction and Pilot Overview.** This chapter provides a high-level description of the key features of the pilot.
2. **Pilot Data and Evaluation Approach.** This chapter provides an overview of the data used as part of this evaluation, and of the analytic methods employed to estimate impacts. A detailed description of the methods used in this evaluation (including model specifications, etc.) may be found in Appendix A.
3. **Results.** This chapter presents the findings of Navigant's analysis, and some discussion of the results.
4. **Key Findings, Conclusions.** This chapter presents Navigant's key conclusions regarding its evaluation of the LH RPP pilot as deployed for the summer of 2018.

The remainder of this introductory chapter is divided into four sections:

- **Pilot Overview.** Provides a brief overview of the pilot.
- **Pilot Participants.** Provides a more detailed description of the treatments applied to the participants.
- Error! Reference source not found.. Describes the rate structure applied as part of this pilot.
- **Evaluation Goals and Objectives.** Provides a summary of the key evaluation goals, as originally developed during the evaluation planning phase.

2.1 Pilot Overview

London Hydro's RPP pilot is an experiment funded by the Ontario Energy Board as part of its ongoing RPP Roadmap, and is a test of two independent treatments, and of their interaction.

This pilot is an experiment designed to test the impacts of these two treatments across three distinct groups of participants, specifically:

- **Real-Time Information (RT).** The impact on participant consumption patterns of the provision of real-time information (the RT treatment) via a mobile application: "Trickl" which provides real-time consumption data, energy saving tips, and notifications when overall energy consumption exceeds that of peer households.

Approximately 1,000 London Hydro customers were enrolled in this stream.

- **Critical Peak Pricing (CPP).** The impact on participant consumption patterns (and demand during critical peak events) of providing customers with a slightly discounted Off-Peak time-of-use (TOU) rate in exchange for being subjected to 18 one-hour critical peak pricing periods over the course of the summer. The critical peak price was set at 59.5 cents per kWh by the OEB.

All CPP participants are provided with a smart plug and a load control switch installed at the participant's electrical panel. Each switch is capable of controlling up to three 30 amp circuits. These enabling technologies respond to a control signal dispatched by London Hydro and are

intended to automate some CPP event demand reductions. CPP participants were also equipped with the Trickl app. This app was used to communicate notification for CPP events and to provide participants with the ability to remotely control the technologies provided by London Hydro.

Approximately 300 participants were enrolled in this stream

- **Combined Effects (CPP/RT).** The impact on participant consumption patterns (and demand during critical peak events) of combining both treatments (CPP and RT together).

Approximately 300 participants were enrolled in this stream

Additional detail regarding the functionality and appearance of the Trickl app may be found in Appendix I, under a separate cover.

In addition to the approximately 1,700 participants enrolled in the three groups, approximately 450 customers were enrolled as control customers.⁸ These customers applied to participate in the pilot program but were not enrolled by London Hydro. This “recruit-and-deny” strategy enabled the pilot to be evaluated as a randomized control trial (RCT). For the purposes of the impact analysis, these RCT control customers act in a manner analogous to that of the placebo group in a pharmaceutical trial. RCTs are generally considered the “gold standard” for program evaluation.

Enabling technology (see below) deployment and participant enrollment took place over the course of the period beginning in July of 2017 through until May 1 of 2018, at which time the pilot became live. From this point on, the participants subject to the CPP rate were liable for the all charges they incurred under the new rate.

To support the success of the price, technology, and informational treatments, London Hydro also pursued an active customer engagement strategy. Over the course of the pilot, London Hydro engaged in a number of customer engagement activities, the most important of which – for summer impacts – are:

- **Breakfast events.** Attended by approximately 500 of the pilot participants, these two events in March 2018 were designed to
 - build enthusiasm for participation;
 - provide participants with information about how they could maximize the value of the treatments; and,
 - proactively address connectivity issues reported by participants and schedule home visits to resolve those issues.
- **Ambassador focus groups.** These focus groups, attended by approximately 60 participants, were intended to leverage participant enthusiasm and obtain participant feedback to be used for course-correction of app feature improvements.
- **Door to Door Engagement.** Proactive, in-person communication with program participants to help resolve connectivity issues and to ensure that participants felt that their experiences and engagement were valued by London Hydro. Proactive technical assistance is important for pilots such as this one. When devices cease to function properly, busy customers not have the inclination to contact London Hydro to resolve the problem. As a result of this door-knocking campaign, London Hydro booked 125 appointments for in-home technical assistance.

⁸ Specific participant counts may be found in Section 3.1

Additional details of marketing efforts and London Hydro’s customer engagement strategy may be found in Appendix I, under a separate cover.

This pilot will continue until April 30, 2019, after which Navigant will complete the second part of this evaluation, the evaluation of impacts in the winter months, and Navigant’s sub-contractor, Ipsos Public Affairs, will conduct an Energy Literacy study of participants.

2.2 Pilot Participants

As noted above, pilot participants are recruited into one of three different groups. Details of the treatments applied to each group are summarized below.

- **RT.** These participants are provided with an in-home energy gateway that delivers information to participating customers via an IOS/Android app: Trickl. The information provided to customers includes:
 - Real-time electricity consumption data
 - Baseload analytics
 - “Push” notifications from the Trickl app to flag when participant energy use exceeds that of similar peers and other timely customized tips.

- **CPP.** These participants are subject to a critical peak price of 59.5 cents per kWh, set by the OEB. CPP events are called by the OEB or its designate as required for evaluation purposes and dispatched by London Hydro. All CPP participants are provided with a smart plug and a load control switch installed at the participant’s electrical panel. Each switch is capable of controlling up to three 30 amp circuits.

- **CPP/RT.** These participants are provided with both the CPP enabling technology, and the real-time energy monitoring equipment and software and are subject to the CPP prices.

2.3 Participant Commodity Prices

All residential electricity consumers in Ontario are subject to time-of-use (TOU) commodity prices. Participants enrolled in the CPP and CPP/RT treatment groups receive a discounted Off-Peak rate in exchange for being subject to a very high critical peak price when events are triggered by the OEB.

These rates, and the schedule by which they are applied are provided in Figure 2, below. A more detailed description of the CPP rate follows.⁹

⁹ A complete description of all rates applied in the OEB RPP Pilots may be found at: Ontario Energy Board, *Memorandum to All Rate Regulated Electricity Distributors [and] All Interested Parties*, April 23, 2018
<https://www.oeb.ca/sites/default/files/letter-rpp-roadmap-pilot-price-update-20180423.pdf>

Figure 2: RPP Standard and Pilot TOU Rates

Pricing Period	Commodity Rate (cents/kWh)	
	Standard RPP Consumers	CPP and CPP/RT Participants
Off-Peak 7pm to 7am, on weekdays 24 hours on weekends and holidays.	6.5	6
Mid-Peak 7am to 11am and 5pm to 9pm, summer ¹⁰ weekdays 11am to 5pm, winter weekdays	9.4	9.4
On-Peak 11am to 5pm, summer weekdays 7am to 11am and 5pm to 9pm, winter weekdays	13.2	13.2
Critical Peak 18 one-hour events in summer 18 one-hour events in winter Events occur only between 4pm and 8pm, prevailing time, on non-holiday weekdays	N/A	59.5

CPP events lasted for one hour each, and participants were provided with fifteen minutes' notification. Given this very short notification period Navigant anticipated that demand response (DR) impacts would be driven almost entirely by the enabling technology.

Each participant was subject to 18 CPP events over the course of the pilot in the summer of 2018, six per month in July and August, and three per month in June and September. CPP events are called as directed by the OEB and are intended to fall on the peak demand hour falling between 4pm and 8pm on the top six (July, August) or top three (June, September) demand days of the month. In the summer of 2018, CPP events all either fell between 5pm and 6pm (13 events) or between 6pm and 7pm (five events). All events occurred within the Mid-Peak TOU period.

The CPP rate to which participants were subject during CPP events was 59.5 cents per kWh.

CPP participants are incented to participate through three mechanisms:

1. All CPP participants pay a discounted Off-Peak TOU price, six cents per kWh, as opposed to the standard rate of 6.5 cents per kWh,
2. All CPP participants will receive a \$25 incentive for enrolling and an additional \$75 incentive payment at the end of the pilot.
3. All CPP participants received 150 Aeroplan™ points for registering for the pilot.

It is Navigant's opinion that the offering of these incentives has not biased the findings of this evaluation. A detailed description of the reasons why may be found in Section A.5 of Appendix A..

¹⁰ Throughout this document, unless explicitly stated otherwise, all references to "summer" and "winter" are intended to convey the RPP summer (May through October) and RPP winter (November through April) periods.

2.4 Evaluation Goals and Objectives.

Per the approved evaluation plan, Navigant was tasked with estimating two types of impact as part of this evaluation: energy impacts, and demand impacts associated with the CPP events. More specifically, Navigant was tasked with estimating:

1. **Ex-Post Energy Impacts.** “Ex-post” impacts refer to the estimated impacts of actually occurring (i.e., historical) events. Ex-post estimated impacts estimated include:
 - The average impact of the RT treatment on participant energy consumption by:
 - TOU period
 - RPP season¹¹
 - The average impact of the CPP treatment *on non-event days*¹² by:
 - TOU period
 - RPP season
 - The average incremental impact of the RT treatment on CPP savings *on non-event days* by:
 - TOU period
 - RPP season

As noted in the evaluation plan, these impacts are reported only when they are found to be statistically significant.
2. **Ex-Post CPP Event Demand Impacts.** “Ex-post” impacts refer to the estimated impacts of actually-occurring (i.e., historical) critical peak pricing events. Ex-post estimated impacts include:
 - The average program demand impact for every hour (all events last an hour) in which CPP events are called.
 - The average incremental effect of the RT treatment on CPP event demand impacts for every hour in which CPP events are called.¹³
3. **Ex-Ante Impacts.** “Ex-ante” impacts refer to the predicted DR capability of a program or treatment. These values are estimated by applying a range of temperatures to the regression-estimated parameters.

In addition to the impacts above, Navigant has reported: the estimated impact on system coincident peak demand¹⁴ an estimated point own-price daily elasticity of demand, and the inter-period substitution elasticity (between Mid-Peak and non-On-Peak periods). These values are provided in Appendix B, a spreadsheet document highlighting OEB-requested output metrics for this report, and are discussed below in the body of the report.

¹¹ “RPP season” refers to the price-setting seasons used by the OEB: summer (May through October) and winter (November through April). Note that throughout this document, unless explicitly stated otherwise, all references to “summer” and “winter” are intended to convey the RPP summer and RPP winter periods.

¹² i.e., excluding days on which CPP events are called

¹³ When this incremental effect is found to be statistically non-significant on average by event, only the fact that no statistically significant impact is reported.

¹⁴ As defined by the IESO EM&V protocols – the average impact between 1pm and 6pm, prevailing time, on non-holiday weekdays in June through August.

3. PILOT DATA AND EVALUATION APPROACH

This chapter of the interim evaluation report provides a high-level description of the data used by Navigant for this analysis, and the methods employed. Technical readers, interested in more detail regarding the specifics of the approach, are encouraged to consult Appendix A, which includes a more technical description of the approach, including regression model specifications.

This chapter is divided into three sections:

- **Data.** This section provides an overview of the data used in this analysis.
- **Experimental Design.** This section provides an overview of the experimental design used for this evaluation.
- **Energy Impact Approach.** This section provides an overview of how TOU-period daily energy impacts were estimated.
- **CPP Demand Impact Approach.** This section provides an overview of how the CPP-driven DR impacts were estimated.

3.1 Data

Navigant used the following types of data to estimate impacts:

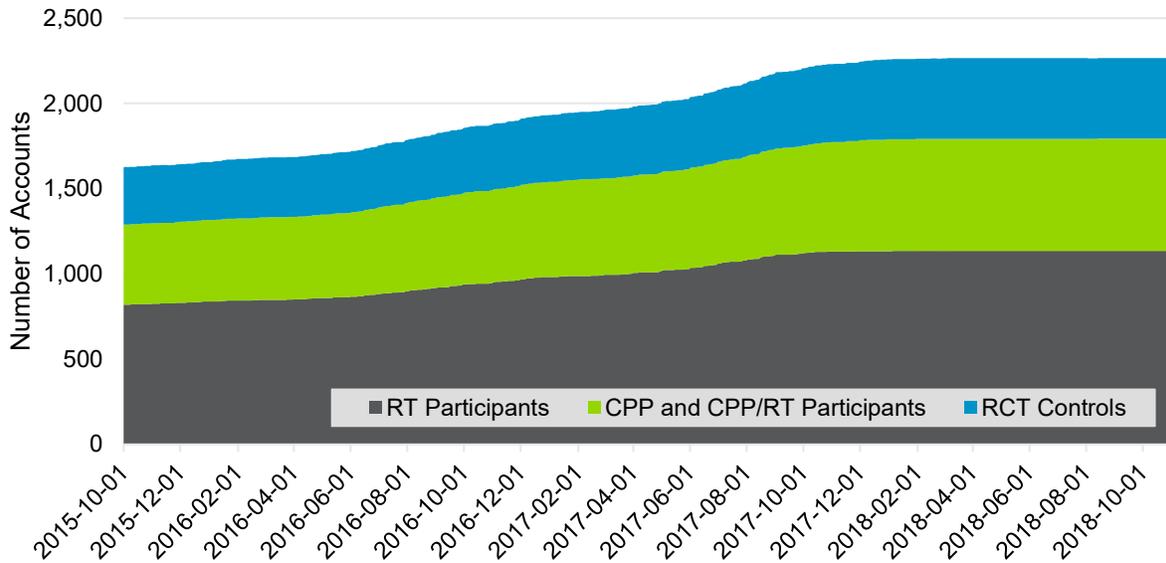
- Participant and non-participant interval (hourly consumption) data.
- Hourly weather data
- CPP event schedule data
- CPP participant group connectivity data

3.1.1 Participant and Non-Participant Hourly Consumption Data

London Hydro provided Navigant with more than three years' worth of participant and non-participant data. The total number of customers for whom data were available on any given day is summarized below in Figure 3. This includes three groups of customers: RT participants, CPP and CPP/RT participants, and "randomized control trial" (RCT) non-participants (controls).

This last group is a group of customers that applied to enroll in the pilot, but were not accepted, so as to act as controls, and provide a true experimental design for the pilot. More details regarding this feature of the evaluation may be found below.

Figure 3: Summary of Interval Data Provided



Interval data used to estimate the results included in this report covered the period from May 1, 2017 through October 31, 2017, and May 1, 2018 through October 31, 2018. The pre-period summer data were used to help control for non-program-related patterns in individual customer consumption (see below for more details).

The final sample size (number of customers) following the data preparation and processing (details of which may be found in Appendix A), are shown in Figure 4, below. Final sample sizes are smaller for the CPP event demand analysis than for the energy analysis due to the requirements of the different regressions estimated.¹⁵

Figure 4: Final Number of Customers Included in Sample – By Analysis Type

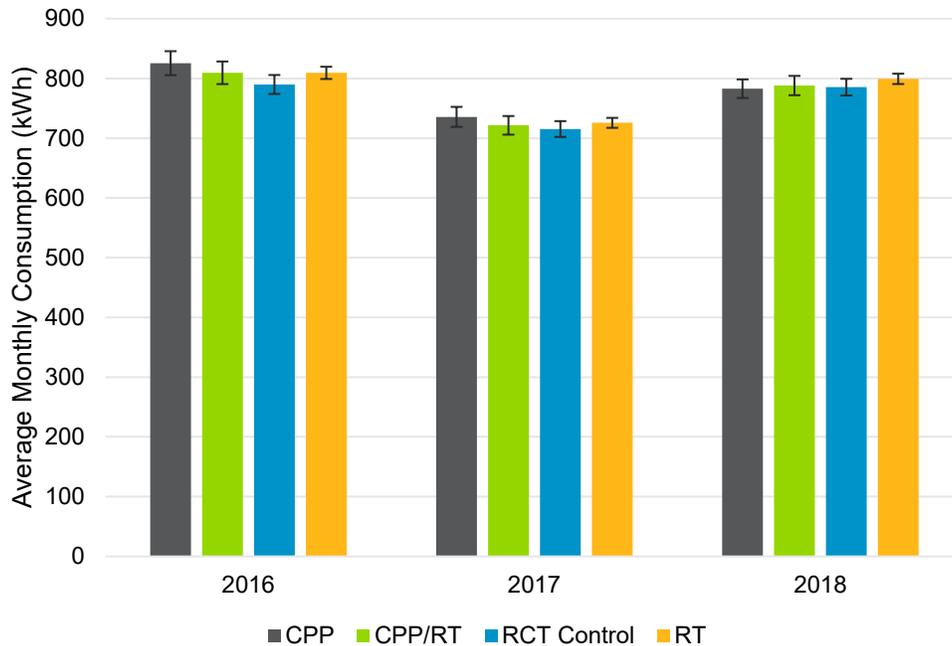
Group	Final Sample for Energy Analysis	Final Sample for CPP Event Demand Analysis
CPP	308	282
CPP/RT	334	308
RT	1,129	N/A
RCT Control	454	446

Although a larger sample is always preferred due to the additional degrees of freedom (and thus higher precision), the sample sizes available were sufficient for the analysis conducted.

¹⁵ The use of day-type determine pre-program consumption data makes the sample size sensitive to the number of summer 2018 days included in the estimation set. See Appendix A for more details.

Monthly consumption values were very similar across all four groups considered in this analysis (CPP, CPP/RT, RT-only, and RCT controls). The average monthly consumption values of each group during the three summers are presented in Figure 5 below. The whisker bars represent the 90% confidence interval around the sample mean in each year. As may be seen, not only are all monthly consumption values very close, but in every year, the confidence intervals of all groups overlap.

Figure 5: Participant and Control Monthly Consumption¹⁶



3.1.2 Hourly Weather Data

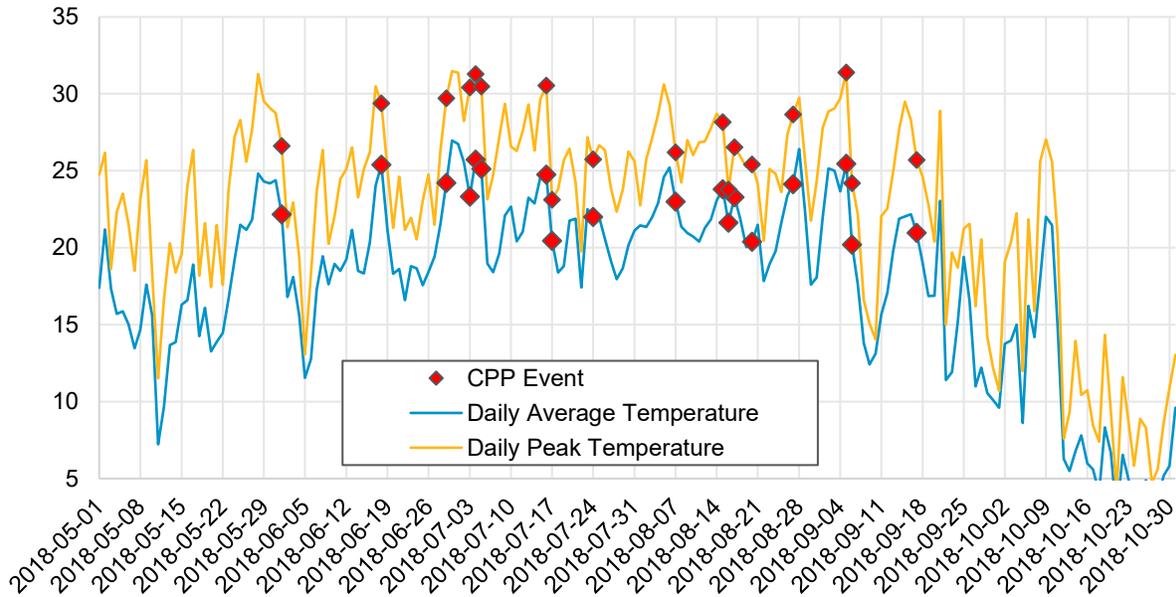
London Hydro provided Navigant with hourly weather data (dry bulb, dew point, relative humidity, etc.) from an appropriate weather station in London Hydro’s service territory for the same period as the interval data, up until May 2018. Data for the months following that period were obtained directly from Environment Canada’s “London A” weather station (TC identifier: YXU).

Unfortunately, the non-dry bulb (e.g., dew point, relative humidity, etc.) time series in the Environment Canada were all missing a sufficiently high number of observations that Navigant deemed it prudent not to use these values in the analysis (i.e., of the weather data, only dry bulb temperature values are used in this analysis).

¹⁶ Average monthly consumption values are provided only for participants and controls included in the energy analysis. The sample population of each year is somewhat larger than the previous one due to move-ins. Monthly average consumption in each summer is calculated by estimating average monthly consumption for each customer by multiplying average hourly consumption by the number of hours in the month (customer/month pairs missing more than 20% of hours in a month are excluded). Customer monthly values are then averaged across customers and the summer to deliver the values provided above.

Figure 6, below, provides a summary of daily mean (blue line) and maximum (yellow line) observed temperatures during the program period. CPP event days are flagged with red diamonds.

Figure 6: Daily Temperatures in Program Period



3.1.3 CPP Event Schedule

Altogether 18 CPP events were called during the summer of 2018. These dates of events are selected by the OEB to maximize the information value of pilot. Altogether 13 events were called for the period between 5pm and 6pm, and five events were called for the period between 6pm and 7pm.

Figure 7: Summer 2018 CPP Schedule

Date	Event Start Time	Event End Time
2018-06-01	6:00 PM	7:00 PM
2018-06-18	5:00 PM	6:00 PM
2018-06-29	6:00 PM	7:00 PM
2018-07-03	5:00 PM	6:00 PM
2018-07-04	6:00 PM	7:00 PM
2018-07-05	6:00 PM	7:00 PM
2018-07-16	5:00 PM	6:00 PM
2018-07-17	5:00 PM	6:00 PM
2018-07-24	5:00 PM	6:00 PM
2018-08-07	5:00 PM	6:00 PM
2018-08-15	6:00 PM	7:00 PM
2018-08-16	5:00 PM	6:00 PM
2018-08-17	5:00 PM	6:00 PM
2018-08-20	5:00 PM	6:00 PM
2018-08-27	5:00 PM	6:00 PM
2018-09-05	5:00 PM	6:00 PM
2018-09-06	5:00 PM	6:00 PM
2018-09-17	5:00 PM	6:00 PM

3.1.4 CPP Group Connectivity Data

As part of this pilot, London Hydro staff have tracked the connectivity of individual CPP and CPP/RT participants. For any given event, participants’ enabling technologies (the switch at the panel and the smart plug) may or may not be connected, via a hub, to the London Hydro dispatch system. Those participants not connected to the system on event days did not benefit from the automatic control of connected appliances (e.g., central A/C).

On average approximately 80% of participants were connected for any given event..

Figure 8: Event-Specific Connectivity Rate

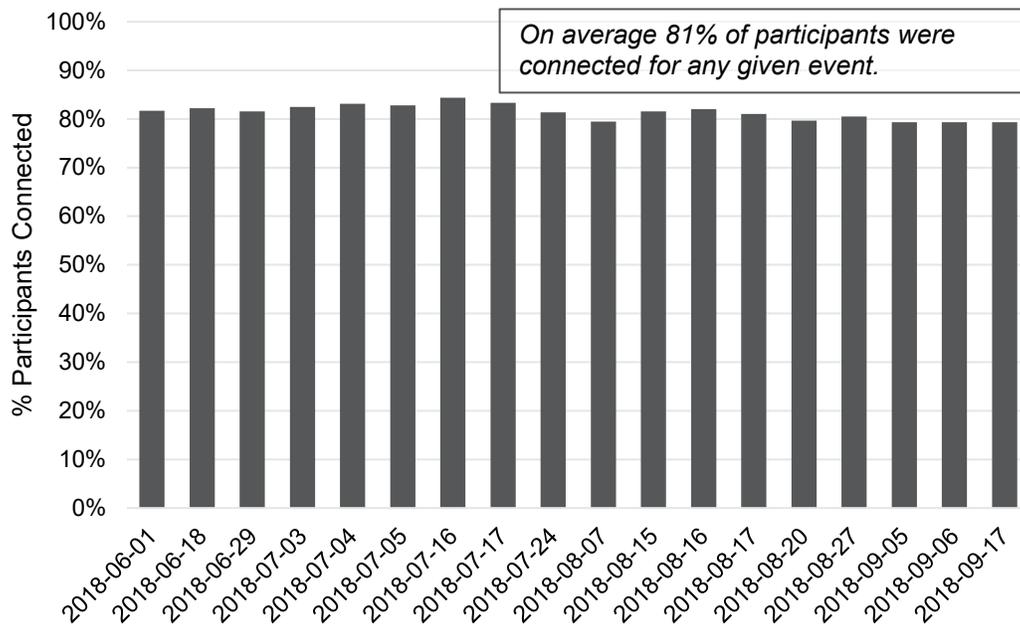
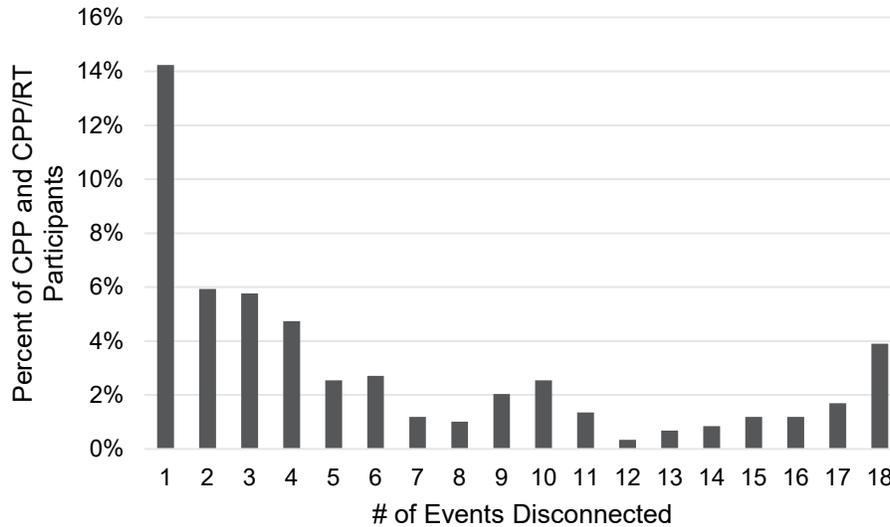


Figure 9, below, shows the distribution across CPP and CPP/RT participants of disconnection frequency. This plot shows, for example, that 14% of participants were disconnected for only a single event, 6% were disconnected for two events, etc. Altogether 46% of participants were connected for all events, and 4% of participants were not connected for any of the events.

Figure 9: Distribution of Disconnection Frequency



These disconnected customers are an advantage for this pilot evaluation, from the standpoint of information gathering.¹⁷ The fact that a meaningful (though relatively small) proportion of the participant population are disconnected for any given event makes it possible to quantify the purely behavioural impact of the CPP event – that is, absent the control technology, are participants still able to respond to the CPP event with 15 minutes’ notice?

Participants not connected are still subject to the pilot pricing and are therefore still considered pilot participants.

3.2 Experimental Design

A pilot program is an experiment, and the primary goal of an experiment is to provide information. In this case, the goal is to provide key decision-makers with the information they require in order to ascertain whether it is advisable to proceed with a wider program roll-out, and whether any changes should be applied to the design of the program itself.

The key quantitative information provided by a pilot is the set of estimated impacts – what was the impact of the pilot on the key metrics of customer behaviour? To isolate the program effect from other, non-program, effects, the establishment of a robust counterfactual is vital. The counterfactual, or baseline, is the “but for” – “*but for the program, how would participants have behaved?*”.

The gold standard for counterfactuals is the randomized control trial (RCT). This is the standard approach for evaluating the effects of pharmaceutical drugs: some participants in the trial are provided with the experimental medication, while others are provided with a placebo. This ensures that results are not biased due to self-selection.

¹⁷ It is important to bear in mind that the key goal of a pilot program is *not* primarily about achieving high savings, in either energy or demand response, but to provide actionable intelligence that can be used in decision-making for a wider program roll-out.

RCTs may also be applied to energy efficiency or demand response evaluation. In this case, the standard approach is to use an enrollment technique known as “recruit-and-deny”. The procedure works in the following manner: applicants to a program are either enrolled in the program (and so become treatment participants), or else denied enrollment (sometimes by being wait-listed) and so act as control customers.

The original design of the program called for RCT controls to be developed for both the RT-only and CPP and CPP/RT groups. During the enrollment process the RT-only stream had too few applicants to support this design, and RCT controls (approximately 450) were drawn only from the population that applied to the CPP and CPP/RT stream.

As a contingency against the possibility that the RCT controls that applied to join the CPP treatment might not be suitable as controls for the RT-only treatment, Navigant developed an alternative approach for creating a control group for the RT-only customers. Control customers were selected from a large pool of non-participating customer based on consumption patterns observed in the summer prior to the program period. The details of this approach may be found in Appendix H.

At the outset of Navigant’s analysis, however, testing of the two control groups revealed that the RCT control group provided a more accurate counterfactual in the testing period (the summer of 2016) than the matched controls¹⁸, and so the RCT controls were used as the control group for all pilot participants in the final analysis.

3.3 Energy Impact Approach

Participant energy impacts were estimated using only data from the program period. Impacts were estimated using a panel data regression of daily energy consumption by TOU period. Although there are only three TOU periods in Ontario, Navigant estimated impacts for four: On-Peak, Mid-Peak, non-holiday weekday Off-Peak, and weekend and holiday Off-Peak. The Off-Peak periods were differentiated to allow for the fact that consumption patterns are substantially different during the overnight Off-Peak than during the weekend or holiday Off-Peak period.

The same regression specification was applied to three different sets of participant and control consumption data:

- RT-only participants and RCT controls
- CPP and CPP/RT participants and RCT controls, including all summer days.
- CPP and CPP/RT participants and RCT controls, *excluding* CPP event days.

The estimated impacts of these regressions are reported and discussed in Section 4.1, below.

¹⁸ In testing the two different control groups in a pre-program and pre-matching period, Navigant found that although both control groups had TOU-period consumption patterns that were not statistically different from those of the participants (i.e., suitable as counterfactuals), the parameters of interest in the test regression were much smaller in absolute value for the RCT group than for the matched control group. This indicated to Navigant that that RCT controls’ consumption patterns were more similar to participants than were the matched controls. This led to the conclusion that the RCT controls were the more suitable control group for the RT-only participants in this analysis.

Key elements of the estimated regression specification include:

- **TOU Period Dummy Variables.** Four dummy variables (one for each period) were included in the model specification. These were interacted with *all* other variables included in the regression equation, delivering estimated impacts equivalent to those that would be obtained if a different regression were used for each TOU period.¹⁹
- **Pre-Period Consumption Values.** Based on a series 15 different day-types (capturing differences in weather – see Appendix A for details), Navigant developed a series of 360 individual-specific pre-program average hourly consumption values. These values are applied to the hourly weather series and then aggregated to the daily level (by TOU period) for the energy analysis and are included in the regression specification to control for pre-existing individual customer consumption patterns. This set of values is analogous to including a highly granular set of different individual-level fixed effects in the regression equation.
- **Monthly/Day-Type Dummies.** The pre-period consumption values described above are interacted in the regression with a series of dummies representing the averaging periods used to develop them. There are 15 day-type dummies, that capture seasonal effects (month of year) as well as coarser temperature effects (extreme, vs mild temperature days). For more details, please see Appendix A.
- **Temperature.** The total number of cooling and heating degree hours observed in the given TOU period on each day of the sample is included to control for any variation in average consumption (not already captured by the pre-period consumption variable discussed above) attributable to weather effects.

Also included is a daily heat-build-up variable and daily cold build-up variable. These 72 hour exponentially decaying moving averages capture the effects on consumption of heat waves or cold snaps.

- **Treatment Dummy.** A treatment dummy variable was included to capture the program effect. The estimate parameter associated with this variable captures the impact of the program. It is included as an intercept variable (i.e., interacted only with the TOU dummy, above) and as a slope variable (also interacted with the number of cooling degree hours). The first of these captures the impact of the program on cooler days, and the second captures the incremental impact of each additional cooling degree hour observed in a given TOU period, i.e., effectively identifies the portion of energy savings derived from space-cooling energy savings.

A full model specification, and additional detail regarding variable development may be found in Appendix A. Essentially the same model specification was used to estimate the average treatment impact during the IESO-defined “system coincident peak” period – the period between 1pm and 6pm on non-holiday weekdays in June, July, and August. The key difference is that there was no TOU period dimension (i.e., each date appeared only a single time for a given customer), and that the dependent variable was total consumption in the system coincident peak period (instead of in one of the four specified TOU periods).

Not included in any of the regression specifications is any kind of interaction effect between the CPP and the RT treatments. That is, none of the results presented in this report are derived from a regression equation that controls for the incremental effect on CPP participants’ impacts of *also* being equipped with

¹⁹ The reason for using a single regression, as opposed to one for each TOU period, was to allow the estimation of covariances between different impact parameters, to ensure that the uncertainty associated with aggregated impacts (e.g., across TOU periods) could be accurately estimated.

the RT technologies (online portal and mobile application). These regressions do not differentiate between CPP and CPP/RT group energy impacts.

This is based upon earlier testing that found that this effect was not statistically significant at any conventional level of significance. More specifically, for the CPP and CPP/RT group, Navigant estimated a regression model in which the treatment dummy variable was interacted with another variable flagging whether that customer also had access to the RT technology. In these test regressions (including and excluding CPP event days), Navigant found that the incremental effect of the RT treatment on CPP participants' changes in behaviour was not statistically significant, and so dropped this interaction from the final analysis.

3.4 CPP Demand Impact Approach

Participant demand response impacts on CPP event days were estimated using only data from summer 2018 CPP event days. Impacts were estimated using a panel data regression of hourly energy use. All impacts were estimated using a single model specification.

Navigant's regression model specification is designed to deliver estimates in four key areas. It is designed to provide:

- **Ex-Post Total Impact.** An estimate of the total historical impact of the program during CPP events. That is, an estimate of the difference between a participant's demand during the CPP event, and what it would have been had there been no program at all. This defines the estimated *total* impact of the program.
- **Ex-Post DR Impact.** An estimate of the historical impact of CPP events, given that the program is in place. Put another way, this is an estimate of the difference between what a participant's demand was during the CPP event, and what it would have been had there been no event on that day, but in all other respects (including the existence of the program) the days were the same. This defines the estimated "*DR only*" impact of the program.
- **Ex-Ante Total Impact.** A prediction of total impacts across a range of temperatures. This defines the estimated *capability* of the program.
- **Ex-Ante DR Impact.** A prediction of the DR-only impacts across a range of temperatures.

Key variables included in the regression specification are:

- **Hour-of-Day Dummies.** A set of 24 hourly dummies. These are interacted with all other non-treatment variables (and in some cases some treatment variables).
- **Temperature.** Heating degree hours, cooling degree hours, and heat build-up.
- **Hourly Pre-Period Consumption Values.** Average participant specific pre-period consumption for the given day-type. These act, as in the energy regression, as highly granular fixed effects. See Appendix A for more details.
- **Non-DR Program Dummies.** A set of variables (the treatment dummy interacted with the hourly dummies) intended to capture the non-CPP-event treatment effects on a CPP event day – i.e., to capture the effect on participant demand of their anticipating when an event *may* occur. This set of variables is included as both intercept dummies, and as slope dummies (interacted with cooling degree hours).

- **DR Event Dummy.** A dummy variable intended to capture CPP event “DR only” impacts. This is included both as an intercept dummy and a slope dummy (interacted with cooling degree hours), both of which are included as-is and also interacted with a variable that captures whether the enabling technologies are connected and able to be automatically controlled via London Hydro’s curtailment signal.
- **Snapback Variables.** Four dummy variables (one for each of the four hours immediately following the DR event) interacted with the cooling degree hours observed during the event. These variables are designed to control for any snapback effects.²⁰

Additional details, and the full model specification may be found in Appendix A.

3.5 Elasticities

As per the OEB evaluation metrics requirements, Navigant used the outputs from the analysis described above to develop estimates of two different metrics of price sensitivity for the group of participants subject to the CPP rate:

- **Own/daily price elasticity of demand.** This describes the relationship between CPP and CPP/RT participants’ average daily demand and the average daily cost of electricity.
- **Inter-period elasticity of substitution.** This describes the relative relationship between electricity pricing and demand for two different time periods – analogous to a cross-price elasticity. The two time periods applied for this analysis are the Mid-Peak and the Off-Peak periods (no CPP events occurred outside of the Mid-Peak period).

Changes in average participant cost were estimated by apply comparing:

- The average cost of electricity in the relevant period assuming counterfactual (baseline) consumption applied to status quo TOU prices. This is the average cost had there been no program.
- with
- The average cost of electricity in the relevant period assuming counterfactual (baseline) consumption applied to *actual* pilot rates. This is the average cost, given that a program exists, but assuming no participant response to the rates.

The details of the calculation itself may be found in Appendix B, the spreadsheet that accompanies this report.

²⁰ Snapback is a phenomenon commonly observed in direct load control programs. If participant A/C is controlled for long enough that indoor temperature materially rises, this can result in more A/C compressor cycles than usual in the hours immediately following the event as the A/C unit works harder usual to restore the home to the set-point temperature.

4. RESULTS

This chapter provides the results of Navigant's impact evaluation of the London Hydro RPP pilot program in the summer of 2018.

This chapter is divided into two main sections:

- **Energy Impacts.** This section provides and discusses the estimated impacts on daily energy consumption of the program for all participants.
- **Critical Peak Event Demand Impacts.** This section provides and discusses the estimated CPP event demand impacts delivered by the CPP and CPP/RT participants.

4.1 Energy Impacts

Navigant's key findings from the energy impact analysis include:

- **CPP participants delivered On-Peak and Mid-Peak energy savings with a reasonably high degree of certainty.** CPP and CPP/RT participants reduced their daily:
 - On-Peak consumption by approximately 5% on average
 - Mid-Peak consumption by approximately 3% on average
- **RT-Only participants delivered modest On-Peak energy savings, although these results are less certain.** RT participants reduced their On-Peak consumption by just over 2%, although these results are less certain than those of the CPP group.
- **CPP participants also equipped with the RT technology are saving the same as CPP-only participants.** Navigant found no statistically significant difference between the energy savings achieved by CPP and CPP/RT participants. This suggests that savings are being driven by a combination of the price-effect (attempting to reduce risk by limiting consumption during periods more likely to observe a critical peak price) and the educational component provided by London Hydro.
- **Energy savings appear to be driven by a variety of end-uses.** Based on the regression-estimated parameters, approximately a third (On-Peak) and 40% (Mid-Peak) of CPP participant savings are insensitive to temperature, with the balance of savings being temperature driven. This suggests that participants did not rely solely on reducing A/C use (typically the largest single discretionary load in a home) to achieve savings. For RT participants approximately 60% of savings appear to be temperature-insensitive.

This section of the impact chapter is divided into two sub-sections:

- **CPP and CPP/RT Participants.** This sub-section provides the estimated impacts of the CPP and CPP/RT treatment, and discusses the results.
- **RT-only Participants.** This sub-section provides the estimated impacts of the RT-only treatment and discusses the results.

4.1.1 CPP and CPP/RT Participants

This section will provide and discuss the estimated energy impacts for the CPP and CPP/RT groups. As noted above, in both the section introduction and in Section 3.3, initial exploratory regression estimation found that the incremental energy impact of the RT treatment for the participants exposed to the CPP treatment was not statistically significant. These interaction terms were then dropped from the model specification for the remainder of the analysis. For the remainder of this section, references to the “CPP group” or “CPP treatment” should be understood to encompass both the CPP and the CPP/RT participants.

Navigant estimated the energy impacts of the CPP group twice, both times with the same model specification, but with slightly different data sets. Navigant’s initial estimation included *all* summer days. Navigant then re-estimated the same model specification, dropping all CPP event days from the data set.

Although both sets of results are presented below, the final results presented in this report (and in Appendix B, the accompanying output spreadsheet of program metrics for the OEB) are those estimated when CPP event days are *excluded* from the data set.

Average impacts in the summer of 2018 are presented in Figure 10, below. This table shows the average daily reduction in consumption (kWh) in the given TOU period, the percentage reduction in the consumption of the given TOU period, and the relative precision of the estimated impact at the 90% confidence level.²¹

Positive values indicate a savings, and negative values indicate an increase in consumption. Statistically non-significant estimates are followed by “(N/S)”. A value is considered statistically not significantly different from zero²² when the relative precision at the 90% confidence level exceeds 100%.

Figure 10: CPP Energy Impacts – Excludes CPP Event Days

TOU Period	Daily Savings		Relative Precision +/-% (90% Confidence)
	kWh	%	
On-Peak	0.30	5.0%	58%
Mid-Peak	0.17	2.9%	90%
Off-Peak	-0.22 (N/S)	-1.96% (N/S)	-136%
Weekend Off-Peak	0.08 (N/S)	0.3% (N/S)	751%

Note that the savings values above are average daily consumption savings, by TOU period. This is equivalent to an average reduction in On-Peak demand of 0.049 kW and an average reduction in Mid-Peak demand of 0.029 kW.

When the model was re-estimated using the system coincident peak demand data set (i.e., a daily frequency data set where the dependent variable is the total daily consumption between 1pm and 6pm on non-holiday weekdays in June, July, and August), Navigant estimated a statistically significant average reduction in energy consumption of 0.46 kWh, or approximately 6% of baseline consumption in that period. The average estimated demand impact in this period is 0.077 kW.

²¹ All estimates of uncertainty presented in this report have been estimated using cluster-robust standard-errors, with clustering applied at the individual customer level.

²² Generally speaking (though exceptions exist), impact estimates that are statistically no different from zero should be considered the same as no impact at all.

Figure 11, below, provides the estimated impacts when CPP event days are *included*. Note that the estimated impact in the On-Peak period barely changes, whereas the Mid-Peak impact doubles when CPP event days are included. This effect is because in the summer of 2018 CPP events all began at either 5pm or 6pm; no CPP events took place within the TOU On-Peak period.

Figure 11: CPP Energy Impacts: Includes CPP Event Days

TOU Period	Daily Savings		Relative Precision +/-% (90% Confidence)
	kWh	%	
On-Peak	0.33	5.1%	55%
Mid-Peak	0.28	4.4%	58%
Off-Peak	-0.23 (N/S)	-1.9% (N/S)	-136%
Weekend Off-Peak	0.08 (N/S)	0.3% (N/S)	751%

The savings values above are average daily consumption savings, by TOU period. This is equivalent to an average reduction in On-Peak demand of 0.054 kW and an average reduction in Mid-Peak demand of 0.046 kW.

Estimated impacts in the On-Peak and Mid-Peak periods are clearly evident when comparing current and prior summer seasonal load profiles.

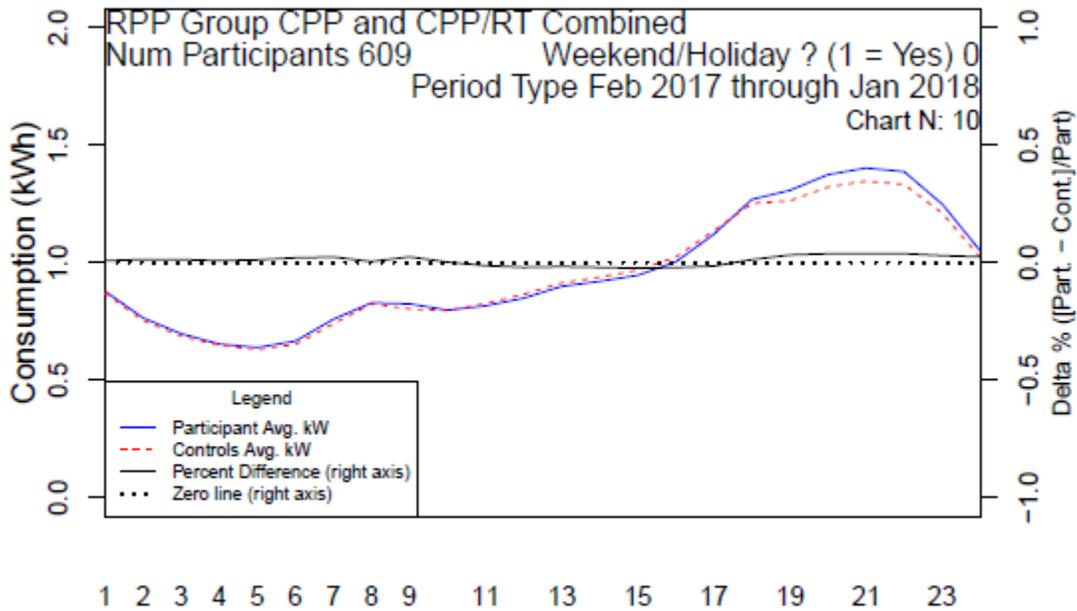
Consider Figure 12, below. This plot shows the average summer 2017 (one year prior to program implementation) load profile of non-holiday weekday consumption for:

- CPP participants (blue line) and
- RCT control customers (red dotted line).

Note how close the two lines are throughout most of the day. Some separation exists in the evening, with CPP participants on average consuming slightly more electricity in the nighttime hours.²³

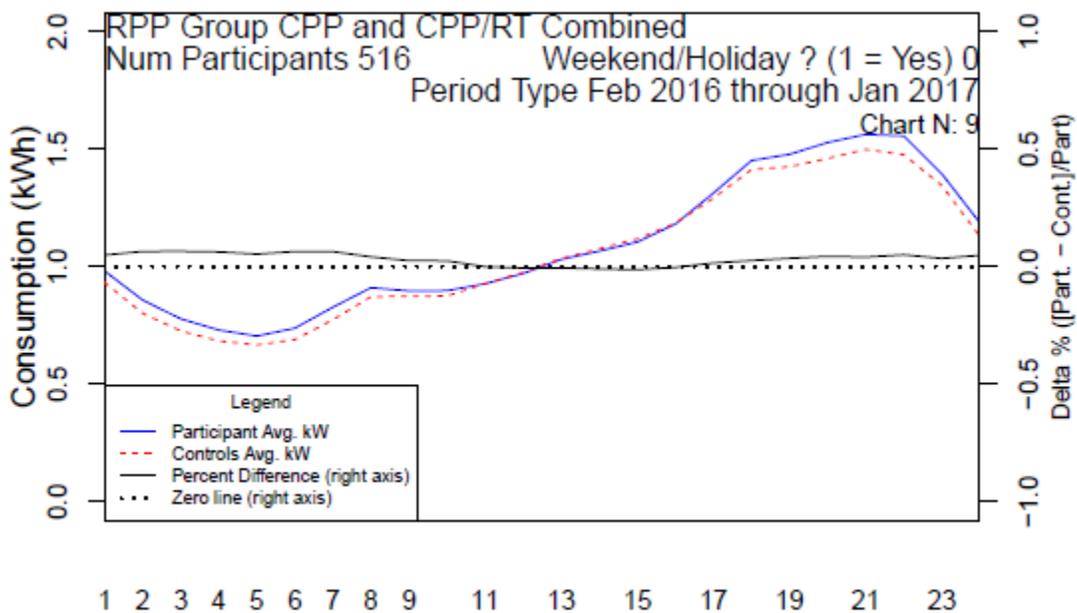
²³ This difference is controlled for using the pre-period consumption values included in the regression equation. That is, impacts are estimated in the program period conditional on this structural difference observed in the pre-period.

Figure 12: CPP Participants – Summer 2017 Weekday Load Profile



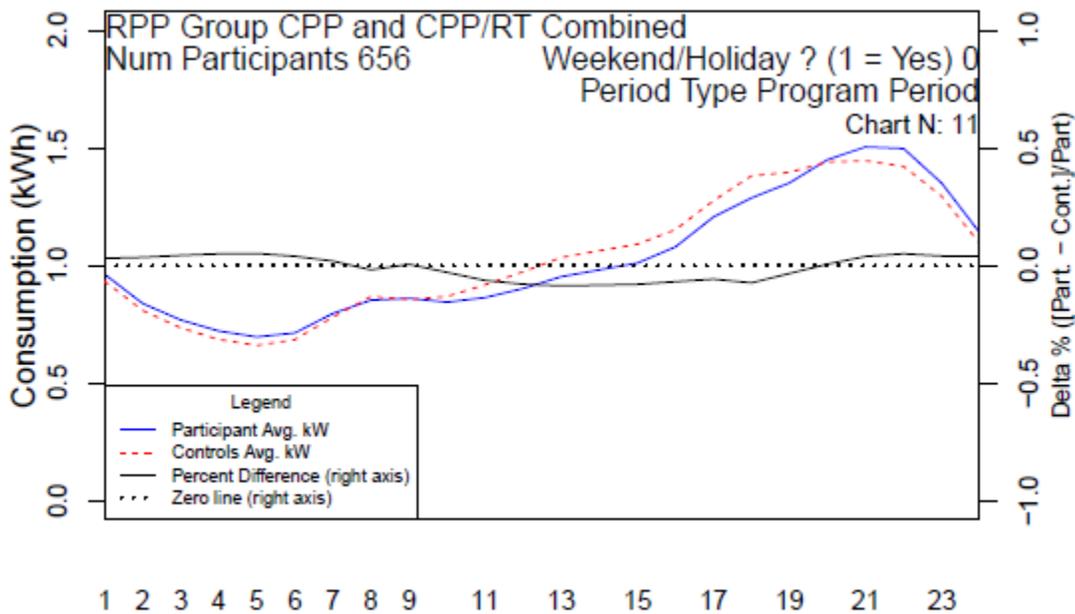
Aside from the late evening hours, the two profiles are nearly identical. Now consider the same profiles one year farther back in time, in the summer of 2016. These are shown below in Figure 13. Although there are now some small differences in the overnight and very early morning hours, the differences between the two profiles are consistent with those observed in the summer of 2018.

Figure 13: CPP Participants – Summer 2016 Weekday Load Profile



Finally, consider the same two sets of load profiles from the summer of 2018, the program period. There is a distinct separation between the two profiles that begins close to the beginning of the morning Mid-Peak period, extends consistently across the On-Peak period, and tails off at the end of the afternoon Mid-Peak period.

Figure 14: CPP Participants – Summer 2018 (Program Period) Weekday Load Profile



Observing the patterns across three years of data it seems clear that the change in consumption observed in the program period – a relatively consistent change across the hours of the day in which a CPP event is most likely – is motivated by the program treatment.

As indicated in Section 3.3, Navigant estimated energy impacts as both a function of the program participation and as a function of the interactive effect between program participation and the weather. That is, the regression-estimated parameters provide an estimate of the average program impact on cooler days (when there are no cooling degree hours) as well as the incremental impact of each cooling degree hour observed in the given period.

Figure 15, below, provides the regression-estimated parameters when CPP event days are excluded from the analysis. This shows both:

- The intercept parameters for On-Peak and Mid-Peak (i.e., estimated annual kWh impact when no cooling degree hours are observed in the period in question), and;
- The slope parameters (i.e., the incremental impact for each cooling degree hour observed in the given period).

In this table, a negative value indicates a reduction in consumption (energy savings). The estimated impact is shown in the “Estimate” column. The p-value column provides an estimate of the uncertainty associated with parameter – a p-value of 0.1 or more indicates that the parameter is not statistically significantly different from 0 at the 10% level of confidence.

Figure 15: CPP Energy Impact Parameters of Interest

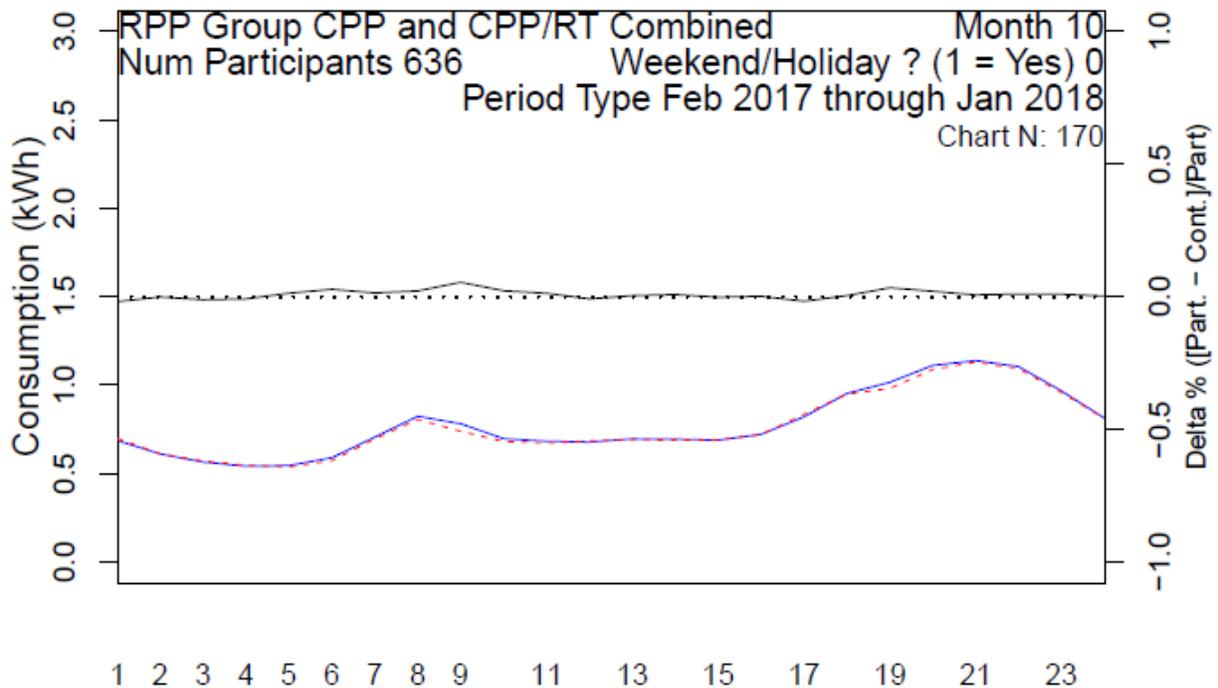
	Intercept Dummy		Slope (Temperature) Dummy	
	Estimate	P-Value	Estimate	P-Value
On-Peak	-0.079	0.327	-0.008	0.001
Mid-Peak	-0.068	0.399	-0.007	0.014

Note that although the intercept parameters for both TOU periods are not statistically significant, the combined effect across intercept and slope parameters (as shown in Figure 10, above) is statistically significant. Further, out of the 127 non-holiday weekdays in the summer of 2018, on 24 of these days (about 19%) there were no cooling degree hours in the On-peak period, and on 29 of these days (23%) there were no cooling degree hours in the Mid-Peak period.

This suggests that the estimated intercept parameter (-0.079 for On-Peak, -0.068 for Mid-Peak) is truly a reflection of participant behaviour, rather than a spurious value as a result of collinearity amongst the independent variables.²⁴ That is, despite the p-value, it seems likely that some base level of conservation is achieved, irrespective of the weather.

This estimated effect is observable in the monthly load profiles. First, consider the average participant and RCT control loads in October of 2017 (prior to the program taking effect), as shown in Figure 18.

Figure 16: CPP Participants – October 2017 Weekday Load Profile

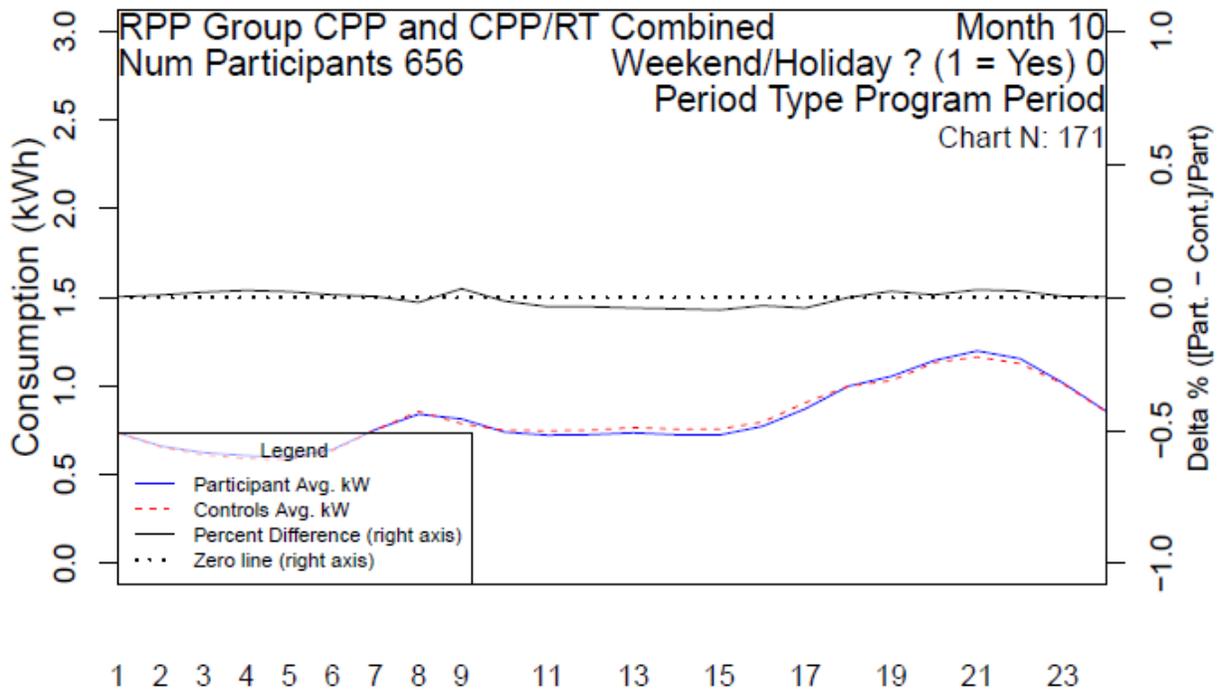


²⁴ For example: if nearly all the non-holiday weekdays included some number of cooling degree hours then it would be more difficult to argue that there are program savings that aren't temperature sensitive, as there would be very few days in which non-temperature-sensitive savings could be achieved in isolation from the temperature-sensitive savings.

Next compare these load profiles against those for October in the program period, as shown below in Figure 17. A slight, but clearly observable, drop in consumption in the mid-day period exists. October 2018 was relatively cool, with no cooling degree hours observed during 18 of the 22 On-Peak periods in that month.

All of this is highly suggestive of the fact that although a significant proportion of energy savings were derived from space-cooling adjustments, a non-trivial proportion of energy savings may have been derived from non-temperature sensitive loads.

Figure 17: CPP Participants – October 2017 Weekday Load Profile



Based on all the estimated model parameters, CPP participants’ consumption over the entire summer of 2018 decreased by a statistically non-significant 36 kWh, or about 0.79%.²⁵ This result (the lack of statistical significance of the savings) is likely a result of noise in the non-On-Peak and non-Mid-Peak periods distorting the result. If only the On-Peak and Mid-Peak (both of which test as statistically significant) savings are considered, and consumption in all other periods (where impacts were found to be non-significant) is assumed to not have changed as a result of the program, then overall summer savings would be approximately 59 kWh, or about 1.3%.

4.1.2 RT-only Participants

This section will provide and discuss the estimated energy impacts for the RT-only group.

²⁵ The p-value associated with this estimate is 0.58, indicating that it would be statistically significant only at the 42% level of confidence.

None of the estimated parameters of interest for this group are statistically significant at the 90% level of confidence. A summary of average daily savings (negative values indicate increases in consumption) is provided in Figure 18, below.

Normally, for an evaluation such as this, Navigant would interpret the statistical non-significance of a parameter of interest (i.e., one designed to capture program savings) as indicating that the program was delivering no savings. In this case, Navigant believes that evidence exists of savings being delivered (despite the non-significance of the result), albeit savings that are highly uncertain in value.

Figure 18: RT-Only Energy Impacts²⁶

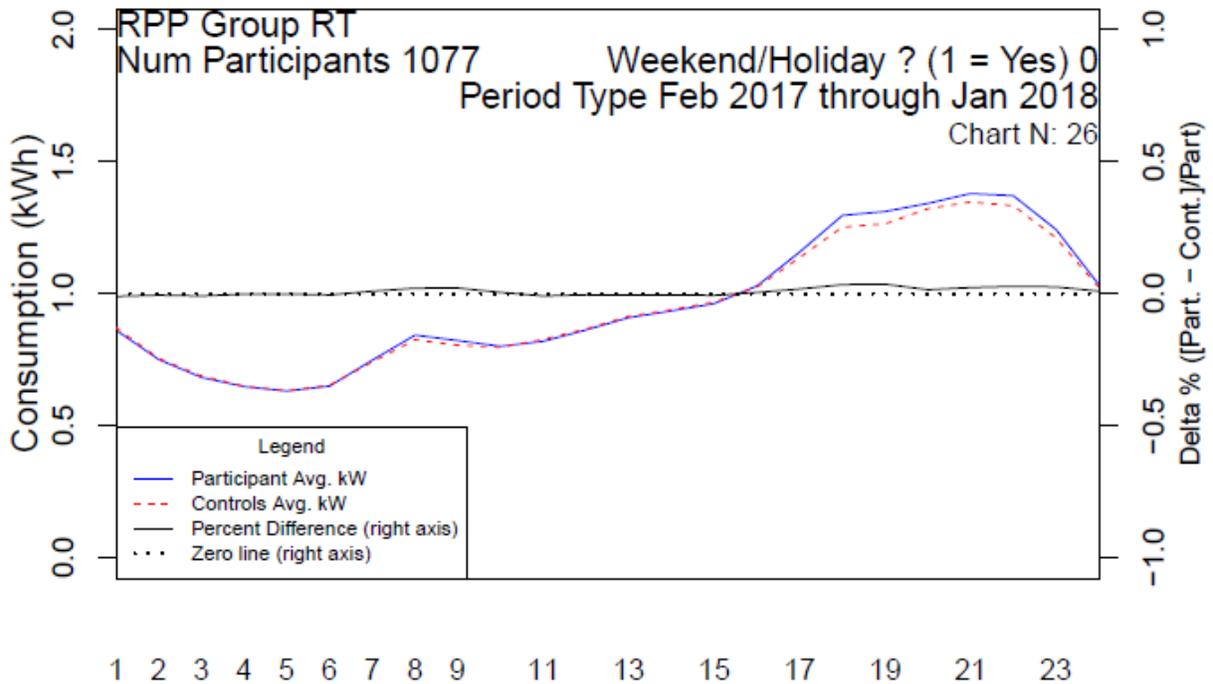
TOU Period	Daily Savings		Relative Precision +/-% (90% Confidence)
	kWh	%	
On-Peak	0.16 (N/S)	2.36% (N/S)	101%
Mid-Peak	0.03 (N/S)	0.42% (N/S)	528%
Off-Peak	-0.2 (N/S)	-1.62% (N/S)	-135%
Weekend Off-Peak	-0.15 (N/S)	-0.53% (N/S)	-373%

First, consider the uncertainty associated with On-Peak period savings. Although the savings are not statistically significant at the 90% level (the relative precision is more than 100%), they are only *just barely* non-significant. The relative precision is 101%, and the p-value associated with the daily On-Peak impact is 0.1046, indicating that although the estimate isn't statistically significant at the 90% confidence level, it *is* statistically significant at the 89.5% confidence level.

Second, when considering the seasonal non-holiday load profiles – as was done above for the CPP participants – a clear (but small) change in mid-day (On-Peak) consumption is clearly visible. As above, begin by observing the seasonal non-holiday load profiles in the summer of 2017, as shown in Figure 19.

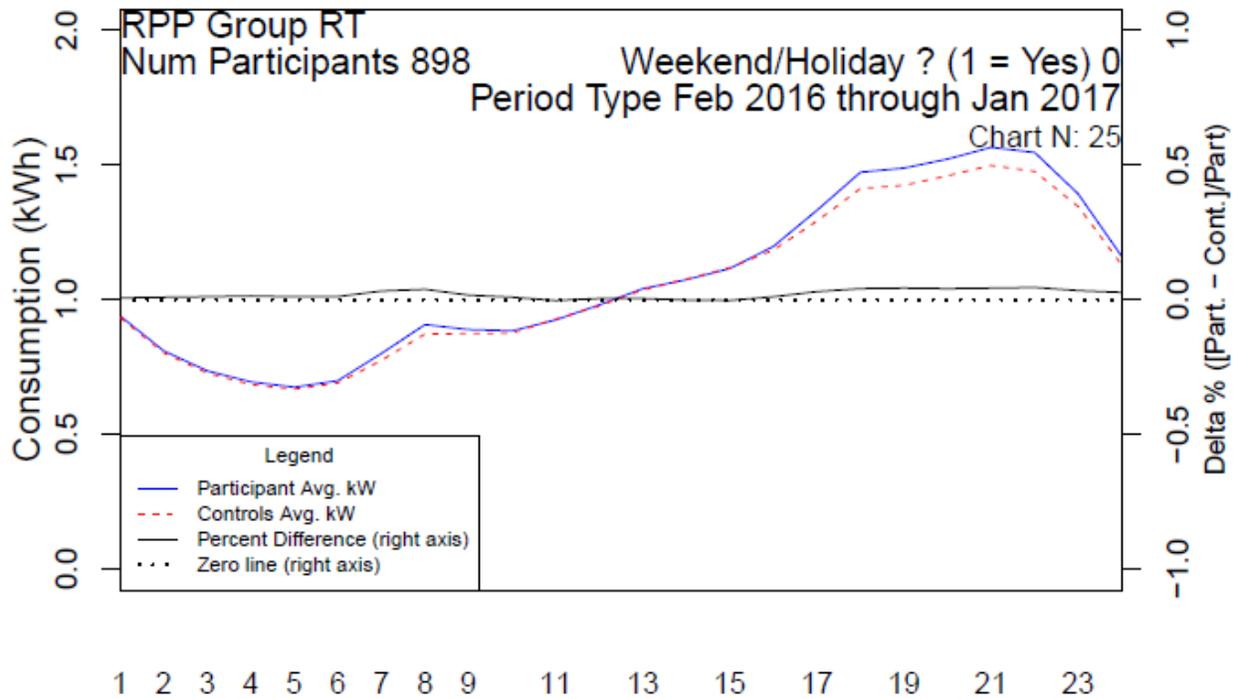
²⁶ The savings values in this table are average daily consumption savings, by TOU period. This is equivalent to an average reduction in On-Peak demand of 0.026 kW.

Figure 19: RT-Only Participants – Summer 2017 Weekday Load Profile



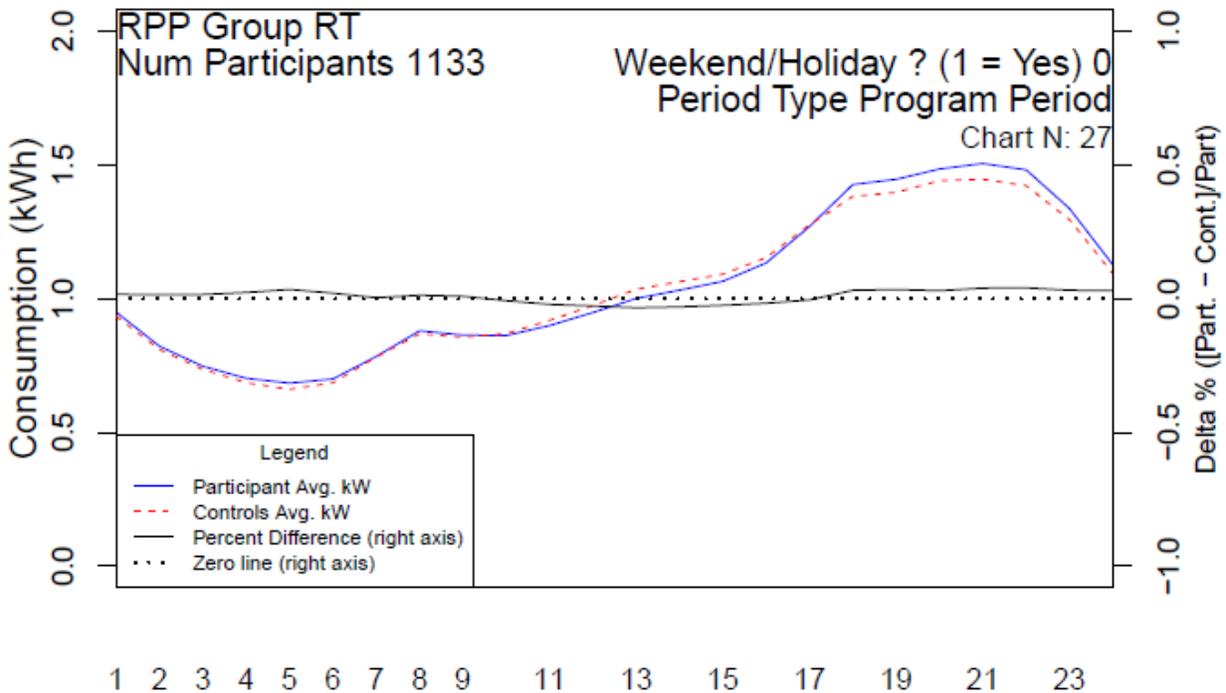
Next, observe the load profiles in the summer before that, summer 2016, as shown in Figure 20. This shows essentially the same pattern – the control and participant profiles are very close during the mid-day period (from about 9am to 5pm) but deviate in the early and later evening. Recall that these consistent differences between the participants and controls are accounted for via the inclusion on the right-hand side of the regression equation of customer-specific pre-period consumption values.

Figure 20: RT-Only Participants – Summer 2016 Weekday Load Profile



Finally, observe the two profiles in Figure 21, the program period (summer of 2018). There is now a small, but distinct, separation between the control and participant profiles in the mid-day On-Peak period. It is this separation that the regression equation is capturing in the estimated impacts provided above.

Figure 21: RT-Only Participants – Summer 2018 (Program Period) Weekday Load Profile



Despite the statistical non-significance of the estimated On-Peak impact, the fact that the parameter is so close to being statistically significant, and the fact that the program effects are intuitive and observable in plots of participant and control hourly load profiles is sufficient for Navigant to feel it is appropriate to report the estimated On-Peak impact shown above as the best available impact of the RT-only group.

Figure 22, below, shows the estimated values for the key parameters of interest for the RT-only group. As above, in Figure 15, this table shows the estimated intercept parameter (estimated impact on days where no cooling degree hours are observed during the TOU period of interest) as well as the estimated slope parameter (the incremental impact for each additional cooling degree hour observed during the period of interest).

Contrasting these values and estimated uncertainties with those of the CPP group yields some interesting insights. Firstly, in Figure 15, there was far less uncertainty associated with CPP participants' temperature-sensitive energy impacts than there was associated with the non-temperature sensitive impacts. For RT participants, this is reversed: the "intercept" estimate is more certain (has a lower p-value than) the slope estimate.

Likewise the magnitudes of the parameter yield some insight when compared across the two treatment groups: the intercept estimates for RT and CPP participants are nearly the same (0.1 for CPP, 0.09 for RT-only) whereas the CPP participants' temperature sensitive is more than three times that of the RT-only participants (0.007 versus 0.002).

Figure 22: RT-Only Energy Impact Parameters of Interest

	Intercept Dummy		Slope (Temperature) Dummy	
	Estimate	P-Value	Estimate	P-Value
On-Peak	-0.091	0.194	-0.002	0.313
Mid-Peak	-0.001	0.991	-0.001	0.543

This contrast between the RT-only and CPP participants’ estimated impact parameters suggests that while the majority of CPP participants’ savings are driven by adjustments in space-cooling, the same is not the case for the RT-only participants. A potential driver of this difference may be the combination of the price effects faced by CPP participants, and their expectations regarding CPP event scheduling. The CPP participants know, from the program education provided to them by London Hydro, that CPP event scheduling is driven by system need, and that system needs tend to be greatest on very hot days.

The appropriate response then, for the CPP participants, is to focus changes in behaviour in reducing consumption in periods when temperature is highest. The simplest method of doing this is to reduce A/C consumption.

RT-only customers face a different set of incentives. Where CPP participants’ expected unit cost for electricity is correlated with temperature, RT-only participants’ expected unit cost is not. Regardless of the temperature, RT-only participants pay the same unit cost in the On-Peak period across the whole summer. The benefit to an RT-only participant in reducing consumption during the On-Peak in October is the same as reducing consumption during the On-Peak of the hottest day of the summer. The “cost” (in terms of the personal discomfort of a house that’s too warm) is not the same, however.

It is therefore intuitive that RT-only participants would focus more of their energy conservation efforts on end-uses that are not weather sensitive, as appears to be the case, based on the estimated parameter values.

Based on all the estimated model parameters, RT-only participants’ consumption over the entire summer of 2018 *increased* by a statistically non-significant 10 kWh, or about 0.2%.²⁷ This result is likely a result of noise in the non-On-Peak periods distorting the result. If only the On-Peak savings are considered (and consumption in all other periods is assumed to not have changed as a result of the program), then overall summer savings would be approximately 20 kWh, or about 0.2%.

When the model was re-estimated using the system coincident peak demand data set (i.e., a daily frequency data set where the dependent variable is the total daily consumption between 1pm and 6pm on non-holiday weekdays in June, July, and August), Navigant estimated a statistically non-significant average reduction in energy consumption of 0.21 kWh, or approximately 2.4% of baseline consumption in that period. The average estimated demand impact in this period is 0.036 kW. Although the estimated impact is statistically non-significant, the p-value of 0.1047 indicates that it is just *barely* statistically insignificant, consistent with the findings reported above for the On-Peak period.

4.2 Critical Peak Event Demand Impacts

Navigant’s key findings include:

²⁷ The p-value associated with this estimate is 0.86, indicating that it would be statistically significant only at the 14% level of confidence.

- **CPP event demand reductions were substantial.** On average, CPP participants delivered 0.67 kW of demand reductions (approximately a third of baseline demand) during CPP events and delivered 1 kW of reductions per participant during the hottest event, on July 4th.
- **There is a behavioural element to CPP event impacts.** CPP participants are equipped with enabling technologies (a switch at the panel, and one smart plug) that respond automatically to London Hydro’s price signal. Even though participants receive 15 minutes’ notification of an event, there are clear behavioural elements to their response over and above the automated response delivered by the switches and smart plugs.
 - *Participants reduced consumption during hours in which CPP events were likely to occur.* CPP participants reduce their exposure to the CPP rate by making changes to their consumption habits in anticipation of CPP events – substantial savings are achieved in hours of the CPP event day leading up to the CPP event, despite participants not having any knowledge of when the event will occur until 15 minutes before it does.
 - *Disconnected participants still delivered demand response.* For any given event, approximately 20% of participants’ devices could not receive, or respond to, London Hydro’s curtailment signal. These participants were still able to, on average, with only 15 minutes’ notice, to reduce demand by 0.2 kW each without the program-deployed enabling technologies.²⁸

Some additional context may be helpful in understanding how remarkable this is: an evaluation of San Diego Gas and Electric’s voluntary CPP rate²⁹ (notification provided no later than 3pm on the day *prior* to the event) found the average response (at an average temperature of 99 degrees Fahrenheit, or approximately 37 degrees Celsius) was only 0.14 kW.

- **Demand reductions appear to be largely, but not overwhelmingly, driven by changes in space-cooling.** An examination of the estimated relationships between impacts and temperature is strongly suggestive of the fact that approximately a third of the average CPP event impact (approximately 0.2 to 0.3 kW) is driven by an end-use, or end-uses, other than space-cooling.
- **Real-time information on consumption did not affect demand reductions.** The impacts of the CPP and CPP/RT group were not statistically significantly different from one another – the availability of the online portal and energy tracking app did not impact participants’ ability to deliver demand reductions

The remainder of this section of Chapter 4 is divided into three sub-sections:

- **Summer 2018 Average Impacts (Ex-Post).** This sub-section provides the estimated impacts by event for all participants, on average. This sub-section provides both the “total” program impacts (the impact compared to if there had been no program at all), and the “DR only” impacts (the impact compared to if the program was in place but on the given day there had been no CPP event).

²⁸ Participants’ whose enabling technologies were not connected to London Hydro’s dispatch system continued to receive event notification via the Trickl app.

²⁹ Christensen Associates Energy Consulting, *2016 Load Impact Evaluation of San Diego Gas and Electric’s Voluntary Residential Critical Peak Pricing (CPP) and Time-of-Use (TOU) Rates*, CALMAC Study ID SDGE0304, April 2017

http://www.calmac.org/publications/PY16_TOU_and_CPP_Ex_Post_and_Ex_Ante_Report.pdf

- **Summer 2018 Average Impacts (Ex-Post) by Connectivity Status.** This sub-section provides the estimated total impact of participants during CPP events, split by whether or not the participant was connected to London Hydro’s direct load control dispatch system at the time of the event.
- **Summer Capability Estimates (Ex-Ante).** This sub-section provides a graphic illustration of the ex-ante program impacts, by connectivity status, across a range of potential outdoor temperatures. Ex-ante impacts are Navigant’s estimate of the program’s capability for delivering demand response under a range of different temperature conditions.

4.2.1 Summer 2018 Average Impacts (Ex-Post)

CPP event impacts are a combination of two distinct types of impact. There is an energy impact that is driven by participants anticipating the possibility of a CPP event and there is a demand response impact that is driven by the actual occurrence of a CPP event. As noted above, CPP customers are achieving consumption (and thus demand) savings across the summer as a whole. This program effect (the energy impact) is one component of the estimated CPP event impact. There is also an incremental demand impact achieved specifically due to, on the given day, London Hydro dispatching a critical peak pricing event.

Program impacts in this section are therefore presented in two ways:

- **Total Program Impact** is the estimated impact of the program as a whole at the time of the CPP event. This combines both energy and DR impacts, and provides the overall demand reduction achieved in the CPP period by the program. In this case the counterfactual (baseline) is participants’ consumption, had there been no program at all.
- **Demand Response Impact** is the estimated incremental impact of just the DR component. In this case the counterfactual (baseline) is participants’ consumption, assuming the existence of the program, but no CPP event on the day in question.

Although the DR-only results are presented below, some caution should be used in interpreting these results. The variables used to estimate the two different types of program effects are, inevitably, quite correlated – there is no CPP event that is affected *only* by the DR impact. This makes isolating this effect challenging, and may mean some of the parameters associated with the DR only impact may be biased and inappropriate for out-of-sample projection.³⁰

For this reason, and due to the fact that they capture the entire program impact, the main results reported by Navigant in its outputs to the Ontario Energy Board, and in the summaries of results presented above are the total program results.

Total ex-post average impacts ranged from 0.4 (+/- 0.07) kW on September 6th, to as much as 1 kW (+/- 0.09 kW) on July 4th. Individual event estimates of the total program impact for each CPP event (and on average across events) are presented in Figure 23, below. This table also provides the average event temperature.

³⁰ The same caveat is not the case for the total program impact – these parameters may be confidently used to project impacts short distances out of sample.

Figure 23: Total Program CPP Event Impacts, Average Connectivity

Event Date	Impact (kW)		Relative Precision +/-% (90% Confidence)	Temperature (°C)
	kW	%		
2018-06-01	0.60	31%	11%	24
2018-06-18	0.65	33%	9%	25
2018-06-29	0.83	36%	9%	28
2018-07-03	0.90	40%	9%	30
2018-07-04	1.00	41%	9%	31
2018-07-05	0.68	35%	10%	25
2018-07-16	0.64	33%	9%	25
2018-07-17	0.47	31%	13%	22
2018-07-24	0.63	35%	9%	25
2018-08-07	0.65	33%	9%	26
2018-08-15	0.76	37%	9%	27
2018-08-16	0.53	32%	11%	23
2018-08-17	0.56	33%	11%	24
2018-08-20	0.61	35%	10%	25
2018-08-27	0.81	38%	9%	29
2018-09-05	0.83	35%	9%	29
2018-09-06	0.40	26%	17%	21
2018-09-17	0.54	30%	11%	24
Average Across Events	0.67	34%	9%	26

Figure 24, below, provides a summary of event “DR only” impacts. These are the estimated impacts when the baseline already accounts for a customer being enrolled in the program. These demand reductions include only participant response to the notification of a CPP event, and not general daily participant response motivated by participants’ understanding that an event *could* occur.

Figure 24: DR Component of CPP Event Impacts, Average Connectivity

Event Date	Impact (kW)		Relative Precision +/-% (90% Confidence)	Temperature (°C)
	kW	%		
2018-06-01	0.53	29%	8%	24
2018-06-18	0.58	30%	7%	25
2018-06-29	0.68	32%	7%	28
2018-07-03	0.77	36%	7%	30
2018-07-04	0.80	36%	8%	31
2018-07-05	0.58	31%	7%	25
2018-07-16	0.58	30%	7%	25
2018-07-17	0.45	30%	12%	22
2018-07-24	0.57	33%	7%	25
2018-08-07	0.58	31%	7%	26
2018-08-15	0.63	32%	7%	27
2018-08-16	0.49	31%	10%	23
2018-08-17	0.51	31%	9%	24
2018-08-20	0.55	33%	8%	25
2018-08-27	0.70	34%	7%	29
2018-09-05	0.71	32%	7%	29
2018-09-06	0.39	26%	16%	21
2018-09-17	0.49	28%	9%	24
Average Across Events	0.59	31%	7%	26

As can be seen, the average difference between the total program impact and the DR-only impact is approximately 0.08 kW – this is the “energy impact” contribution to the total program impact. This is higher than the average summer-wide demand impact of the program in the Mid-Peak period shown above (just below Figure 10) of 0.029 kW (all CPP events occurred between 5pm and 6pm or between 6pm and 7pm – in the Mid-Peak period).

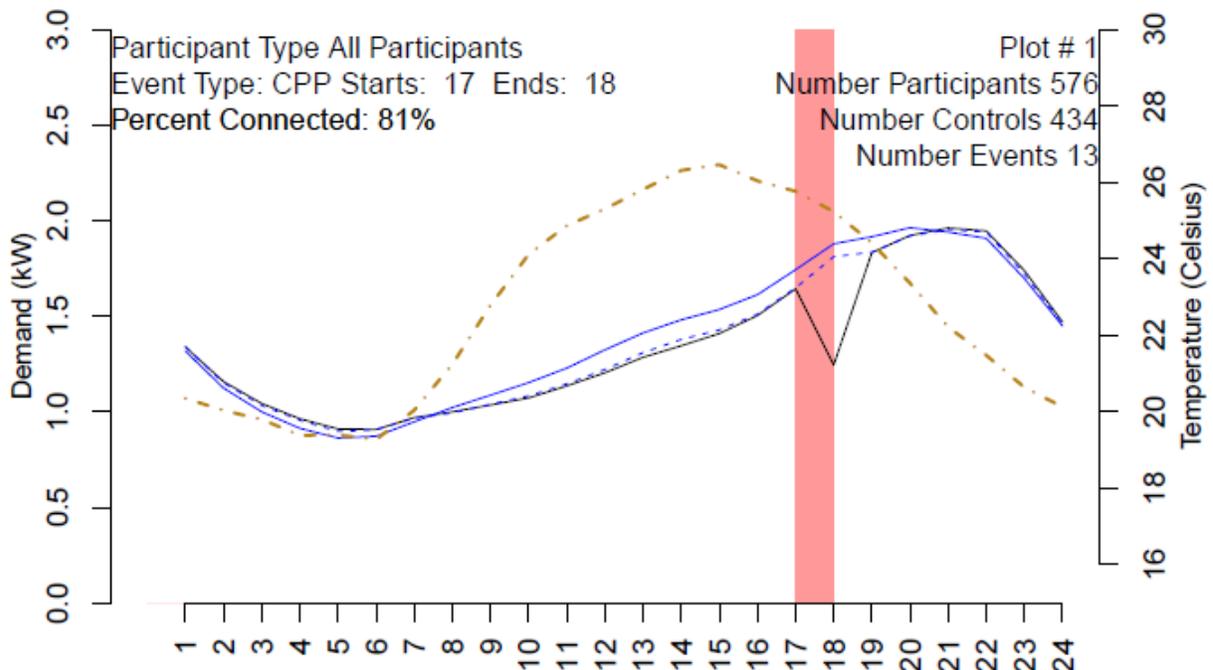
The CPP event day “energy impact” is higher than the summer average because event days are, on average, much warmer than typical summer days. For example, the average CPP event period temperature was 26 degrees Celsius. In contrast, the average temperature observed in all Mid-Peak periods across the summer was only 18.75 degrees Celsius.

The contrast between the two types of impacts can clearly be seen in Figure 25, below.

- The **black solid line** is the actual average load of all participants during on the 13 CPP event days where events ran from 5pm to 6pm.
- The **blue solid line** is the predicted average load of participants *had there been no program at all*. The difference between the blue and black solid lines is the “total program impact” reported above.
- The **blue dashed line** is the predicted average load of participants, assuming the presence of a program, but assuming that *no CPP event occurred on that day*. The difference between the blue dashed and black solid lines is the DR only impact reported above.
- The **goldenrod dot-dashed line** is the average temperature observed in the given hour (read on the right axis).

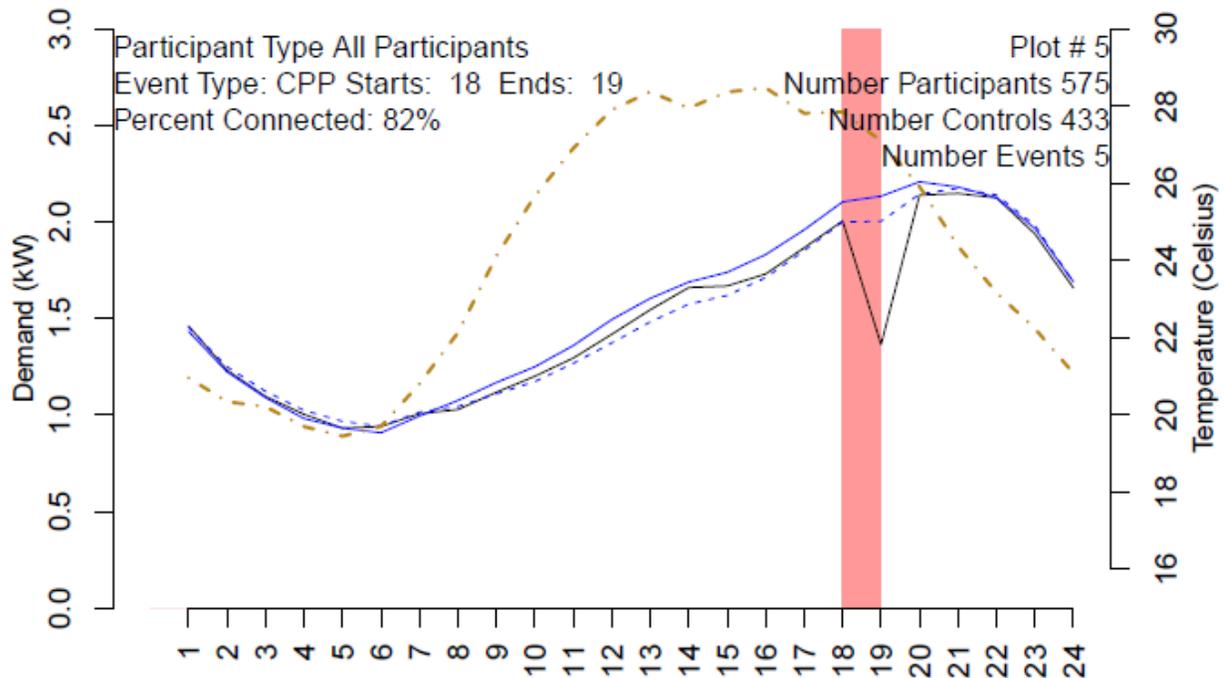
The red box highlights the hour in which the event occurs (from 5pm to 6pm).

Figure 25: Average CPP Event Day Load Profile – Events Beginning at 5pm



The average load profiles for the five events running from 6pm to 7pm show a similar pattern, as seen below in Figure 26, below.

Figure 26: Average CPP Event Day Load Profile – Events Beginning at 6pm



The CPP event response is clearly evident in both these plots – the sharp decrease in demand (black line) during the event hour is obvious, and characteristic of residential direct load control programs. One interesting feature of these plots is the apparent lack of any material snapback.

“Snapback” is a characteristic phenomenon of A/C direct load control DR programs; in the hours immediately following an event, participant loads are typically higher than the baseline. During the event, A/C compressor runtime is restricted (for A/C cycling programs), reducing demand. This leads to higher-than normal temperatures in the building, which results in longer than normal compressor run-times in the period immediately following the event.

The lack of estimated snapback for this pilot is likely due to a combination of three factors:

- **Events are short.** Shorter events mean less time for a home with curtailed A/C to heat up. Provided the indoor temperature doesn’t increase very much beyond the set-point temperature, snapback should be minimal. Navigant has noted this behaviour in previous A/C direct load control evaluations.³¹

³¹ See for example, Figure 3 and footnote #9 of Navigant Consulting, presented to Progress Energy Carolinas, *EM&V Report for the EnergyWise Home Program – Summer 2011 and Winter 2011 – 2012*, September 2012 <https://dms.psc.sc.gov/attachments/matter/2BB3B03A-155D-141F-1D48A6BCE191C362> Public Service Commission of South Carolina, Docket N. 2008-251-E and Docket No. 2012-93-E

- **Events are late.** The snapback period is coincident with the beginning of the evening cooling period. As can be seen in Figure 25, for example, the average outdoor temperature goes from approximately 25 degrees Celsius during the event, to just 21 degrees three hours later. One reason there may not be much snapback is that participants may rely to some degree on letting in cooler outside air for evening space-cooling.
- **Not all response is driven by space-cooling.** There is some evidence (see below) to suggest that demand response impacts are not driven wholly by space-cooling, but that participants are controlling other end-uses (whether manually, via the panel-located switch, or the smart plugs) to achieve bill savings. Snapback is characteristic only of controlled space-conditioning and water-heating end-uses. Lighting, pump, or motor curtailment will not typically result in any snapback.

4.2.2 Summer 2018 Average Impacts (Ex-Post) by Connectivity Status

As noted above, in Section 3.1.4, a key asset for this evaluation was the availability of participant connectivity data. This data source, and the fact that approximately 20% of participants were not connected for any given event, allowed Navigant to – through the inclusion of an appropriate dummy variable in the regression – effectively isolate impacts driven by the enabling technologies, and impacts that are purely behavioural.

Navigant’s initial hypothesis was that, given the very short notification lead time provided to participants the “DR only” impact for disconnected participants would be very small, perhaps not even statistically significant. That is, Navigant anticipated that participants that were disconnected would respond only to the longer-term price signal – there could be a CPP event at any time – rather than the event-specific price signal. Based on Navigant’s analysis, however, it appears as though at least some participants are able to respond to the CPP event notifications and undertake purely behavioural demand reductions in response to the CPP event notification.

First, for context, consider the average impacts of participants that *were* connected, as shown in Figure 27, below. Note of course that impacts are materially higher than those presented in Figure 23, which shows the total program impact under the *average* connectivity rate. Under the average connectivity rate, the average total program impact is 0.67 kW per participant. Assuming 100% connectivity, the average impact is 0.09 kW higher, at 0.76 kW.

Figure 27: Total Program CPP Event Impacts, 100% Connectivity

Event Date	DR Impact (kW)		Relative Precision +/-% (90% Confidence)	Temperature (°C)
	kW	%		
2018-06-01	0.67	36%	10%	24
2018-06-18	0.72	37%	9%	25
2018-06-29	0.94	42%	8%	28
2018-07-03	1.03	45%	8%	30
2018-07-04	1.13	47%	9%	31
2018-07-05	0.76	38%	9%	25
2018-07-16	0.71	36%	9%	25
2018-07-17	0.51	35%	13%	22
2018-07-24	0.71	40%	9%	25
2018-08-07	0.74	39%	8%	26
2018-08-15	0.86	41%	8%	27
2018-08-16	0.59	35%	10%	23
2018-08-17	0.63	36%	10%	24

2018-08-20	0.69	39%	9%	25
2018-08-27	0.93	43%	8%	29
2018-09-05	0.96	41%	8%	29
2018-09-06	0.43	29%	16%	21
2018-09-17	0.61	34%	10%	24
Average Across Events	0.76	39%	8%	26

Now, consider Figure 28, below. This shows the average total program impact per participant, but only for those participants that *weren't* connected. Although the average impact is much lower than for the fully-connected participants it is still both material and statistically significant – on average 0.3 kW per customer. For context, this is the same estimated impact as delivered by peaksaverPLUS® during the 29-degree test event that occurred on August 26, 2014.³²

Note however that estimated impacts of disconnected participants are not nearly as sensitive as those of connected participants to temperature. The average impact of the 100% connected group during the July 4 event (the hottest event day) was 1.13 kW, half again as much demand response as delivered on average across all events. In contrast, the impact of the disconnected participants on that same day was only 0.39 kW, only a 30% jump over the average across events for that group of participants.

Figure 28: Total Program CPP Event Impacts, 0% Connectivity

Event Date	DR Impact (kW)		Relative Precision +/-% (90% Confidence)	Temperature (°C)
	kW	%		
2018-06-01	0.30	15%	32%	24
2018-06-18	0.28	14%	33%	25
2018-06-29	0.35	15%	33%	28
2018-07-03	0.33	15%	42%	30
2018-07-04	0.39	14%	40%	31
2018-07-05	0.31	16%	31%	25
2018-07-16	0.28	15%	33%	25
2018-07-17	0.26	14%	38%	22
2018-07-24	0.28	15%	33%	25
2018-08-07	0.29	14%	33%	26
2018-08-15	0.33	16%	32%	27
2018-08-16	0.27	17%	35%	23
2018-08-17	0.27	16%	34%	24
2018-08-20	0.28	18%	33%	25
2018-08-27	0.31	15%	38%	29
2018-09-05	0.32	13%	40%	29
2018-09-06	0.25	16%	44%	21
2018-09-17	0.27	15%	34%	24
Average Across Events	0.30	15%	32%	26

The results above are the total program impact. These include both the general reduction in energy consumption motivated by the participant's understanding that he or she could – at a moment's notice – become exposed to very high critical peak prices. As such, it is conceivable this element of response could be the entirety of demand response – i.e., that no incremental demand response is motivated when CPP event notification is received by the participant. Intriguingly, the model estimated parameters

³² See Table 1-1 of

Nexant, Inc. prepared for the Independent Electricity System Operator, *peaksaverPLUS® Program 2014 Load Impact Evaluation*, August 2015

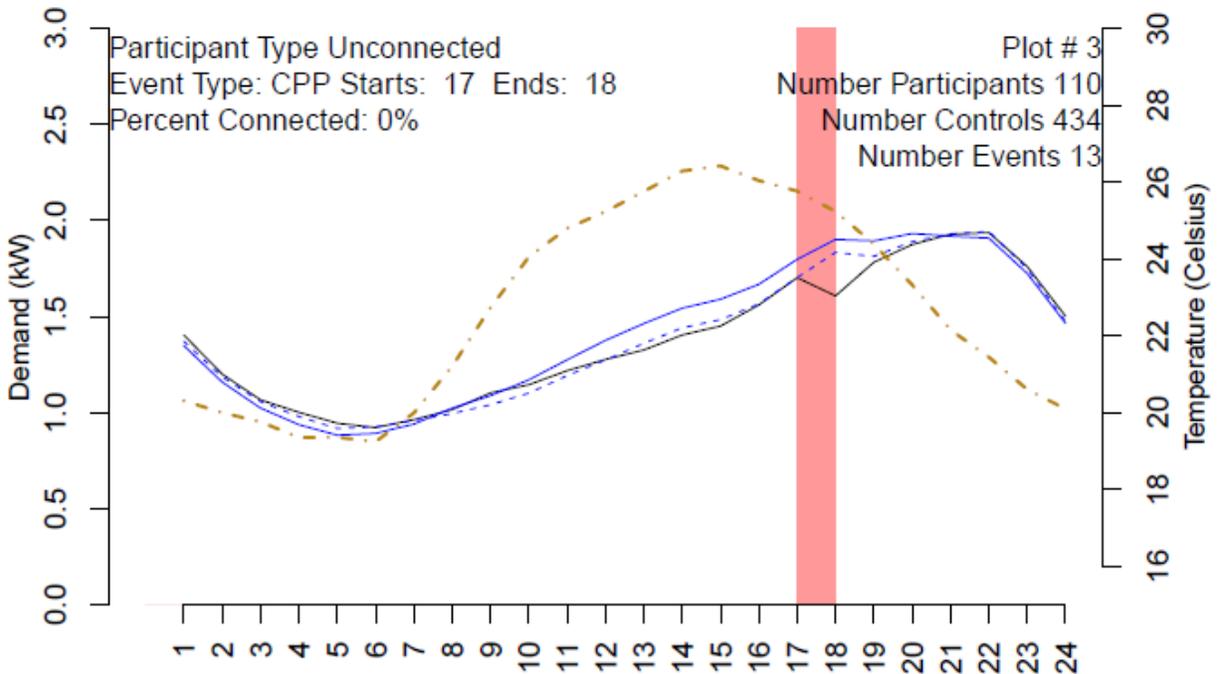
suggest that approximately two thirds of the total program effect for disconnected customers is the “DR only” effect, see Figure 29, below.

Figure 29: DR Component of CPP Event Impacts, 0% Connectivity

Event Date	DR Impact (kW)		Relative Precision +/-% (90% Confidence)	Temperature (°C)
	kW	%		
2018-06-01	0.22	11%	37%	24
2018-06-18	0.21	11%	38%	25
2018-06-29	0.20	9%	49%	28
2018-07-03	0.19	9%	63%	30
2018-07-04	0.19	7%	70%	31
2018-07-05	0.21	12%	38%	25
2018-07-16	0.22	12%	38%	25
2018-07-17	0.23	13%	40%	22
2018-07-24	0.22	12%	38%	25
2018-08-07	0.21	11%	39%	26
2018-08-15	0.21	11%	42%	27
2018-08-16	0.23	15%	38%	23
2018-08-17	0.22	14%	37%	24
2018-08-20	0.22	14%	37%	25
2018-08-27	0.20	10%	52%	29
2018-09-05	0.19	8%	55%	29
2018-09-06	0.24	16%	44%	21
2018-09-17	0.22	13%	37%	24
Average Across Events	0.21	11%	39%	26

These results are also reflected in the plotted actuals and baselines for the group of participants not connected, see for example Figure 30, below. Although there is a significant impact across the On-Peak and Mid-Peak hours (in anticipation that an event *might* be called), there is clearly some kind of CPP-event specific response, distinguished by the characteristic sharp drop in demand during the event.

Figure 30: Average CPP Event Day Load Profile – Events Beginning at 5pm, Disconnected Participants



Although an unexpected result, Navigant is confident in the robustness of the finding: there is some group of participants that is, without the benefit of the enabling technology, receiving the event notification, and, within fifteen minutes, sufficiently reducing demand to deliver the distinctive DR-shaped load profile. Gaining a better understanding of how these impacts are distributed across participants (many participants with small impacts, or a few with very large ones?) as well as what strategies are being used to deliver the demand response could be a valuable goal of further research into this group. Some intuition regarding the latter question may be assessed by examining the estimated regression parameters that deliver the impacts.

The estimated parameters associated with the DR only impacts are presented in Figure 31, below. The first row presents the parameters that deliver the estimated impacts achieved by all participants, with or without a connection. The second row presents the parameters that deliver the incremental estimated impact due to that participant being connected.

Two types (columns) of parameter are estimated for each effect type (connected versus disconnected) : an intercept parameter (which captures the impact when no cooling degree hours are observed during the event period), and a slope parameter (which captures the estimated incremental effect of each additional cooling degree hour observed on impacts). The table presents both parameter estimates (where a negative value denotes a demand *reduction*) and p-values. Recall that the p-values are a measure of uncertainty. An estimate with a p-value of more than 0.1 is not statistically significant at the 90% level of confidence.

Figure 31: DR Impact Parameters and P-Values

Type of Impact	Intercept Dummy		Slope (Temperature) Dummy	
	Estimate	P-Value	Estimate	P-Value
Without Connection	-0.25	0.00	0.01	0.60
Incremental Impact when Connected	-0.03	0.73	-0.06	0.00

These values seem to suggest that the “base impact” delivered by a participant, before considering the incremental effects of the enabling technology that depends on a connection is not only not very weather sensitive (the effect has a p-value of 0.6, making it statistically non-significant), but what temperature sensitivity there is moves in the opposite from expected direction – that is, as temperatures increase, the base “DR only” impacts fall.

The opposite appears to be the case for the incremental impacts delivered when a participant is connected. In that case, nearly the entirety of the incremental effect is a function of the weather.

These results suggest two things:

- Most automated, DR only response is achieved via A/C curtailment of some kind.
- Purely behavioural DR only response may driven primarily by non-A/C end-uses.

Note that some caution should be used in interpreting these values. Although these capture the DR only effects of the program, the other variables included to capture the longer-term effects (hourly dummies interacted with a treatment/participant dummy, and the same variable interacted with cooling degree hours) are likely to be correlated with the DR only parameters. Projecting impacts out of sample should be done cautiously, given the possibility that some estimated parameters may be spurious as a result of multi-collinearity.³³

4.2.3 Summer Capability Estimates (Ex-Ante)

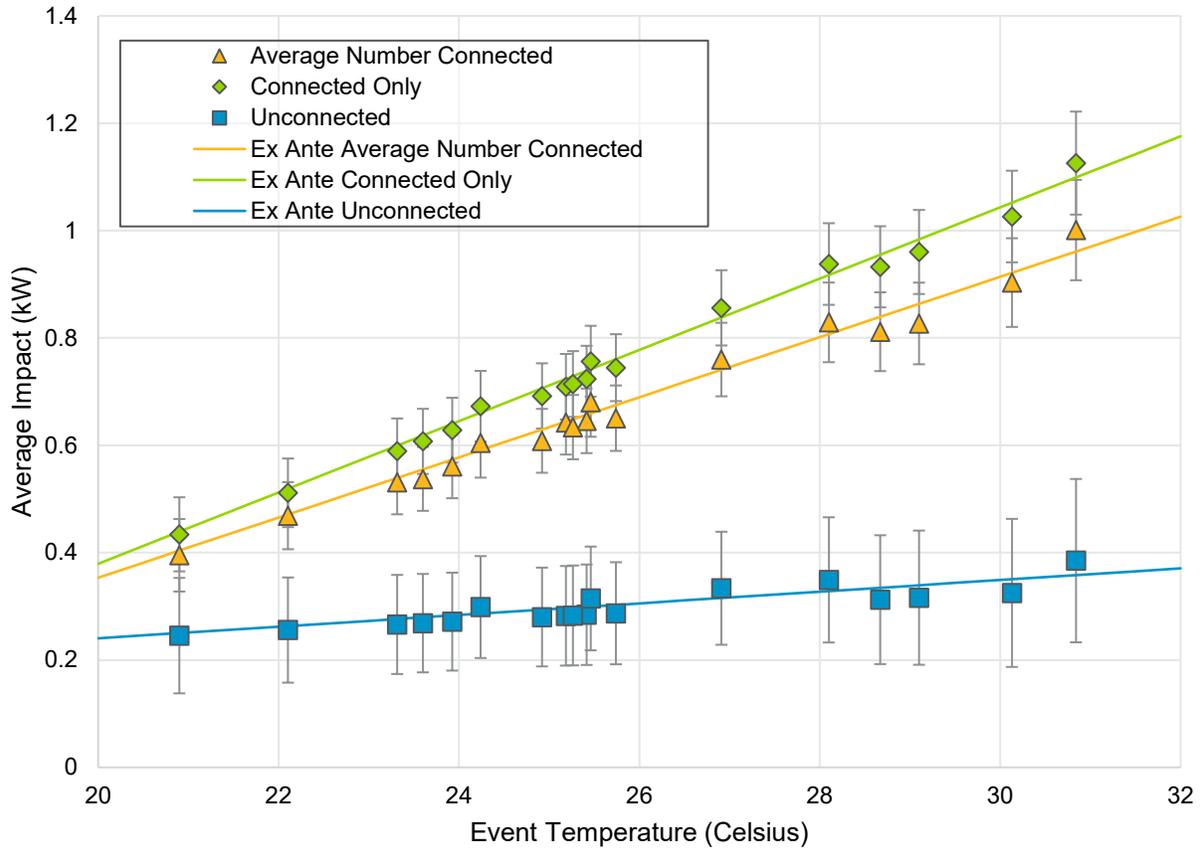
A standard output for most evaluations of programs with a DR component is a set of “ex-ante” estimates. An ex-ante impact estimate is the estimated impact of a program under certain pre-specified conditions. Typically, these are weather-related – for example presenting a program’s estimated DR capability under a utility’s 1-in-2, 1-in-10 (as in California), or “design criterion” (as in Florida) weather. Also common – when no design criterion weather values have been established – is to present ex-ante impacts across a range of different temperatures. Figure 32 illustrates the estimated relationship between the average demand response capability of the program under a range of outdoor temperatures: the ex-ante DR impacts of the pilot – a key output of this study.

Navigant has estimated the total program impact of a CPP event at a range of temperatures from 20 degrees to 32 degrees Celsius. Three sets of ex-ante impacts have been produced: one set assuming all participants are connected, one set assuming the average connectivity rate observed in the summer of 2018, and a third set, assuming all participants are disconnected. These ex-ante values are represented in Figure 32 below as a set of solid lines.

³³ As above, the total effect across all the parameters is robust, it is only when considering the DR only “sub-effect” that more caution should be exercised.

The ex-ante impacts are presented alongside the individual event ex-post impacts, which are represented by the markers in Figure 32. The whiskers around each marker represent the 90% confidence interval associated with that estimated impact. The solid lines represent the series of estimated ex-ante impacts, or program capability under a range of different temperatures. Note that the impacts presented here are the total program impacts, not the DR-only impacts.

Figure 32: Ex-Ante and Ex-Post Impact Scatter Plot



4.3 Elasticity Findings

Based on the results above, Navigant estimated both an own-price elasticity of daily electricity consumption and an inter-period elasticity of substitution between the Mid-Peak period and the Off-Peak Period.

The point estimate of the own-price elasticity of demand, derived from the parameters estimated as part of the regression described above is -3.97. This is an unusually large value. Demand for electricity is typically regarded as quite inelastic in the short-run, whereas the estimated value suggests that it is in fact highly elastic.

This result is driven by the fact that the average daily cost of electricity for CPP and CPP/RT participants increased by 0.3%, and average daily consumption fell by 1.2%.

Navigant would recommend that this estimated value be used only very cautiously, for a number of reasons. Firstly, the average change in price is *very* small, as is the average change in consumption. It should be remembered that rates were set to be revenue neutral under the assumption of no behaviour change, so any average change in daily electricity costs (as calculated for this evaluation) is reflective principally of structural differences between this sample and that used to set the prices.

Secondly, this value may well capture a major disconnect between *perceived* electricity costs, and actual costs. Even though the rate is intended to be revenue neutral when participants make no changes to behaviour, the relatively large value of the CPP price, the sudden nature of events (with only 15 minutes' warning), may have led participants to perceive not responding to the rate to be much more costly than actual non-response would have been.

The estimated inter-period elasticity of substitution is -0.26. The negative sign indicates that the two “goods” – Mid-Peak and Off-Peak consumption – are gross substitutes. The complete calculation of this value may be found in Appendix B.

4.4 Revenue Adequacy

An evaluation requirement of the OEB for the evaluation of this pilot is the publication of a table indicating the revenue adequacy of this program. This table, Figure 33, provides a comparison of aggregate consumption volumes and revenues associated with the participants included in the energy analysis. All revenues shown below include only the commodity cost (i.e., the TOU rate) and do not reflect delivery charges, taxes, etc.

Figure 33: Revenue Adequacy

Participant Group	Consumption Volumes in kWh	Revenues (Pilot Price Plan)	Revenues (Status-Quo TOU)	Average Revenue (Pilot Price Plan)	Average Revenue (Status-Quo TOU)
CPP	1,296,978	\$103,830	\$104,729	\$0.08	\$0.08
CPP/RT	1,384,227	\$110,515	\$111,653	\$0.08	\$0.08
RT	5,326,843	N/A	\$432,959	N/A	\$0.08
Control	2,148,459	N/A	\$175,666	N/A	\$0.08

These values are drawn from London Hydro’s billing system. These values were calculated using participant and control customer bills with a billing cycle start date no earlier than 2018-04-15, and a billing cycle end date no later than 2018-11-15.³⁴ This includes only those participants included in the analysis (i.e., participants that exited the program prior to completion have been excluded).

What Figure 33 shows is that the difference between actual commodity revenues collected by London Hydro and the revenue that would have been collected under standard TOU rates - had the same

³⁴ Billing cycles do not match calendar months exactly, so some imprecision exists in attributing consumption to the defined summer program period.

program effects been observed under those rates - is very small on a relative basis. The average difference between the two sets of revenue is less than 1% in absolute value.

Navigant has calculated the differential between CPP and CPP/RT customers' commodity costs, and what they would have paid had these bills been calculated using standard TOU commodity rates. The frequency distribution of these differences is shown in Figure 34 (CPP-only) and Figure 35 (CPP/RT) below.

Note that these are *not* bill impacts. A participant's bill impact is the difference between what the participant actually paid, and what that participant would have paid under standard TOU rates *had their consumption not changed in response to the program*.

Figure 34: Distribution of CPP-Only Participant Cost Differentials

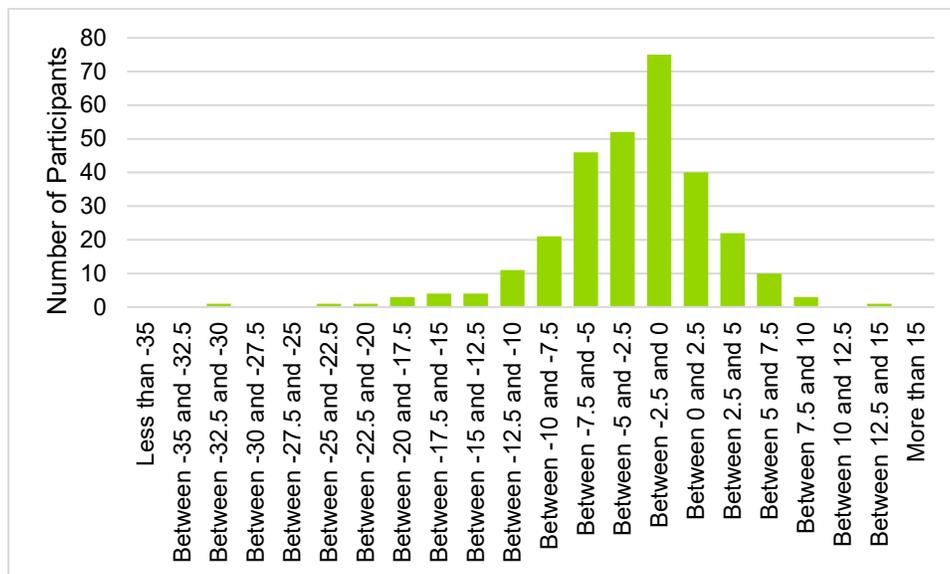
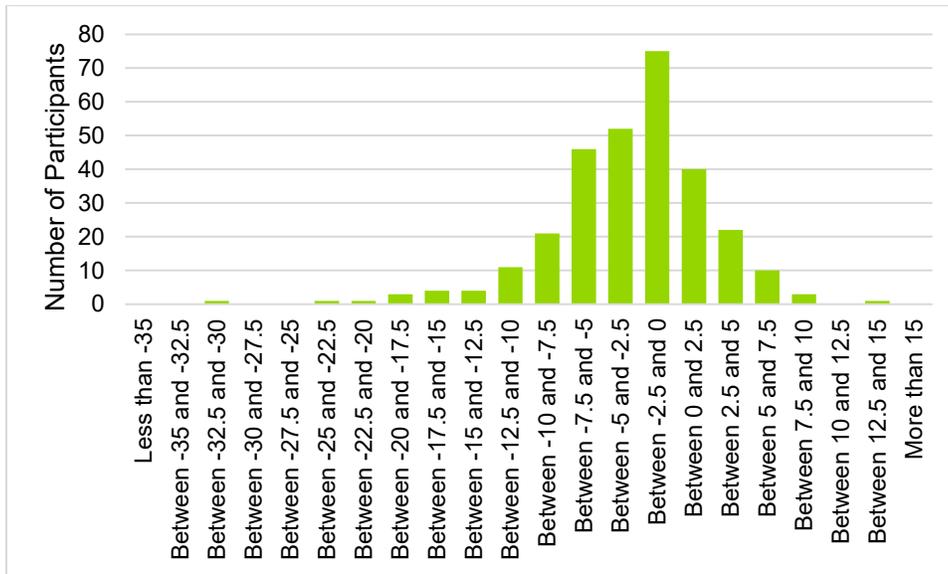


Figure 35: Distribution of CPP/RT Participant Cost Differentials



5. KEY FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This final chapter of the report is divided into three sections.

- **Key Findings.** This section provides some of the most important quantitative outputs of the two main analyses undertaken.
- **Conclusions.** This section contextualizes the quantitative findings and interprets the implications of those findings.
- **Recommendations.** This section provides a set of concrete recommendations for next steps, as the OEB continues to deploy its RPP Roadmap.

5.1 Key Findings

There are two sets of key findings for this interim report: those associated with the energy savings impact analysis, and those associated with the CPP event demand reduction analysis.

5.1.1 Energy Impact Key Findings

Navigant's key findings from the energy impact analysis include:

- **CPP participants delivered On-Peak and Mid-Peak energy savings with a reasonably high degree of certainty.** CPP and CPP/RT participants reduced their daily:
 - On-Peak consumption by approximately 5% on average
 - Mid-Peak consumption by approximately 3% on average
- **RT-Only participants delivered modest On-Peak energy savings, although these results are less certain.** RT participants reduced their On-Peak consumption by just over 2%, although these results are less certain than those of the CPP group.
- **CPP participants also equipped with the RT technology are saving the same as CPP-only participants.** Navigant found no statistically significant difference between the energy savings achieved by CPP and CPP/RT participants. This suggests that savings are being driven by a combination of the price-effect (attempting to reduce risk by limiting consumption during periods more likely to observe a critical peak price) and the educational component provided by London Hydro.
- **Energy savings appear to be driven by a variety of end-uses.** Based on the regression-estimated parameters, approximately a third (On-Peak) and 40% (Mid-Peak) of CPP participant savings are insensitive to temperature, with the balance of savings being temperature driven. This suggests that participants did not rely solely on reducing A/C use (typically the largest single discretionary load in a home) to achieve savings. For RT participants approximately 60% of savings appear to be temperature-insensitive.

5.1.2 CPP Event Demand Impact Key Findings

Navigant's key findings from the demand impact analysis include:

- **CPP event demand reductions were substantial.** On average, CPP participants delivered 0.67 kW of demand reductions (approximately a third of baseline demand) during CPP events and delivered 1 kW of reductions per participant during the hottest event, on July 4th.
- **There is a behavioural element to CPP event impacts.** CPP participants are equipped with enabling technologies (a switch at the panel, and a smart plug) that respond automatically to London Hydro's price signal. Even though participants receive only 15 minutes' notification of an event, there are clear behavioural elements to their response over and above the automated response delivered by the switches and smart plugs.
 - *Participants reduced consumption during hours in which CPP events were likely to occur.* CPP participants reduce their exposure to the CPP rate by making changes to their consumption habits in anticipation of CPP events – substantial savings are achieved in hours of the CPP event day leading up to the CPP event, despite participants not having any knowledge of when the event will occur until 15 minutes before it does.
 - *Disconnected participants still delivered demand response.* For any given event, approximately 20% of participants' devices could not receive, or respond to, London Hydro's curtailment signal. These participants were still able to, on average, with only 15 minutes' notice, to reduce demand by 0.2 kW each without the program-deployed enabling technologies.³⁵

Some additional context may be helpful in understanding how remarkable this is: an evaluation of San Diego Gas and Electric's voluntary CPP rate³⁶ (notification provided no later than 3pm on the day *prior* to the event) found the average response (at an average temperature of 99 degrees Fahrenheit, or approximately 37 degrees Celsius) was only 0.14 kW.

- **Demand reductions appear to be largely, but not overwhelmingly, driven by changes in space-cooling.** An examination of the estimated relationships between impacts and temperature is strongly suggestive of the fact that approximately a third of the average CPP event impact (approximately 0.2 to 0.3 kW) is driven by an end-use, or end-uses, other than space-cooling.
- **Real-time information on consumption did not affect demand reductions.** The impacts of the CPP and CPP/RT group were not statistically significantly different from one another – the availability of the online portal and energy tracking app did not impact participants' ability to deliver demand reductions

5.2 Conclusions

Navigant has drawn three main conclusions from this interim evaluation of the London Hydro RPP Pilot:

- **The available evidence suggests that education and customer engagement are key factors in enabling participant response.** Education and engagement are key elements of *all* programs and pilots that seek to motivate a behavioural response from participants. The question may be

³⁵ Participants' whose enabling technologies were not connected to London Hydro's dispatch system continued to receive event notification via the Trickl app.

³⁶ Christensen Associates Energy Consulting, *2016 Load Impact Evaluation of San Diego Gas and Electric's Voluntary Residential Critical Peak Pricing (CPP) and Time-of-Use (TOU) Rates*, CALMAC Study ID SDGE0304, April 2017

http://www.calmac.org/publications/PY16_TOU_and_CPP_Ex_Post_and_Ex_Ante_Report.pdf

asked, why does Navigant single this as a key factor rather than attributing impacts *only* to the pricing and informational/technological treatment? This hypothesis is driven by two findings:

- *The RT treatment motivates no incremental energy or demand impact from CPP/RT participants, but delivers energy savings for RT-only participants.* For both energy impacts and CPP event demand impacts, Navigant found that the combined CPP/RT treatment did not deliver any incremental statistically significant impacts, indicating that the RT treatment provided no additional benefit to participants already subject to CPP.

Yet, the RT-only treatment *did* deliver material energy savings. These two findings seem at odds – if the RT treatment on its own delivers savings, and the CPP treatment on its own delivers savings, why would the two treatments combined not deliver more savings than one of the treatments alone?

Navigant believes that the most likely explanation is that in fact the RT technology –the app – isn't what's responsible for the energy savings.³⁷ Rather, these offerings are the shiny object that entices customers to participate in the program, and savings are delivered through the concerted effort of the utility to educate participants in effective, practical strategies that deliver modest energy savings.

- *The price-only treatment (CPP) motivates a change in behaviour even when there is no direct price signal to do so.* The majority of the energy savings achieved by the CPP-only group were achieved in non-event periods.³⁸

Certainly, this behaviour may be explained through the lens of expected value – participants assessing when peak prices will occur and making behavioural adjustments on this basis. The problem with this hypothesis is that it cannot explain why impacts were greatest in the On-Peak period, and yet, *by design*, the CPP price can only occur in the final hour of that period (from 4pm to 5pm).

A rational economic actor responding purely to price might adjust their behaviour in the window from 4pm to 5pm, but otherwise has no motivation to adjust their behaviour in the On-Peak period.

It is on the basis of these two observations regarding the estimated impacts that Navigant infers that the customer engagement strategy used by London Hydro to support the deployment of the pilot design was a critical factor in empowering customer decision-making, and ultimately delivering the final reported results.

- **Critical peak pricing can be a tool for energy conservation as well as demand reduction.** CPP participants are provided with 15 minutes' notice when a CPP event occurs. This limits the scope of what actions participants can take in the short term when they receive event notification.

³⁷ Evaluations of real-time information pilots often yield savings estimates that are very low, or are statistically insignificant, suggesting that simply providing customers with data is insufficient for motivating real savings. Participants require an intermediary, such as the utility or some third-party home energy report provider to translate those data into *information*.

For a summary of real-time information studies and the associated impacts, see for example Table 13 on PDF page 41/95 of:

Navigant, prepared for Newfoundland Labrador Hydro, *Real Time Monitor Pilot Program: Impact and Process Evaluation*, March 2016

https://www.exec.gov.nl.ca/exec/occ/publications/RTM_Complete_Rpt_F_Mar31_2016.pdf

³⁸ CPP events only account for 18 hours off the summer.

In response to this challenge, it appears that participants have worked to limit their exposure to the critical peak rate by reducing consumption in hours in which events are likely to occur.

Participants have been educated to understand that CPP events are driven by system needs, and that system needs are driven (in the summer) by weather. And so, daily energy impacts (even when no event takes place) are correlated with temperature. Participants undertake actions that reduce their risk exposure even as the risk of a CPP event climbs (i.e., temperature increases). Put another way, participants are provided with a qualitative understanding of the factors that drive the prices they will face and develop rules of thumb for responding to those prices.³⁹

- Participants can be remarkably nimble in responding to very short-term changes in price.** Navigant did not expect to find that disconnected participants delivered *any* demand response. It was Navigant’s hypothesis that the very short notification period would mean that “DR only” response (as opposed to the more general response in anticipation of a potential event) would be limited to those participants whose enabling technologies were connected to London Hydro’s systems and able to respond automatically to London Hydro’s curtailment signal.

The findings of this analysis require a rejection of this initial hypothesis. On average, it appears that disconnected participants were able to contribute approximately 0.2 kW of “pure” demand response during the CPP events. That is, on average, participants were able, with 15 minutes or less notice, to reduce demand on average by 0.2 kW without the program-deployed enabling technologies.

5.3 Recommendations

Navigant has three key recommendations for the Ontario Energy Board’s ongoing development of the RPP Roadmap:

Recommendation 1: *Undertake a secondary impact analysis, tying participant engagement data back to consumption data.* Navigant has concluded that customer education and engagement were key elements to the impacts estimated. Aspects of this hypothesis can be tested, and refined, through the inclusion in the regression equation of additional data. For example: using attendance records from London Hydro hosted informational breakfasts, the effect of attending those sessions on impacts could be tested. Such additional testing may reveal, depending on what data are available, what components of London Hydro’s customer engagement strategy were most effective in motivating the estimated energy impacts.

Recommendation 2: *Better understand the behavioural demand response strategies undertaken by participants.* One of the most surprising findings of this evaluation was the magnitude of “DR only” CPP event demand response that appears to be behavioural. Navigant would recommend that additional analysis be undertaken to a) better understand which individuals were contributing (i.e.,

³⁹ It has previously been noted that when participants are provided with prices that change too frequently to allow a true “real-time” response (e.g., real-time pricing), they develop a set of rules for behaviour changes that reflect their average expectations of price changes. See for example:

Navigant, submitted to Ameren Illinois Utilities, *Power Smart Pricing 2009 Annual Report*, April 2010

<https://www2.illinois.gov/sites/ipa/Documents/CUB-Comments-Appendix-D-2009-Navigant-Power-Smart-Pricing-Annual-Report.pdf>

was it small impacts from many participants, or large impacts from a few), b) understand what strategies those participants deployed to achieve what they did, and c) try to quantify the degree to which those behaviours could be motivated in the wider Ontario population of potential CPP rate participants.

APPENDIX A. APPROACH – ADDITIONAL DETAIL

This appendix provides additional technical details regarding Navigant’s approach to estimating the impacts reported in this analysis.

This Appendix is divided into four sections:

- **Data.** This section provides some additional detail regarding participant data included in the analysis.
- **Energy Analysis Model Specification.** This section provides the model specification and variable definitions for the regression model used to estimate average energy impacts.
- **CPP Event Day Demand Model Specification.** This section provides the model specification and variable definitions for the regression model used to estimate average energy impacts.
- **Pre-Period Consumption Variable Creation.** This section provides additional detail regarding how the pre-period consumption variable was developed.

A.1 Data

Section 3.1.1 in the main body of the report provides an overview of the number of individual participants (and RCT controls) for whom London Hydro was able to provide hourly consumption data. This section of this appendix specifies the starting sample size, the final sample size used for estimation, and the number of sample participants dropped between those two sets.

Energy Analysis

Figure 36, below shows the count of individuals included in the analysis. The first numeric column provides the count of individuals included in both the interval data (hourly consumption) and the cross-sectional data (e.g., enrollment and installation date, etc.), and the right-most column provides the count of individuals included in the data set from which the regression specification was estimated.

The middle numeric column provides a count of the number of individuals shed from the sample due to their having no pre-period summer interval data.

Figure 36: Energy Analysis Sample

Group	In Cross-Sectional and Interval Data	Dropped Due to Lack of Pre-Period kWh	Used In Analysis
CPP	318	10	308
CPP/RT	339	5	334
RT	1,133	4	1,129
RCT Control	469	15	454

Figure 37, below, below shows the count of individuals included in the analysis. The first numeric column provides the count of individuals included in both the interval data (hourly consumption) and the cross-sectional data, and the right-most column provides the count of individuals included in the data set from which the regression specification was estimated.

The third column from the left flags the number of individuals that were dropped from the sample because no connectivity data were available for these individuals.⁴⁰ No customers were dropped from the data set due to disconnections, but only where data were not available (i.e., when it was impossible for Navigant to determine whether they were connected or not for a given event). The second column from the right provides a count of the number of individuals shed from the sample due to their having no pre-period summer interval data. Note that this number is larger than the number of individuals shed from the energy analysis in Figure 36, above. This is because the CPP analysis was limited to days with the day-type “F_1”, “F_2”, “F_3”, “E_1”, “E_2”, and “E_3” (for definitions of these day-types please see section A.4, below), whereas the energy analysis includes all day-types.

Figure 37: CPP Event Demand Sample

Group	In Cross-Sectional and Interval Data	Dropped Due to Lack of Connectivity Data	Dropped Due to Lack of Pre-Period kWh	Used In Analysis
CPP	318	18	18	282
CPP/RT	339	21	10	308
RCT Control	469	0	23	446

A.2 Energy Analysis Model Specification

Equation 1, below, presents the model specification used to estimate the participant energy impacts presented above, in the body of this report.

Equation 1: Energy Analysis Model Specification

$$\begin{aligned}
 y_{i,t,p} = & \sum_{p=1}^{P=4} \sum_{d=1}^{D=15} \beta_{p,d,1} \cdot tou_{t,p} \cdot daytype_{i,d} \cdot prekWh_{i,p,d} + \sum_{p=1}^{P=4} \beta_{p,2} \cdot tou_{t,p} \cdot cdh_{t,p} + \\
 & + \sum_{p=1}^{P=4} \beta_{p,3} \cdot tou_{t,p} \cdot hdh_{t,p} + \sum_{p=1}^{P=4} \beta_{p,4} \cdot tou_{t,p} \cdot hbu_{t,p} + \sum_{p=1}^{P=4} \beta_{p,5} \cdot tou_{t,p} \cdot cbu_{t,p} + \\
 & + \sum_{p=1}^{P=4} \gamma_{p,1} \cdot tou_{t,p} \cdot treat_i + \sum_{p=1}^{P=4} \gamma_{p,2} \cdot tou_{t,p} \cdot cdh_{t,p} \cdot treat_i + \varepsilon_{i,t,d}
 \end{aligned}$$

Where:

$y_{i,t,p}$ = Customer i 's energy consumption (kWh) in TOU period p (On-Peak, Mid-Peak, Off-Peak Weekdays, Off-Peak Weekends/Holidays) of day of sample t .

$tou_{t,p}$ = A set of four dummy variables. Each one is equal to one when the consumption value on the LHS of the equation is in the same TOU

⁴⁰ In all but two cases, the participants with missing connectivity data are those participants that have exited the program prematurely.

period as that flagged by the dummy. For example: when $y_{i,t,p=1}$ then, $tu_{i,1} = 1$, $tu_{i,2} = 0$, $tu_{i,3} = 0$, and $tu_{i,4} = 0$.

$daytype_{i,d}$	=	A set of 15 dummy variables. Each is equal to one when the day of sample t is day-type d . See section A.4, below for more details regarding day-types.
$prekWh_{i,p,d}$	=	The sum of pre-period consumption in TOU period p , of day-type d for customer i . This is the given customer's average TOU period consumption for the given day-type in the pre-program period (summer of 2017).
$cdh_{t,p}$	=	The sum of the cooling degree hours (base of 18 degrees Celsius) observed in TOU period p of day of sample t .
$hdh_{t,p}$	=	The sum of the heating degree hours (base of 18 degrees Celsius) observed in TOU period p of day of sample t .
$hbu_{t,p}$	=	The average heat build-up observed in the hours that fall within TOU period p , on day of sample t . This is a 72-hour geometrically decaying average of cooling degree hours, as observed in hour of sample s . It is calculated in the following manner:
$cbu_t = \frac{\sum_{h=1}^{72} 0.96^h \cdot cdh_{s-h}}{1,000}$		
$cbu_{t,p}$	=	The average cold build-up observed in the hours that fall within TOU period p , on day of sample t . This is calculated in the same way as, $hbu_{t,p}$, except that cooling degree hours are replaced by heating degree hours.
$treat_i$	=	A dummy variable that takes a value of 1 if customer i is a participant, and zero otherwise.
$\varepsilon_{i,t,d}$	=	Errors.

This model is estimated once for three different samples:

- RT-only participants and RCT controls
- CPP and CPP/RT participants and RCT controls, including all summer days.
- CPP and CPP/RT participants and RCT controls, *excluding* CPP event days.

A.3 CPP Event Day Demand Model Specification

Equation 2 below, presents the model specification used to estimate the participant CPP event demand impacts presented above, in the body of this report. Important note: Equation 1 use the subscript “*t*” to denote the day of sample. Equation 2, below, uses the “*t*” subscript to denote the *hour* of the sample.

Equation 2: CPP Event Demand Model Specification

$$\begin{aligned}
 y_{i,t} = & \sum_{h=1}^{H=24} \beta_{h,1} \cdot he_{h,t} + \sum_{h=1}^{H=24} \beta_{h,2} \cdot he_{h,t} \cdot cdh_t + \sum_{h=1}^{H=24} \beta_{h,3} \cdot he_{h,t} \cdot hdh_t + \\
 & \sum_{h=1}^{H=24} \beta_{h,4} \cdot he_{h,t} \cdot hbu_t + \sum_{h=1}^{H=24} \beta_{h,5} \cdot he_{h,t} \cdot EMACdh_t + \sum_{h=1}^{H=24} \beta_{h,6} \cdot he_{h,t} \cdot prekWh_{i,d,h} + \\
 & \sum_{h=1}^{H=24} \rho_{h,1} \cdot he_{h,t} \cdot treat_i + \sum_{h=1}^{H=24} \rho_{h,2} \cdot he_{h,t} \cdot treat_i \cdot cdh_t + \\
 & \gamma_1 \cdot treat_i \cdot event_t + \gamma_2 \cdot treat_i \cdot event_t \cdot cdh_t + \\
 & \gamma_3 \cdot treat_i \cdot event_t \cdot connected_{i,t} + \gamma_4 \cdot treat_i \cdot event_t \cdot cdh_t \cdot connected_{i,t} + \\
 & \sum_{s=1}^{S=4} \delta_{s,1} \cdot s_{i,t,s} \cdot eventcdh_t + \sum_{s=1}^{S=4} \delta_{s,1} \cdot s_{i,t,s} \cdot eventcdh_t \cdot connected_{i,t} + \varepsilon_{i,t}
 \end{aligned}$$

Where:

- $y_{i,t}$ = Customer *i*'s demand (kW)⁴¹ in hour of sample *t*.
- $he_{h,t}$ = A set of 24 dummies, one for each hour of the day, equal to 1 when hour of sample *t* falls in hour of day *h*, and zero otherwise.
- cdh_t = The number of cooling degree hours observed in hour of sample *t*, with a base of 18 degrees Celsius.
- hdh_t = The number of heating degree hours observed in hour of sample *t*, with a base of 18 degrees Celsius.
- hbu_t = The average heat build-up hour of sample *t*. This is a 72-hour geometrically decaying average of cooling degree hours. It is calculated in the following manner:

$$cbu_t = \frac{\sum_{h=1}^{72} 0.96^h \cdot cdh_{t-h}}{1,000} \cdot$$
- $EMACdh_t$ = The five-hour exponential moving average of cooling degree hours observed in hour of sample *t*.

⁴¹ Interval data in fact show consumption, but since the goal of this is to estimate demand impacts, and hourly consumption and average hourly demand are equivalent values, it is shown as demand here.

$prekWh_{i,d,h}$	=	Customer i 's average demand during hour of day h , in day-type d of the pre-program (i.e., summer 2017) period. The day-type is that of the day on which hour of sample t falls. See A.4 for more details.
$treat_i$	=	A dummy variable equal to one if customer i is a participant, and zero otherwise.
$event_t$	=	A dummy variable equal to one if hour of sample t is a CPP event, and zero otherwise.
$connected_{i,t}$	=	A dummy variable equal to one if participant i is connected to London Hydro's automatic curtailment system on the event day on which hour of sample t falls, and zero otherwise.
$S_{i,t,s}$	=	A set of four dummy variables to capture the effects (if any) of snapback. Each variable is equal to 1 when hour of sample t is the s -th hour observed since the end of the event observed on the day on which hour of sample t occurs. For example, if the event occurs between 5pm and 6pm, at 7pm these four variables will take the following values: $S_{i,t,s=1} = 1, S_{i,t,s=2} = 0, S_{i,t,s=3} = 0, \text{ and } S_{i,t,s=4} = 0.$

This model is estimated once. The estimated values of the ρ parameters capture the “energy impact” of the treatment, whereas the γ parameters capture the “DR only” impact. That is, this second set of parameters capture the difference between what average demand during the event would have been had there been no event *but the program was still in place*, and what average demand actually was. The “total” program impact is the “sum product” of both sets of parameters and the appropriate variable values.

A.4 Pre-Period Consumption Variable Creation

As noted in several instances in both the body of the report and in the earlier sections of this Appendix, Navigant includes on the right-hand side of the regression equation a variable capturing an average of each participant’s pre-program consumption. In the summer this variable is a 720-element⁴² vector of average pre-period consumption values.

The 720 elements is the product of 30 day-types, and 24 hours in each day. Day-types are defined by three components:

- Month of year
- Day of week
- Average daily temperature

Figure 38, below, shows how day-types are assigned. So, for example:

⁴² Altogether this vector has 720 elements for a whole year, but only 360 for the summer, and 360 for the winter.

- Day-type F_1 would be assigned to all non-holiday weekdays in July or August with an average drybulb temperature exceeding 23 degrees.
- Day-type D_5 would be assigned to all weekends and holidays in May and October
- Etc.

Figure 38: Day-Type Definitions

		Day Type				Weekends/ Holidays
		Weekdays				
		1	2	3	4	5
Winter	Period A: Jan & Feb	<= -11	-7 to -11	-3 to -7	> -3	All Days
	Period B: Mar & Dec	<= -10	-6 to -10	1 to -6	> 1	
	Period C: Apr & Nov	<= 1	2 to 1	6 to 2	> 6	
Summer	Period D: May & Oct	>= 18	15 to 18	11 to 15	< 11	All Days
	Period E: Jun & Sept	>= 23	21 to 23	16 to 21	< 16	
	Period F: Jul & Aug	>= 23	21 to 23	20 to 21	< 20	

The thresholds are selected with reference to the pre-program period observed temperatures. Specifically, thresholds are selected such that, in the pre-program period, approximately:

- 10% of non-holiday weekdays are type 1 (most extreme temperatures)
- 20% of non-holiday weekdays are type 2
- 30% of non-holiday weekdays are type 3
- 40% of non-holiday weekdays are type 4 (mildest seasonal days)

Once day-types are assigned to each day, each customer’s 720 element (360 in the summer, 360 in the winter) vector of pre-program period consumption is calculated by averaging their consumption, grouped by hour of day and day-type.

These are then associated with the appropriate program period observation by defining the program period day-types based on the criteria in Figure 38, above, and joining the pre-period values based on that and the hour of day.

A.5 Participant Incentives and the Question of Bias

Following its review of Navigant’s interim impact evaluation of the LH RPP pilot, the OEB requested that Navigant respond to the following:

Please provide a discussion of the \$25/\$75 incentive and any impact offering that incentive might have by introducing or inflating customer bias.

In the context of pilot program evaluation “bias” can take on different meanings, but the two most common definitions used are that of “omitted variable bias”, and “sample bias”.

Omitted Variable Bias

The question here is this: *is there some systematic way in which the treatment and control groups are different from one another that has not been controlled for* (typically either through the selection of the control group or the inclusion of a variable on the right-hand-side of the regression)?

Failing to control for some systematic difference between the two groups that is correlated with the treatment effect would lead to the (erroneous) attribution of that systematic difference to the treatment effect, biasing results.

Since the offer of the incentive is made to all program applicants (treatment and controls), there is no consistent difference here between the two groups, and therefore it is possible to rule out that the offer of the incentive has biased estimated impacts. This is one of the great benefits of a randomized control trial.

Sample Bias

Sample bias identifies an instance in which a sample collected for a study is not representative of a broader population to which sample impacts are to be extrapolated.

By making the pilot opt-in (as opposed to mandatory), it is biased by construction. Since only a sample of the population will volunteer to participate, participant self-selection means that it is probable that unobservable characteristics (characteristics, like enthusiasm for energy conservation, that may be correlated with electricity consumption) of the sample would not match those of the overall residential electricity consumer population.

The LH RPP pilot impacts cannot be considered representative of what could be achieved by *imposing* the pilot treatments on the entire population but can be considered representative of what could be achieved by *offering* the same pilot treatments to the overall population, with the same incentives. In other words, the question of sample bias depends entirely on the context to which one wishes to apply the impacts.

The experience of the pilot provides valuable information, when considering a wider implementation, particularly on the question of incentives. Consumers appear to be relatively risk-averse when it comes to alternative rate structures: prior to offering the incentive, there were concerns that London Hydro would not be able to attain the enrollment required for the participant group, let alone the control group.

In effect, the incentive is a form of first-year bill protection. The incentive protects a customer from some of the down-side risk of the rate but does so in a fashion that interferes only minimally with the price signal on a day-to-day basis. The key process lesson here is that enticing consumers to try something different requires offering them a risk-free trial. This is not an isolated observation,

but one borne out by other programs in the utility rate space, as well as numerous other industries.

Consider, for example, OG&E's SmartHours program. This is a variable peak pricing program with a quite aggressive price differential – a critical peak price more than eight times the Off-Peak price. And yet, despite this, the program maintains an enrollment of approximately 120,000 customers⁴³, or approximately 15% of its *total* customer count.⁴⁴ A key feature of the program is first-year bill protection – a risk-free trial of the alternative rate.

⁴³ OG&E, *SmartHours – End of SmartHours Season*, accessed 2019-04-03

https://www.oge.com/wps/portal/oge/save-energy/smarthours!/ut/p/z1/IZFNC4JAEIZ_SwevzqQm1m1tY_0gsEK0vYSFrYK6opZ_PyEvQfYxp5nheedlZoBDDLxK7rllulxWSTHUR26eLI1uHA-1LbMPJpK9vWSMLXRmGhCNAK7RNTQPvSEIa4v6u6W/to2MA_0vPFG2DxKd0twjo3LV_1ONEEPzVfxLgn8dHwEeL6Qu8Am9W_GbiAReFPD_QaqzbgngTXpNm7RRb83QzrqublcKktj3vSqkFEWqXmSp4DtJJtsO4lcS6jIMwxjzoLyslxmD02c2DA!/dz/d5/L2dBISEvZ0FBIS9nQSEh/

⁴⁴ OG&E has approximately 840,000 customers of all classes. Navigant was not able to determine what proportion of these are residential customers at the time of writing, but per the Q4 2018 company financial statement, residential sales account for only about a third of total sales. This suggests that SmartHours customers could represent nearly a quarter of total residential customers.