Regulated Price Plan Pilot – Dynamic Pricing Final Report

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Alectra Utilities with its partner BEworks

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About Alectra

Alectra's family of energy companies distributes electricity to more than one million homes and businesses in Ontario's Greater Golden Horseshoe area and provides innovative energy solutions to these and thousands more across Ontario. The Alectra family of companies includes Alectra Inc., Alectra Utilities Corporation and Alectra Energy Solutions. Learn more about Alectra at alectrautilities.com.

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About BEworks

Founded in 2010, BEworks is an unconventional management consulting firm that applies scientific thinking to transform the economy and society. BEworks' team of experts in cognitive and social psychology, neuroscience, and marketing answer clients' most complex business questions, execute disruptive growth strategies, and accelerate innovation.

Part of the kyu collective of companies since January 2017, the firm's client list includes Fortune 1000 companies, not-for-profit organizations and government agencies. BEworks was co-founded by Dan Ariely, renowned behavioural scientist, Kelly Peters, the firm's CEO and BE pioneer, and top marketing scholar Nina Mažar.

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Executive Summary

In 2016, the Ontario Energy Board (OEB), through its Regulated Price Plan (RPP) Pilots, sought to examine the impact of alternative pricing schemes and non-price interventions on conservation and demand management behaviours among utility customers. Alectra Utilities (Alectra), and its partners, have tested the impact of three separate Time-of-Use (TOU) pricing schemes (Dynamic, Overnight, and Enhanced) with two non-price interventions ("Nudge Reports", and programmable smart thermostat technology) over a 12-month reporting period (May 01, 2018 to April 30, 2019 inclusive) to achieve the OEB's RPP Pilot objectives. Collectively, the three pricing pilots were communicated and marketed to customers under the name Advantage Power Pricing (APP).

Based on findings from the impact analyses conducted at the 6-month reporting period, the OEB opted to extend the reporting period beyond the originally scoped 12 months for one of the pricing pilots (Dynamic pricing) for an additional five months. This program extension provides behavioural response impacts to Dynamic pricing over a second Summer season and also allows for the assessment of behavioural response to different frequencies of Critical Peak Period (CPP) events. To that end, Dynamic pricing participants were randomly assigned to receive either six or nine CPP events in the 5-month extension period. This report supplements the 12-month report on the impacts of Alectra's RPP Pilot by presenting the final 5-month impacts of Dynamic pricing. This report also represents a comprehensive impact analysis of the entire 17-month reporting period for Dynamic pricing and therefore also includes the 12-month impacts owing to Dynamic pricing that were previously reported in the 12-month report on the impacts of Alectra's broader RPP Pilot.

Dynamic Pricing

Under TOU pricing in Ontario, the calendar year is divided into two 6-month periods referred to as Summer months (May 01 to October 31 inclusive) and Winter months (November 01 to April 30 inclusive). Just as in the 6- and 12-month reporting periods, participants in the Dynamic pricing Treatment received variable On-Peak pricing, depending on anticipated demand forecasts, that differed from Status-Quo On-Peak TOU pricing by having High, Medium, and Low On-Peak Periods (Table 1). During the 6- and 12-month reporting periods, Dynamic pricing participants were also exposed to six CPP events in each of the Summer 2018 and Winter 2018-2019 months. Each of these events lasted for four hours and customers were subjected to an especially high On-Peak kWh price during this time.

The times of day (during weekdays) that are designated as On-Peak and Off-Peak hours vary depending on whether they fall within Summer or Winter months (Table 1). As such, we report impact estimates related to TOU price periods separately for Summer and Winter months throughout this report.

Table 1: Dynamic Pricing kWh Prices

Price Period	Hours	Price (cents/kWh)	
		Nov - April	May - Oct
Off-Peak	Weekdays: 12am-3pm and 9pm-12am Weekends: All day	4.9	4.9
Low On-Peak	50% of Weekdays: 3pm-9pm	10.0	9.9
Medium On-Peak	30% of Weekdays: 3pm-9pm	19.9	19.8
High On-Peak	20% of Weekdays: 3pm-9pm	39.8	39.7
Critical Peak	On the top six or nine system peak days in summer and winter, each event lasting four hours. Start time of events determined by peak demand hour of event day	49.8	49.8

Dynamic Pricing + 6 CPP Days and Dynamic Pricing + 9 CPP Days: In the 5-month extension period (Summer 2019), Dynamic pricing Treatment participants were subdivided and randomly assigned to receive either six or nine CPP events. These participant groups are subsequently referred to in this report as "Dynamic 6" and "Dynamic 9", or "Legacy Dynamic 6" and "Legacy Dynamic 9", respectively (the 'Legacy' groups are described further below). Given the substantial consumption reductions owing to CPP events demonstrated in the 6- and 12-month impact analyses, it is of interest to know whether these types of impacts would be again observed over a second Summer period and/or whether these impacts would be affected by an increase in CPP event frequency.

Legacy Dynamic Customers

There are two distinct customer groups in the Dynamic pricing pilot: (1) customers who enrolled in Dynamic pricing as part of the current RPP Pilot initiative, and (2) Legacy Dynamic customers who were already enrolled in prior instantiations of Dynamic pricing offered by Alectra beginning in 2015. Throughout this report, we analyze these two customer groups as separate pilots, referred to as 'Dynamic' and 'Legacy Dynamic' pricing pilots. There are three important qualitative differences between Dynamic and Legacy Dynamic customer groups that necessitate that they be treated independently for the purposes of this impact analysis:

1. **Duration of Dynamic pricing exposure:** Legacy Dynamic customers have been subjected to the Variable Peak and Critical Peak pricing events that typify Dynamic pricing for a substantially longer time than newly enrolled Dynamic customers

2. **Duration of exposure to price protection:** Legacy Dynamic customers were subjected to price protection for the entirety of the Legacy program, whereas newly enrolled

customers had, at most, a few months of price protection prior to the start of the current RPP Pilot

3. **Differences in analytic approach:** Due to the fact that Legacy Dynamic customers have been taking part in the program for, in some cases, up to 3-4 years at the commencement of the current pilot, there exists no appropriate historical baseline consumption period on which to conduct a difference-in-difference analytical approach

Status-Quo TOU (Control)

Customers assigned to the pricing Control conditions for the Dynamic pricing pilot experienced Status-Quo TOU prices. The Status-Quo TOU rates and associated price periods are shown in Table 2.

Table 2: Status-Quo TOU Pricing kWh Prices

Price Period	Summer Hours (May – October)	Winter Hours (November – April)	Price (cents/kWh)	
			Nov - April	May-Oct
Off-Peak	Weekdays: 12am-7am and 7pm-12am Weekends: All day	Weekdays: 12am-7am and 7pm-12am Weekends: All day	6.5	6.5
Medium-Peak	Weekdays: 7am-11am and 5pm-7pm	Weekdays: 11am-5pm	9.5	9.4
On-Peak	Weekdays: 11am-5pm	Weekdays: 7am-11am and 5pm-7pm	13.2	13.2

Non-Price Interventions

Nudge Reports: Half of the participants in each of the Dynamic pricing Treatment and Control groups, as well as half of the participants in the Legacy Dynamic Treatment group, were randomly assigned to receive a non-price intervention in the form of a Nudge Report. Due to delays in obtaining Legacy Dynamic Control customer data required for data disaggregation and customized feedback, participants in this condition were not distributed Nudge Reports. The Nudge Reports were a monthly report that accompanied the Shadow Bill for pricing Treatment participants (or was sent as a stand-alone report in the case of pricing Control participants). This monthly report is referred to as a 'Nudge Report' because it contains information drawn from the field of behavioural economics intended to nudge conservation behaviours among recipients. Specifically, the Nudge Report communication encouraged recipients to 'pledge' to reduce their On-Peak electricity consumption, displayed personalized tips for achieving this goal, and provided personal benchmarking feedback so that recipients could track their On-Peak consumption behaviour month-to-month.

Smart Thermostat Technology: In addition to measuring the effect of Nudge Reports as a non-price intervention, the impacts of smart thermostat technology in driving conservation and load-shifting behaviours among pilot participants was also investigated. Households were designated as "*Technology*" if they possessed or acquired an eligible smart thermostat (either independently or through incentive programs offered by Alectra Utilities) *and* registered that device with

Alectra during program enrollment to enable automatic load curtailment. Eligible devices included Honeywell, Nest, ecobee, and Energate Foundation. All of these registered devices received some form of automatic load curtailment during Critical Peak events and during Variable On-Peak events in Summer 2018 and Winter 2018-2019 (except for Nest, for which load curtailment was limited to Critical Peak events as part of the 'Rush Hour Rewards' program). Only ecobee and Energate devices retained curtailment functionality in Summer 2019.

Program Results

Sample Sizes

Sample sizes as a function of experimental condition are shown in Table 3 and Table 4 below. Detailed information concerning exclusion criteria is provided in Section 4, with detailed exclusions for each provided in Sections 5.3.1 and 5.4.1.

Table 3: Number of participants in the Dynamic Pricing Pilot

	Summer 2018			Winter 2018-19		Summer 2019		
	Starting N	Total Exclusions	Final N	Total Exclusions	Final N		Total Exclusions	Final N
Dynamic Pricing, No Nudge Report	385	47	338	103	235	Dynamic 6 Pricing, No Nudge Report	13	107
						Dynamic 9 Pricing, No Nudge Report	10	98
Dynamic Pricing + Nudge Report	385	40	345	110	235	Dynamic 6 Pricing + Nudge Report	10	105
						Dynamic 9 Pricing + Nudge Report	9	118
Status-Quo TOU Pricing, No Nudge Report	385	21	364	22	342		16	326
Status-Quo TOU Pricing + Nudge Report	385	23	362	21	341		19	322
Total	1540	131	1409	256	1153		77	1076

Table 4: Number of Participants for Legacy Dynamic Pilot

	Summer 2018	Winter 2018-19

	Starting N	Total Exclusions[1]	Final N	Starting N	Total Exclusions	Final N
Registration Bin 1						
Legacy Dynamic	778	114	664	839	111	728
Status-Quo TOU Control	778	114	664	839	111	728
	Summer 2019					
Legacy Dynamic 6 CPP Days	327	56	271			
Legacy Dynamic 9 CPP Days	336	48	288			
Status-Quo TOU Control	663	104	559			
Registration Bin 2						
Legacy Dynamic	650	147	503	639	141	498
Status-Quo TOU Control	650	147	503	639	141	498
	Summer 2019					
Legacy Dynamic 6 CPP Days	253	49	204			
Legacy Dynamic 9 CPP Days	250	46	204			
Status-Quo TOU Control	503	95	408			

Summary of Analytical Approach

As a result of seasonal variations and year-over-year fluctuations in weather patterns, there was substantially higher overall electricity consumption in the 17-month pilot period relative to the preceding 17 months. For this reason, we employ a difference-in-difference (DID) approach for the estimation of impacts owing to Dynamic pricing (which was the condition comprised of

[1] Total Exclusions: This is simply the sum of Opt-Outs + Move-Outs + Missing Data + Outliers. Full descriptions of each of these exclusion criteria are provided in Section 4. Advantage Power Pricing Impact Analysis Methodology.

participants who enrolled in the pricing pilot in 2018 at the start of the current study; see below for distinction from Legacy Dynamic). The DID compares the year-to-year difference in consumption between Treatment and Control groups. For example, if from the pre-Treatment to the Treatment period, a given Control group consumed 0.05 kWh more electricity, but the corresponding Treatment group consumed only 0.01 kWh more electricity, we can then report that the Treatment lead to a 0.04 kWh reduction in consumption relative to the Control group. We present DID impact analysis results as mean hourly kW differences between Treatment and Control, where negative values indicate less consumption owing to Treatment (price or non-price). We subsequently derive and report percentage change equivalents from the results of the kW impact estimates. In all regression tables, mean hourly kW impact estimates represent the *additional* change in mean hourly kW consumption between periods for participants receiving an experimental Treatment, compared to the change in kW consumption exhibited by participants in the appropriate Control group. We extrapolate percent change in mean hourly kW consumption owing to a pilot Treatment variable by dividing the mean hourly kW impact coefficient by the relevant Treatment group's counterfactual consumption, which we derived by subtracting the impact coefficient from the Treatment group's observed mean hourly consumption in the relevant TOU price period in the pilot Treatment period. Thus, percent impact estimates represent the percentage by which the observed consumption in the Treatment group differs from their counterfactual consumption had they not been Treated. As these values were calculated from the kW impacts, we did not conduct statistical significance testing directly on the percentage values. Statistical significance of impacts is only reported for the mean hourly kW effects from the linear regression models.

There are two instances in which mean hourly kW impact estimates were not derived and statistically analyzed using a difference-in-difference (DID) approach: (1) all Legacy Dynamic pilot impact estimations; and (2) the Technology impact estimations for the Dynamic pilot, pertaining to the incremental impacts owing to curtailment-enabled Smart thermostats. Firstly, Alectra began offering a version of Dynamic pricing to its customers in 2015, and over the course of three separate registration periods, has been continuing to offer Dynamic pricing to a subset of its residential customer base. This means that at the commencement of the current RPP Pilot program, there existed approximately 1,500 households already enrolled in Dynamic pricing. In an attempt to gather data on the longevity of previously estimated consumption impacts owing to Dynamic pricing, Alectra and the OEB sought to retain this 'Legacy' Dynamic customer group as part of the current RPP Pilot. The start dates of this Legacy Dynamic pricing mean that the employment of a DID approach to impact estimation is problematic. Mainly, in order to compare consumption in the current pilot period (May 01, 2018 – October 30, 2019) to a pre-Treatment historical baseline period, a historical data set that is (in many cases) over four years old would have to be used. Despite the fact that this would be a very 'noisy' and arguably inappropriate historical data set with which to employ a DID approach, historical data sets for Legacy Dynamic matched Control customers was not made available to the evaluator during the implementation and evaluation stages of this pilot. This is further complicated by the fact that Legacy Dynamic pricing customers enrolled into Dynamic pricing at three different historical time periods, meaning that different historical baseline periods would have to be used for different groups of customers within the Legacy Dynamic customer group (this is discussed further below). It is for these reasons that we compare Legacy Dynamic pricing with Status-Quo TOU Control pricing in each year on record separately, without using the DID approach.

Caution should be used when making qualitative or quantitative comparisons between Dynamic and Legacy Dynamic impacts. Legacy Dynamic participants have been exposed to the Dynamic pricing structure for (in some cases) up to four years, whereas newly enrolled Dynamic participants have only been exposed to Dynamic pricing for a little over a year and a half. Even with this in mind, any comparisons made between these two groups of customers would not provide an accurate picture of the effect of exposure duration to Dynamic pricing on electricity consumption behaviour. This is because Legacy Dynamic participants enjoyed full price protection for the entirety of the Legacy program (price protection was removed only as part of the 17-month evaluation period that comprises this report). Thus, because of differences in the analytical approach, differential exposure durations to Dynamic pricing, and differences in the length of exposure to price protection, any comparisons between the Legacy and newly enrolled Dynamic customer groups should only be made with these important differences in mind.

Secondly, the smart thermostat "Technology" analysis compares households with registered smart thermostats to those without registered devices *during the 2018-2019 Treatment period only*. Exact timing of smart thermostat installation for each household is unknown, therefore Technology was analyzed comparing kWh consumption of households with and without registered smart thermostat during the Treatment period only, and we did not employ a difference-in-difference approach. All registered smart thermostats received some form of automatic load curtailment during certain peak TOU periods during the unprotected pilot period. Analyzing Technology during the Treatment period only avoids any noise introduced by potential smart thermostat usage during the pre-Treatment pricing period. Put differently, we assume that there are likely consumption reduction benefits conferred by (1) owning and using a smart thermostat, and (2) registering that thermostat for automatic load curtailment. If we were to employ a DID approach to Technology impact estimates, some Technology customers would be compared to a pre-Treatment period in which they used a smart thermostat that was not load-curtailment enabled, some would be compared to a pre-Treatment period in which they did not possess a smart thermostat at all, and still some would be compared to a pre-Treatment period in which they owned a smart thermostat for some, but not all of the pre-Treatment period. We therefore opted to simply compare those with registered smart thermostats to those without registered smart thermostats during the Treatment period only.

Impact of Pricing Structures

The impacts owing to Dynamic pricing, covering Summer 2018 (May to October 2018, inclusive), Winter 2018-19 (November 2018 to April 2019, inclusive), and Summer 2019 extension period (June to October 2019, inclusive) are summarized in Table 5. Here we present only the impact estimates for the highest and lowest priced TOU periods across pilots, however detailed TOU period impact estimates are provided in Section 5. Impact estimates represent mean hourly kW consumption differences from the pre-Treatment baseline period to the Treatment period, compared between Dynamic pricing participants and Status-Quo TOU pricing matched Control participants (i.e., impact estimates derived from the difference-in-difference methodology). Estimated average hourly electricity consumption impacts during High On-Peak hours owing to Dynamic pricing in the Summer periods amounted to -0.260 kW in Summer 2018, and -0.148 kW and -0.121 kW, per hour on average in Summer 2019 for the 6 and 9 CPP event groups respectively. The reduction in the magnitude of the estimated impacts during High

On-Peak hours from Summer 2018 to Summer 2019, likely owes at least in part to the fact that average hourly temperatures during these times of day were about 4 degrees lower in Summer 2019. The Winter 2018-2019 impact owing to Dynamic pricing was estimated to be -0.122kW . In addition, there were no differences in consumption between Dynamic pricing participants and matched Control participants during Dynamic Off-Peak hours. During Critical Peak Periods in the Summer, consumption impacts amounted to -0.354 kW in Summer 2018 and -0.38 kW and -0.35 kW per hour on average in Summer 2019 for the 6 and 9 CPP event groups respectively. Winter consumption impacts during CPP events amounted to -0.168 kW per hour on average.

Table 5: Main effects of price plans (comparing Treatment group versus Control group)

<table>
<tr><th rowspan="3">Dynamic Pricing</th><th colspan="11">Main Effect of Price (Relative to Status-Quo TOU Control)</th></tr>
<tr><th colspan="3">Summer 2018</th><th colspan="3">Winter 2018-19</th><th colspan="5">Summer 2019 Extension</th></tr>
<tr><th>High On-Peak</th><th>Off-Peak</th><th>CPP Days</th><th>High On-Peak</th><th>Off-Peak</th><th>CPP Days</th><th colspan="2"></th><th>High On-Peak</th><th>Off-Peak</th><th>CPP Days</th></tr>
<tr><td rowspan="2">kW</td><td rowspan="2">-0.26***</td><td rowspan="2">0.000</td><td rowspan="2">-0.354***</td><td rowspan="2">-0.122***</td><td rowspan="2">0.001</td><td rowspan="2">-0.168***</td><td rowspan="2">Dynamic 6</td><td>kW</td><td>-0.148***</td><td>-0.002</td><td>-0.382***</td></tr>
<tr><td>%</td><td>-8.528</td><td>-0.207</td><td>-19.625</td></tr>
<tr><td rowspan="2">%[2]</td><td rowspan="2">-12.968</td><td rowspan="2">0</td><td rowspan="2">-17.239</td><td rowspan="2">-10.558</td><td rowspan="2">0.114</td><td rowspan="2">-12.948</td><td rowspan="2">Dynamic 9</td><td>kW</td><td>-0.121***</td><td>-0.003</td><td>-0.35***</td></tr>
<tr><td>%</td><td>-7.632</td><td>-0.321</td><td>-18.802</td></tr>
</table>

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

As discussed above, the Legacy Dynamic peak impact analyses calculated the difference in electricity consumption for the Legacy Dynamic pricing Treatment group compared to Status-Quo TOU Control pricing group during the experimental periods without the DID method. Results are reported as mean hourly kW consumption difference in Table 6. This pilot was also divided into two different sub-groups, based on different dates of registration. Two different subgroups of participants were analyzed separately, based of different periods of pilot enrollment: Registration Bin 1 (registration date on or before May 1st, 2015) and Registration Bin 2 (registration date between October 1st, 2015 and May 4th, 2016). Registration Bin 1 consumed significantly less electricity than their Status-Quo TOU matched Control group during the Summer 2018 High On-Peak period (-0.144 kW per hour on average), while neither Bin differed from Control with respect to Winter High On-Peak consumption. Neither of the Legacy Dynamic Summer 2019 Treatment groups exhibited significantly lower High On-Peak usage relative to matched Controls. Interestingly, all Registration Bin 2 participants exhibited higher Off-Peak consumption compared to their matched Controls, with the exception of Winter (2018-

[2] % impacts are calculated as kW impact / (PostTOUUsage - kW impact), where PostTOUUsage is the average consumption between the Dynamic Pricing + Nudge Report and Dynamic Pricing + No Nudge Report groups from Tables 27, 28 and 29.

2019) period. For Critical Peak Periods, both Registration Bin 1 and Registration Bin 2 exhibited lower consumption in the Summer periods than matched Controls, ranging from -0.152 kW to -0.24 kW per hour on average, however, there were no differences in Critical Peak Period consumption for the Winter (2018-2019) period compared to their matched Controls.

Table 6: Main effects of Legacy Dynamic price plan during 2018 (comparing Treatment group versus Control group)

Legacy Dynamic Pricing		Main Effect of Price (Relative to Status-Quo TOU Control)										
		Summer 2018			Winter 2018-19			Summer 2019 Extension				
		High On-Peak	Off-Peak	CPP Days	High On-Peak	Off-Peak	CPP Days			High On-Peak	Off-Peak	CPP Days
Bin 1	kW	**-0.144****	**0.108*****	**-0.241*****	-0.005	**0.057***	-0.03	Dynamic 6	kW	-0.079	**0.089****	**-0.24*****
	%	-7.496	11.878	-11.996	-0.465	6.898	-2.475		%	-5.133	10.418	-13.337
Bin 2	kW	-0.065	**0.072***	**-0.152***	-0.005	0.091	-0.021	Dynamic 9	kW	-0.067	**0.116*****	**-0.225*****
	%	-3.59	7.959	-7.851	-0.354	8.447	-1.321		%	-4.306	13.599	-12.511

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

Overall, impact estimates indicate significant High On-Peak electricity consumption savings for Dynamic pricing pilot participants. Moreover, the consumption impact estimates for this pilot are more consistent with 'load clipping' than 'load shifting', as the lower High On-Peak consumption exhibited by Dynamic pricing participants, relative to Status-Quo TOU Controls, did not co-occur with higher Off-Peak consumption. For the Legacy Dynamic pricing participants, we observe lower High On-Peak consumption only for the Summer 2018 period for registration Bin 1, albeit with higher Off-Peak consumption relative to Controls, consistent with load-shifting. Given that there were several differences between Dynamic and Legacy Dynamic pilots that necessitated distinct analytic approaches to impact estimation, one might imagine that these differences may also explain why High On-Peak and Off-Peak patterns of consumption also differed qualitatively between these two pilots. Specifically, Legacy Dynamic participants have been exposed to Dynamic pricing for a much longer period of time and may therefore have decreased their responsiveness to Dynamic pricing signals over time. On the other hand, Legacy Dynamic participants have enjoyed price protection for the majority of their time in Dynamic pricing, perhaps affecting how they learned to respond to Dynamic pricing signals (i.e., that increased costs relative to Status-Quo TOU would not be incurred for High On-Peak consumption, and that the especially low Off-Peak rate could be capitalized on by increasing electricity consumption during these hours).

Importantly, for the Summer 2019 period, across both pilots, we see very similar estimated consumption impacts between the CPP 6 and CPP 9 groups, suggesting that High On-Peak and Off-Peak behavioural response was not affected by the frequency of CPP events (6 vs. 9).

Non-Price Interventions

In addition to the pricing interventions, half of the participants in each of the pricing Treatment and Control groups for the Dynamic pricing pilot and half of the participants in the pricing Treatment group for the Legacy Dynamic pricing pilot were randomly assigned to receive 'Nudge Reports'. This non-price intervention took the form of a monthly report that accompanied the Shadow Bill for pricing Treatment participants (or was sent as a stand-alone report in the case of pricing Control participants). This monthly report is referred to as a 'Nudge Report' because it contains information drawn from the field of behavioural economics intended to nudge conservation behaviours among recipients. Specifically, the Nudge Report displays personalized tips for reducing On-Peak consumption and provides personal benchmarking feedback so that recipients can track their On-Peak consumption behaviour month-to-month.

Impact estimates owing to Nudge Reports were not statistically significant for any TOU periods within the Dynamic and Legacy Dynamic pilot (an abbreviated summary of which is presented in Table 7).

Table 7: Effects of Nudge Report on Mean Hourly kW Consumption (comparing Nudge Report recipients versus non-recipients)

App Price Plan	Main kWh effect of Nudge Report (Relative to No Nudge)						
Dynamic Pricing Pilot		High On-Peak		Off-Peak		Season Total	
		kW	%[3]	kW	%	kW	%
	Summer 2018	-0.015	-0.792	0.007	0.709	0.005	0.478
	Winter 2018-19	0.024	2.206	0.011	1.246	0.01	1.094
	Summer 2019	-0.066	-4.16	-0.01	-1.075	-0.014	-1.398
Legacy Dynamic Pricing Pilot		High On-Peak		Off-Peak		Season Total	
		kW	%	kW	%	kW	%
	Summer2018	-0.005	-0.279	-0.029	-2.865	-0.024	-1.772
	Winter 2018-19	-0.005	-0.404	0.005	0.494	-0.004	-0.352
	Summer 2019	-0.1^	-6.564	-0.042	-4.306	-0.047	-4.615

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

In addition to measuring the effect of Nudge Reports as a non-price intervention, the impacts of smart thermostat technology in driving conservation and load-shifting behaviours among pilot participants was also of interest. Households were designated as "Technology" households if they participated in a smart thermostat incentive program offered by Alectra Utilities. Participation in such incentive programs means that "Technology" customers registered an eligible device to receive automatic load curtailment during Medium On-Peak, High On-Peak,

[3] % impacts are calculated as kW impact / (PostTOUUsage - kW impact), where PostTOUUsage is the average consumption between the Dynamic Pricing + Nudge Report and Standard TOU Pricing + Nudge Report groups from Tables 27, 28 and 29.

and Critical Peak TOU periods. Exact timing of smart thermostat installation for each household remains unknown, therefore Technology was analyzed comparing the mean hourly kW consumption of households with and without registered smart thermostats during the Treatment period only, without employing a difference-in-difference approach.

We found overall savings in mean hourly electricity consumption owing to Dynamic (-0.031 kW to -0.114 kW seasonal total) and Legacy Dynamic pricing households (-0.061 kW to 0.208 kW seasonal total) with registered smart thermostat (Table 8). These savings were largest during the Winter 2018-2019 season. In Summer 2019, participants in the Legacy Dynamic 6 group broke away from the overall pattern and saw a small but significant increase in Off-Peak electricity consumption relative to matched Controls owing to smart thermostat possession/registration (+0.122 kW per hour on average).

Table 8: Effects of smart thermostat Technology on Mean Hourly kW Consumption

APP Price Plan	Main effect of Technology in kWh (Relative to No Technology)								
		CPP Days		High On-Peak		Off-Peak		Season Total	
		kW	%	kW	%	kW	%	kW	%
Dynamic Pricing Pilot	Summer 2018	-0.150	-8.544	-0.062	-3.541	-0.015	-1.527	-0.031	-2.347
	Winter 2018-19	-0.145^	-12.344	**-0.145***	-13.704	**-0.110****	-12.241	**-0.114***	-11.531
	Summer 2019	-0.152	-9.692	-0.065	-4.314	-0.086	-8.885	-0.064	-5.532
		High On-Peak				Off-Peak		Season Total	
		kW		%		kW	%	kW	%
Legacy Dynamic Pricing Pilot	Summer 2018	**-0.127***		-6.887		0.052	5.383	-0.061	-4.379
	Winter 2018-19	**-0.281*****		-20.078		**-0.171*****	-15.283	**-0.208*****	-16.363
	Summer 2019	-0.082		-5.33		0.012	4.51	-0.064	-6.09

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Bill Savings

The impacts of Dynamic and Legacy Dynamic pricing on customers' electricity bills are shown in Table 9. The average monthly APP bills were compared to the average monthly TOU bills that participants would have paid if they showed the exact same consumption patterns but were billed as per Status-Quo TOU prices instead of APP (Dynamic) prices. Summary statistics show that Dynamic and Legacy Dynamic participants experienced small savings in the Summer 2018 period and moderate savings in the Winter 2018-19 period. However, participants in both Dynamic and Legacy Dynamic pricing experienced costs in Summer 2019 owing to participation in APP. Figures showing the distribution of the total savings per pricing pilot are shown in Appendix D.

Table 9: Monthly Bill Savings

Summer 2018	May	June	July	August	September	October	Average Monthly Savings
Dynamic	$11.93	$4.99	-$17.80	-$12.64	$2.37	$12.81	$0.28
Legacy Dynamic	$11.73	$5.22	-$16.45	-$11.01	$2.99	$12.34	$0.81
Winter 2019-19	November	December	January	February	March	April	Average Monthly Savings
Dynamic	$13.98	$10.14	-$0.79	-$14.42	-$3.19	$10.54	$2.71
Legacy Dynamic	$14.54	$10.43	-$1.31	-$16.16	-$3.84	$11.01	$2.45
Summer 2019		June	July	August	September	October	Average Monthly Savings
Dynamic 6 CPP	--	$12.25	-$12.04	-$22.28	-$2.46	$8.78	-$3.15
Dynamic 9 CPP	--	$11.40	-$13.19	-$21.56	-$1.21	$8.96	-$3.12
Legacy Dynamic 6 CPP	--	$11.44	-$12.51	-$19.64	-$0.36	$9.06	-$2.40
Legacy Dynamic 9 CPP	--	$11.57	-$12.53	-$19.67	-$0.16	$9.27	-$2.30

Bill Savings are Denoted as Positive

Conclusions

Alectra Utilities examined the impact of Dynamic pricing as an alternative pricing structure to Status-Quo TOU pricing amongst residential electricity consumers over a 17-month period. This examination was conducted as part of the Province's re-examination of the Regulated Price Plan in Ontario and included Dynamic and Legacy Dynamic pricing pilots in combination with two non-price manipulations, Nudge Reports and smart thermostat technology. Both Dynamic pricing and Legacy Dynamic pricing pilots yielded some reductions in On-Peak consumption. Over the full 17-month duration of the pilot, Dynamic pricing pilot yielded an estimated consumption reduction of 0.025 kW per hour on average (-2.47%; Table 33). However, for the Legacy Dynamic Pilot, High On-Peak reductions in consumption were offset by increases in Off-Peak electricity consumption, resulting in an increase in average hourly consumption over the 17-month duration of the pilot by these participants (Table 61).

Nudge Reports did not yield significant consumption impacts over and above the impacts of Dynamic pricing TOU periods. Smart thermostats that were registered to allow Alectra to curtail consumption during higher priced times of day were associated with electricity consumption impacts for some Summer CPP and High On-Peak periods and these impacts were largest during Winter On-Peak periods in both pilots.

The five-month extension of Dynamic and Legacy Dynamic pricing beyond the original 12-month reporting period of Advantage Power Pricing (the public-facing name of Alectra Utilities' instantiation of the Regulated Price Plan Pilot Project) was approved in order to address two primary research questions:

1. Will the responsiveness to High On-Peak and Critical Peak price events estimated for Dynamic and Legacy Dynamic customers in the Summer of 2018 persist a year later (i.e., in the Summer of 2019)?

2. Does the responsiveness to CPP events by Dynamic and Legacy Dynamic customers depend on the frequency of those events (i.e., will increasing the number of CPP events from six to nine per season result in diminished behavioural response to such events)?

With respect to the first research question, the magnitude of the consumption savings owing to High On-Peak pricing was numerically smaller for the Summer 2019 season relative to Summer 2018. This likely owes in large part to the fact that electricity consumption is variable and highly dependent on weather. High On-Peak average hourly temperatures were approximately 4 degrees Celsius lower in Summer 2019 relative to Summer 2018 (average hourly temperatures as a function of season and TOU period are provided in Table 25 later in this report). Of course, part of the quantitative reduction in High On-Peak impact across the two Summers may reflect diminished behavioural response to Dynamic pricing. It is not possible to ascertain the relative contributions of seasonal weather fluctuations and diminished behavioural response in driving the smaller estimated consumption impact in Summer 2019 relative to Summer 2018. Importantly, CPP event responsiveness was nearly identical in both Summer 2018 and Summer 2019 for households in both Dynamic and Legacy Dynamic pilots. Responsiveness to short, infrequent CPP events, therefore, shows no evidence of diminished behavioural response over a two-Summer reporting period.

With respect to the second research question, consumption impact estimates clearly indicate that average hourly consumption savings during CPP events do not differ between households who received six such events and those who received nine. We can conclude therefore, that for a given CPP event, behavioural response is not affected by the frequency at which such events occur, at least within the range of event frequencies that were manipulated here.

Contents

1. Introduction

In an effort to achieve the conservation and demand management (CDM) objectives in the province of Ontario, the Ontario Energy Board has been seeking to examine the impact of alternative electricity pricing schemes under the Regulated Price Plan (RPP) as well as the impact of non-price interventions (such as communications and technology) on electricity consumption behaviour among residential customers. Alectra Utilities participated in the RPP Pilot Program to test the impact of three separate Time-of-Use (TOU) pricing schemes and two non-price interventions on conservation, load-shifting, and peak period consumption reduction behaviours amongst a sub-set of its customers.

TOU pricing was introduced in Ontario with the goal of reducing electricity consumption among residential and commercial consumers during 'peak' times of day when demand on generation and distribution infrastructure is highest. TOU pricing charges consumers different hourly Kilowatt-Hour (kWh) prices depending on the time of day. Ontario adopted a three-period TOU pricing structure comprised of Off-Peak (when prices are lowest), Medium-Peak, and On-Peak (when prices are highest) periods. TOU pricing periods are meant to closely mirror actual system peak demand (as per the Independent Electricity System Operator). The logic behind TOU pricing is based on traditional economic theory which holds that consumption of a given commodity will decrease as the price of that commodity increases. TOU pricing is therefore intended to function as a disincentive to electricity consumption during On-Peak periods when prices are highest.

In an effort to further improve the efficacy of TOU pricing in achieving the Province's conservation and demand management objectives, the OEB has undertaken a re-examination of the RPP in an effort to uncover new ways of achieving those objectives. The OEB identified two primary areas of opportunity to better align the RPP with the province's conservation goals:

1. *Implementing Price Pilots: The OEB stated that it would work with Local Distribution Companies (LDCs) to undertake several pricing (and non-price) pilots. The pilots will run for at least one calendar year to assess whether there is persistence in the impact of the intervention.*

2. *Empowering Consumers – Enhancing energy literacy and non-price tools: The OEB stated that it intends to launch non-price pilot initiatives, such as piloting automated load control technology and behavioural interventions.*

The first prioritized opportunity area outlined by the OEB acknowledges that perhaps the price differential between On-Peak and Off-Peak TOU periods is currently insufficient to function as meaningful financial disincentive to the consumption of electricity during peak hours. It is therefore hypothesized that more severe financial disincentives for On-Peak consumption might result in On-Peak conservation and/or load-shifting behaviours among consumers. The second prioritized opportunity area outlined by the OEB acknowledges that perhaps financial levers are not the only (and perhaps not the most effective) method of promoting behaviour change. This perspective (grounded in the field of behavioural economics) holds that individuals do not always respond to pricing signals in the way that traditional economic theory would predict. This occurs because we are subject to myriad cognitive biases such as temporal discounting. In the context of electricity consumption, this means we are prone to value our comfort in the present moment (resulting in over-use of electricity consuming appliances such as air conditioners) and to discount the future costs associated with that behaviour. It is therefore hypothesized that non-price behavioural interventions that mitigate the effects of these cognitive biases may represent a complementary approach to financial disincentives in promoting conservation and/or load shifting behaviours.

One of the three pricing pilots tested within the broader RPP pilot undertaken by Alectra Utilities (the Dynamic pricing pilot) proved successful with respect to both of these objectives during the first 12 months of the RPP Pilot. Dynamic pricing as an alternative pricing scheme to Status-Quo TOU pricing yielded substantial reductions in electricity consumption during High On-Peak times of day during the Summer and Winter months as well as during all Critical Peak pricing periods. In addition, incremental consumption impacts were estimated during High On-Peak Summer hours and Critical Peak periods owing to non-price communications (Nudge Reports) and technology assets (programmable smart thermostat ownership/registration). Given the demonstrated potential of Dynamic pricing as an alternative to Status-Quo TOU pricing, a decision was made in May 2019 to extend the Dynamic pricing pilot for another five months (June 01, 2019 – October 31, 2019 inclusive). The stated goals of this extension were to: (1) obtain data for a second Summer reporting period for Dynamic pricing, and (2) test the impact of variable frequencies of Critical Peak Period (CPP) events (6 vs 9) within a given seasonal period. The consumption impacts owing to Dynamic pricing during the entire 17-month duration of the Dynamic pilot (including the original 12-month reporting period and the five-month extension period) are the subject of the remainder of this report.

In the sections that follow, we first outline the details of the Dynamic pricing pilots and the non-price interventions that were tested experimentally as part of the RPP pilot project. We then present a detailed impact analysis, separately for each of the two customer groups who took part in Dynamic pricing (i.e., newly enrolled customers, and Legacy Dynamic customers). Finally, we present the findings from customer-facing surveys distributed throughout the 17 months of the Dynamic pricing pilot program that aimed to measure TOU comprehension and motivations to conserve electricity among pilot participants.

2. Dynamic Price Plan

Customers participating in the Dynamic pricing pilot experienced variable On-Peak prices depending on anticipated demand determined by the IESO. This pricing pilot is designed to appeal to customers who are typically home in the afternoon. Participating customers were informed of the variable On-Peak price each day at 4pm (at which point they are informed of what the price will be the following day). Customers were informed of the variable peak price each day either by logging into their APP online portal or subscribing to receive SMS text and/or email alerts from Alectra at 4pm each day. These customers also experienced CPP events lasting four hours each with an especially high kWh price. For the extension period, which comprises the Summer period months of June 01, 2019 – October 31, 2019 inclusive, half of Dynamic pricing customers and Legacy Dynamic customers were subjected to a total of six CPP events, and half were subjected to nine such events. These groups are referred to in this document as Dynamic 6/Legacy Dynamic 6 and Dynamic 9/Legacy Dynamic 9, respectively. The prices and associated price periods are shown in Table 10 below.

Table 10: Dynamic Pricing TOU Periods and Associated kWh Rates in cents (CAD)

Price Period	Hours	Price (cents/kWh)	
		Nov - April	May - Oct
Off-Peak	Weekdays: 12am-3pm and 9pm-12am Weekends: All day	4.9	4.9
Low On-Peak	50% of Weekdays: 3pm-9pm	10.0	9.9
Medium On-Peak	30% of Weekdays: 3pm-9pm	19.9	19.8
High On-Peak	20% of Weekdays: 3pm-9pm	39.8	39.7
Critical Peak	On the top six or nine system peak days in summer and winter, each event lasting four hours. Start time of events determined by peak demand hour of event day	49.8	49.8

Status-Quo Time-of-Use Pricing: Customers assigned to the Control groups experienced Status-Quo TOU prices. The Status-Quo TOU prices and associated periods are shown in Table 11.

Table 11: Status-Quo TOU Pricing TOU Periods and Associated kWh Rates in cents (CAD)

Price Period	Summer Hours (May – October)	June - October
Off-Peak	Weekdays: 12am-7am and 7pm-12am Weekends: All day	6.5¢
Mid-Peak	Weekdays: 7am-11am and 5pm-7pm	9.5¢
On-Peak	Weekdays: 11am-5pm	13.2¢

Electricity costs associated with pilot participation were communicated to pricing pilot participants via Shadow Bills. Shadow Bills are a monthly electricity consumption report that communicates to pilot participants how much electricity they have consumed in the prior billing period and how the associated costs of that electricity compare with that of Status-Quo TOU pricing (i.e., what customers would have been charged if they had the exact same consumption pattern in the billing period, but were billed according to Status-Quo TOU prices). The primary function of this Shadow Bill was to communicate bill cost savings or increases as a result of pricing pilot participation. It was hypothesized that (1) positive feedback (i.e., bill cost savings) would encourage participants to further augment their consumption patterns to realize additional savings and remain in the program. It was hypothesized that (2) negative feedback (i.e., bill cost increases) would encourage participants to begin to augment their consumption behaviours in order to realize bill cost savings. The Shadow Bill was mailed in paper form to pilot participants each billing period as a separate piece of communication to the actual monthly Alectra Utilities bill. An example Shadow Bill is shown in Appendix B. All customers in Dynamic and Legacy Dynamic pricing pilots received Shadow Bills.

3. Non-Price Interventions

In order to address the second key objective of the RPP pilot program as outlined by the OEB (i.e., *Empowering Consumers: Enhancing energy literacy and non-price tools*[4]) Alectra, in collaboration with BEworks, Util-Assist, and Bidgley, created communications that were distributed to customers on a monthly basis. These reports served to provide behavioural 'nudges' to customers to drive conservation and load-shifting behaviours (Nudge Reports). In addition, Alectra, in collaboration with Nest, Ecobee, and Energate, offered smart thermostats to pricing pilot participants to help them better realize consumption savings through automatic load curtailment functionality. It was hypothesized that pricing pilot participants with programmable smart thermostats that were registered with Alectra and subject to automatic load curtailment during Variable On-Peak and Critical Peak pricing events would exhibit greater consumption reductions than pricing pilot participants without registered devices. We describe the rationale and logistics of each of the two non-price interventions (Nudge Reports and Technology) below.

3.1.1 Nudge Reports

Exactly half of customers in both the pricing Treatment groups within the Dynamic pricing pilot and Legacy Dynamic pilot were randomly selected to receive Nudge Reports[5]. In addition, half of the customers in the Dynamic pricing pilot matched Control group were randomly selected to receive Nudge Reports. No customers in the Legacy Dynamic matched Control group received Nudge Reports due to the unavailability of customer data at the time these reports were created. Nudge Reports are one-page communications that accompanied the Shadow Bills each month for Dynamic and Legacy Dynamic pricing Treatment customers and were sent as a stand-alone report each month for Dynamic Control customers (i.e., those on Status-Quo TOU pricing who do not receive Shadow Bills). Nudge Reports employed behavioural economic approaches to drive load shifting and conservation behaviours. Specifically, four different behavioural approaches – a commitment device, feedback and benchmarking, personalized recommendations, and salient reminders – were featured in the Nudge Reports. We describe each of these tactics in turn, including the behavioural approach and relevant supporting research.

Commitment device: The initial cycles of Nudge Reports included a monetary offer whereby customers were asked to take a pledge to reduce their electricity usage during On-Peak times of day. A monetary incentive ($5 rebate) was offered to consumers when they sent an SMS message indicating their intent to sign the pledge (e.g., "YES") to a short code.

Commitment devices such as pledges can be an effective strategy for changing behaviour where intention does not match action. According to cognitive dissonance theory[6], people have the tendency to keep attitudes and beliefs in line with their externalized behaviours. Consequently,

[4] https://www.oeb.ca/sites/default/files/uploads/RPP_Roadmap_Report_of_the_Board_20151116.pdf
[5] No customers in the Overnight pricing pilot received Nudge Reports due to a lower than expected enrollment rate for that pilot. As a result, we were not able to introduce an additional experimental factor while maintaining sufficient experimental power to detect the interactive effects of both price *and* Nudge Reports on consumption behaviour.
[6] Festinger, L. (1957). A Theory of Cognitive Dissonance, Evanston, ILL, Row, Peterson.

when people perceive that they have freely chosen to commit to a behaviour, this becomes internalized within their self-concept, making it more likely that people will follow through on behaviours consistent with the initial (comparatively trivial) act of commitment. An example of this phenomenon is known as the *foot-in-the-door* technique whereby asking individuals to agree to a small request makes it more likely for them to later comply with a larger request[7]. In the present context, it was hypothesized that pledges would act as initial small requests that aimed to regulate subsequent conservation behaviours.

There is support in the scientific literature for using commitment devices to nudge individuals towards environmentally friendly behaviours including energy conservation[8,9,10]. In one study, researchers found that when hotel guests made a specific commitment at check-in and received a lapel pin as a reminder of their pledge, they were 25% more likely to reuse their towels[11]. A study on household recycling found that a commitment intervention where participants were asked to sign a pledge card and then received a sticker to remind them of their commitment resulted in a significant increase in the frequency of recycling during the pledge period, relative to a control group[12].

Additional research indicates that providing people with a financial incentive to commit to a prosocial cause can increase compliance with that cause[13]. Using a monetary reward in the present pilot was hypothesized to increase the likelihood that consumers would agree to the conservation pledge (although we did not test this experimentally since all customers who received Nudge Reports were offered the pledge with a monetary incentive). The pledge campaign ran for 3 months (bills mailed from June to August 2018). There was a total of 101 Dynamic pilot participants and 106 Legacy Dynamic pilot participants who responded to the pledge and were therefore eligible for the $5 bill credit.

Consumption feedback and benchmarks: Using Bidgely's load disaggregation data, appliance level usage feedback information was provided to customers receiving monthly Nudge Reports. A meta-analytic review of 21 unique papers on the impact of feedback on electricity consumption supports the idea that individualized feedback leads consumers to better understand and control their usage[14]. The findings revealed an average of 5% to 12% reduction in electricity

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[7] Freedman, Jonathan L., and Scott C. Fraser. "Compliance without pressure: the foot-in-the-door technique." Journal of personality and social psychology 4, no. 2 (1966): 195.
[8] Katzev, R. D., & Johnson, T. R. (1984). Comparing the Effects of Monetary Incentives and Foot-in-the-Door Strategies in Promoting Residential Electricity Conservation. Journal of Applied Social Psychology, 14(1), 12-27.
[9] Pallak, M. S., & Cummings, W. (1976). Commitment and voluntary energy conservation. Personality and Social Psychology Bulletin, 2(1), 27-30.
[10] Werner, C. M., Turner, J., Shipman, K., Twitchell, F. S., Dickson, B. R., Bruschke, G. V., & Wolfgang, B. (1995). Commitment, behavior, and attitude change: An analysis of voluntary recycling. Journal of Environmental Psychology, 15(3), 197-208.
[11] Baca-Motes, K., Brown, A., Gneezy, A., Keenan, E. A., & Nelson, L. D. (2012). Commitment and behavior change: Evidence from the field. Journal of Consumer Research, 39(5), 1070-1084.
[12] Burn, S. M., & Oskamp, S. (1986). Increasing community recycling with persuasive communication and public commitment. Journal of Applied Social Psychology, 16(1), 29-41.
[13] Katzev, R. D., & Pardini, A. U. (1987). The comparative effectiveness of reward and commitment approaches in motivating community recycling. Journal of Environmental Systems, 17(2).
[14] Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? Energy efficiency, 1(1), 79-104.

consumption as a result of different feedback mechanisms. Particularly, the meta-analysis examined the variable impact of feedback mechanisms and found that the most effective feedback is delivered frequently and consistently over a long period of time, includes specific appliance level information, and is presented in a clear and appealing way.

In addition, Nudge Reports included a historical benchmark visual comparing consumers' On-Peak usage in the billing cycle to their calibrated average historical On-Peak usage. The visual included a feedback message informing consumers of whether their On-Peak consumption deviated negatively or positively relative to a moving average. Research suggests that consumers typically respond well to goal-specific feedback resulting in reductions in electricity usage. For example, in a field study of residential energy use, families that were asked to set a goal to reduce their electricity consumption and were provided with frequent feedback on their progress achieved an average of 13%-15.1% in electricity savings[15]. In prior BEworks research conducted on behalf of the Ontario Energy Board, participants were more likely to understand and indicate intent to conserve electricity after receiving negative comparisons to past usage behaviour paired with a visual of a red, wide house (meant to appear as though it were 'bloated' with energy) relative to other types of feedback[16]. Together, feedback and benchmarking provide information attributable to specific actions, allowing consumers to make comparisons to standards of behaviour and exert effort towards the most effective courses of action[17].

Personalized recommendations: Nudge Reports included personalized energy saving recommendations using Bidgely's personalization algorithm. These recommendations accompanied usage feedback information to provide customers with actionable tips on how to become more energy efficient. Prior research reveals that highly personally relevant and specific information can be effective in reducing household energy consumption. In one study, home energy audits that provide tailored energy savings options to households reduced electricity consumption by 21% compared to a control group[18]. In addition to personalized information, research shows that when people have a detailed plan for when and how they intend to reach a goal, they are more likely to attain it[19]. Psychologists refer to these actionable plans as *implementation intentions*. Theories supporting the use of implementation intentions postulate that when anticipated situations are linked with a goal-directed response, people are less likely to be deterred by obstacles impeding the completion of a task[20]. By providing customers with specific load-shifting and/or consumption reduction actions that are relevant to them, it was hypothesized that customers would be more likely to follow through with these recommended conservation actions.

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[15] McCalley, L.T. & Midden, J.H. Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation. Journal of Economic Psychology, 23, 589–603
[16] BEworks, 2014. https://www.oeb.ca/oeb/_Documents/EB-2004-0205/BEworks_TOU_Report.pdf
[17] Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: a historical review, a meta-analysis, and a preliminary feedback intervention theory. Psychological bulletin, 119(2), 254.
[18] Winett, R. A., Love, S. Q., & Kidd, C. (1982). The effectiveness of an energy specialist and extension agents in promoting summer energy conservation by home visits. Journal of Environmental Systems, 12(1).
[19] Gollwitzer, P.M. & Brandstätter, V (1997). Implementation intentions and effective goal pursuit. Journal of Personality and social Psychology. 73, 186.
[20] Gollwitzer, P. M. Implementation intentions: strong effects of simple plans. American Psychologist. 54, 7, 493.

Salient reminders: Potential behavioural barriers to load shifting include failing to pay attention to and/or simply forgetting the pricing schedule when consuming electricity on a daily basis. To address these barriers, consumers received visual memory aids to act as reminders to shift consumption behaviour in accord with their pricing schedule. These took the form of a visually salient, color-coded TOU pricing schedule that consumers had the opportunity to cut out then place in a prominent area of their home, such as on their fridge or in the laundry room. This visually salient linear timeline also clearly illustrated TOU period costs and showed how much more On-Peak and Medium-Peak periods cost relative to Off-Peak periods.

3.1.2 Thermostat Technology

As part of the RPP pilot project objectives it was also of interest to measure the impacts of smart thermostat technology that allows for automatic load curtailment during high priced TOU periods in driving conservation and load-shifting behaviours. Eligible smart thermostats can be adjusted dynamically and automatically in response to weather effects and changes in price by a customer's local distribution company, and it was therefore hypothesized that pilot participants with smart thermostats that were registered to receive such curtailment would realize additional incremental consumption savings relative to those without registered devices. As such, all Technology impact estimations are restricted to customers who registered their thermostats through Alectra to receive automatic load curtailment, which reduced heating/cooling load during higher-priced TOU (i.e., Variable On-Peak and Critical Peak). Customers with eligible devices were required to opt-in to load curtailment, which was accomplished by simply registering their device. In our analysis of smart thermostat technology as a non-price manipulation, we designate customers with registered smart thermostats as 'Technology' customers. This means that the impacts of smart thermostats on consumption behaviour derive not simply from owning an eligible smart thermostat but from receiving some form of automatic load curtailment. As can be seen in Table 12, the availability and nature of load curtailment varied by thermostat type.

Table 12: Thermostat Curtailment Periods

	Curtailment Period	
Thermostat Type	Dynamic (On-Peak)	Dynamic (Critical Peak)
Energate	Based on customer-selected 'comfort' setting	Based on customer-selected 'comfort' setting
Honeywell	Based on operating time	Based on operating time
Ecobee	Based on operating time	Based on operating time
Nest	N/A	Based on Rush Hour Rewards[21]

[21] https://support.google.com/googlenest/answer/9244031?co=GENIE.Platform%3DAndroid&hl=en

Energate Foundation Thermostat Load Curtailment Functionality by Dynamic TOU Period: For Energate Foundation thermostats, the amount of load curtailment at any given time was determined by: (1) the price of electricity, with higher priced TOU periods being subjected to higher curtailment, and (2) the thermostat comfort settings chosen by the homeowner, which ranged from 'Max Comfort' (no curtailment whatsoever) to 'Max Savings' (the highest possible curtailment). The mapping of TOU period to potential curtailment (in °C) for each of the three pricing pilots are shown in Table 13 below. Also shown in Table 14 is the mapping of smart thermostat Comfort Settings to Savings Percentages.

Table 13: Dynamic Pilot - Mapping of TOU Period to Max Savings

TOU Period	Max Savings (°C)
Off-Peak	0
Low On-Peak	1
Medium On-Peak	2
High On-Peak	3
Critical Peak	4

Table 14: Curtailment Enabled Energate Thermostats - Mapping of Savings Percentage to Comfort Setting

Savings Percentage (%)	Comfort Setting
0	Max Comfort
25	Comfort
50	Balanced
75	Savings
100	Max Savings

Given the above information, this means that a Dynamic pricing customer with a curtailment-enabled registered smart thermostat who selected the 'Balanced' comfort setting, would have seen Critical-Peak curtailment of 2 degrees Celsius (50% of the Max Savings for that TOU period). The relationship between Savings Percentage and Comfort Setting is Energate thermostat-specific.

Honeywell and Ecobee Thermostat Load Curtailment Functionality: Unlike Energate curtailment functionality, curtailment settings for Honeywell and Ecobee owners was based on Air Conditioning run-time, not degree settings. The mapping of run-time curtailment to peak period within Dynamic pricing is shown in Table 15.

Table 15: Honeywell and Ecobee Thermostats – Mapping of Pricing Period to Run-Time

Pricing Period	Maximum Air Conditioner Run Time
Off-Peak	N/A
Low On-Peak	30 minutes/hour
Medium On-Peak	24 minutes/hour
High On-Peak	18 minutes/hour
Critical Peak	12 minutes/hour

4. Advantage Power Pricing Impact Analysis Methodology

4.1 General Approach

Here we outline the methodological approach for the participant sampling and experimental designs employed to assess impacts of the Dynamic and Legacy Dynamic pilot interventions on conservation and demand management behaviours. Specific design and sampling specifications unique to each pilot are included in corresponding subsections.

The first step in the sampling procedure was to isolate the sample frame from which participants would be drawn for participation in the pilot. In doing so, there were several considerations/constraints. First, only households within the PowerStream legacy service territory were considered eligible. Second, eligible participants must not have been participating in any other pilot programs with conservation and/or demand management objectives (e.g., Home Energy Report pilots). Specifically, households receiving Home Energy Reports (or designated as part of the Control group for Alectra's Home Energy Report program) were not included in the sample frame. In addition, households participating in Alectra's Advantage Planet program were also ineligible for participation. The remaining households were then recruited for participation in Dynamic pricing or assigned to the matched Control group. No recruitment or assignment of Legacy Dynamic households or associated matched Control households was conducted; their participation in Dynamic pricing was simply continued from the legacy program. For calculations and assumptions related to experimental power, see Appendix E.

In the sections that follow, we describe the sampling procedure and present participant numbers as a function of experimental condition for each of the pricing pilots. The presentation of sample size numbers is intended to provide transparency on the different criteria under which participants who originally opted in, or who were automatically assigned to matched Control conditions for the pilot, were excluded from the data set used to estimate impacts. The columns in the sample size tables should be read as follows:

Starting N: The number of participants in each experimental condition (Price Treatment, Control; Nudge Report Treatment, Control) at the beginning of the relevant reporting period (Summer or Winter Treatment period months).

Opt-Outs: The number of participants who communicated to Alectra that they wished to discontinue participation in the pilot at any point during the relevant reporting period.

Move-Outs: The number of participants who moved at any point during the relevant reporting period

Missing Data: The number of participants for whom sufficient hourly Smart Meter data was not available to allow for consumption impact estimation in the relevant reporting period.

Outliers: The number of participants for whom their average hourly kW consumption was deemed to be excessively high or low (i.e. <0.05kW/h or >15kW/h), indicating that they may not be a representative household with respect to electricity consumption within the Alectra service territory.

Total Exclusions: This is simply the sum of Opt-Outs + Move-Outs + Missing Data + Outliers.

Final N: This is simply the Starting N subtracting the Total Exclusions. Final N represents the number of households that contributed electricity consumption data to the impact analyses for the relevant reporting period.

4.1.1 Dynamic Pricing Sampling Procedure

Since the TOU pricing periods under the Dynamic pricing structure do not align with Status-Quo TOU pricing periods, customers participating in the Dynamic pilot experienced significant material changes to their TOU schedules. In addition, the inclusion of CPP events and Variable Peak pricing required that participating residential customers be notified on a daily basis of whether there would be Low-, Medium-, High-, or Critical-Peak periods. For these reasons, the Dynamic pilot was run on an opt-in basis, requiring that eligible residential customers sign-up for (opt-in to) Dynamic pricing. As such, the Dynamic plan was run as a Matched Controlled Trial, meaning that once enrollment into the pricing Treatment group was completed, a Control group was created from the remaining sample frame that matched pricing Treatment participants on historical consumption behaviours. Additional detail on the matching algorithm and the consumption metrics used to derive the matched Control group can be found in Appendix A. Once the Treatment and matched Control groups for the Dynamic pilot were established, half were randomly assigned to receive Nudge Reports. The distribution of participants to each of the four Dynamic pricing pilot groups for the Summer 2018 and Winter 2018-19 periods is shown in Table 16.

Beginning in October 2017, eligible households were contacted via direct marketing efforts to voluntarily sign up for either the Dynamic plan as part of the current instantiation of the Regulated Price Plan Pilot project. At the conclusion of the original 12-month reporting period of the RPP Pilot program, Dynamic pricing customers were notified that the program would be extended an additional five months (June – October 2019) and were reminded to opt-out of the program if they wished to be returned to Status-Quo TOU pricing. The Summer 2019 extension period covered June-October 2019 instead of the full 6-month May-October Summer season because customers were not informed of the extension of Dynamic pricing until late May[22]. Customers were then randomly assigned to receive either six or nine CPP events within the 5-

[22] The reporting period for the original pilot concluded at the end of April 2019, however Dynamic pricing was extended through May while the OEB considered implementing a full Summer 2019 extension period, with the addition of the CPP event frequency factor. For this reason, May is considered to be a 'transition month' whereby participants continued to experience Dynamic pricing, but were not informed of the longer term extension, or of their assignment to the CPP 6 vs CPP 9 groups. We could not, therefore, include consumption data for May 2019 in the extension period analysis. The official start date of the extension period is June 1, 2019, when participants were notified of the extension, given the opportunity to opt-out, and assigned to CPP 6/9 experimental groups.

month reporting period of the extension of the pilot and are hereafter referred to as the "Dynamic 6" and "Dynamic 9" groups, respectively. Participant numbers as a function of condition in the Summer 2019 pilot period are displayed in Table 17.

Table 16: Number of Participants in Dynamic Pilot, Summer 2018 and Winter 2018-19

Summer 2018 Reporting Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data[23]	Outliers	Total Exclusions	Final N
Dynamic Pricing, No Nudge Report	385	34	9	0	0	4	47	338
Dynamic Pricing + Nudge Report	385	29	6	0	0	5	40	345
Status-Quo TOU Pricing, No Nudge Report	385	0	14	0	1	6	21	364
Status-Quo TOU Pricing + Nudge Report	385	1	17	0	0	5	23	362
Total	1540	64	46	0	1	20	131	1409
Winter 2018-19 Reporting Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data	Outliers	Total Excls.	Final N
Dynamic Pricing, No Nudge Report	338	25	8	0	70	0	103	235
Dynamic Pricing + Nudge Report	345	38	4	0	67	1	110	235
Status-Quo TOU Pricing, No Nudge Report	364	0	20	0	0	2	22	342

[23] See Section 4.2.4 Issues or Concerns for further explanation.

Status-Quo TOU Pricing + Nudge Report	362	4	14	0	0	3	21	341
Total	1409	67	46	0	137	6	256	1153

Table 17: Number of Participants in Dynamic Pilot, Summer 2019

Summer 2019 Extension Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data	Outliers	Total Excls.	Final N
Dynamic 6 Pricing, No Nudge Report	120	2	9	1	0	1	13	107
Dynamic 9 Pricing, No Nudge Report	108	5	4	1	0	0	10	98
Dynamic 6 Pricing + Nudge Report	115	3	5	2	0	0	10	105
Dynamic 9 Pricing + Nudge Report	127	6	2	1	0	0	9	118
Status-Quo TOU Pricing, No Nudge Report	342	0	12	0	0	4	16	326
Status-Quo TOU Pricing + Nudge Report	341	4	13	0	0	2	19	322
Total	1153	20	45	5	0	7	77	1076

4.1.2 Legacy Dynamic Pricing Pilot

Alectra began offering a version of Dynamic pricing to its customers in 2015, and over the course of three separate registration periods, had been continuing to offer Dynamic pricing to a subset of its residential customer base. This means that at the commencement of the most recent instantiation of the RPP pilot program, there existed approximately 1,500 households already enrolled in Dynamic pricing. In an attempt to gather data on the longevity of previously estimated behavioural response to Dynamic pricing, Alectra and the OEB sought to retain this 'Legacy' Dynamic customer group. There exist three key differences between the Legacy and 'new' Dynamic customer bases that necessitate that we treat these groups independently, both in terms of the sampling procedure and subsequent analysis.

- The Legacy Dynamic households had been subjected to Dynamic pricing for (in some cases) up to 3 years at the commencement of the reporting period of the current evaluation

- Until the start of the current pilot reporting period, Legacy Dynamic pricing was offered with full price protection, representing an important qualitative difference between the legacy and most recent instantiations of Dynamic pricing

- The Legacy Dynamic pricing pilot was created as an opt-in pricing pilot with a matched Control group; however, separate matched Control groups were created for Summer and Winter impact analyses (whereas the present evaluator has created a single matched Control group for all impact analysis pertaining to the "new" Dynamic households)

Legacy Dynamic households were not required to re-enroll into the current pilot program, but instead were informed via email and/or direct mail that Dynamic pricing was being extended until April 2019, with the removal of price protection beginning in May 2018. As with the new Dynamic customers, half of Legacy Dynamic households were then randomly assigned to receive Nudge Reports for the duration of the pilot. Unlike the New Dynamic matched Control customers however, Nudge Reports were not distributed to Legacy Dynamic matched Control customers. Procurement of household premise IDs for Legacy Dynamic Control customers (which were not known by Alectra since they were identified by an independent evaluator several years prior) was not completed in a timely enough manner to begin distributing Nudge Reports to those customers at the commencement of the pilot.

At the conclusion of the original 12-month reporting period of the RPP Pilot program, Legacy Dynamic pricing customers were notified that the program would be extended an additional five months (June – October 2019) and were reminded to opt-out of the program if they wished to be returned to Status-Quo TOU pricing. Customers were then randomly assigned to receive either six or nine CPP events within the 5-month reporting period of the extension of the pilot. After assignment, we confirmed that the two groups did not statistically differ on historical energy consumption.

4.2 Treatment of Hourly Consumption Data

4.2.1 Description of the Data

The impact analyses that follow used quantitative data to perform inferential statistical analyses to test the effects of pricing Treatments and non-price interventions on household electricity consumption. The consumption impacts were derived from hourly Smart Meter readings for each household over the course of at least two years (12 months of pre-pilot data and 17 months of pilot data) measured in kilowatt hours (kWh) and was delivered to the evaluator (BEworks Inc.) from Savage Data Systems, Alectra's Operational Data Store. For estimated consumption impacts, hourly means are reported in kilowatts (kW).

4.2.2 Preprocessing Activities

The data cleaning process to convert raw hourly data to the data used for the statistical analysis involved converting the hourly data into means tables based on the appropriate timeframe. In total, there were four means tables created for each of the two pilots (Dynamic and Legacy Dynamic) for a total of eight means tables. The means tables consisted of:

- Time-of-Use Period Impacts: Hourly means in kW for each defined peak period, for each month, for each household

- Average Conservation Impacts: Hourly means in kW for each month, for each household

Preprocessing also involved removing households based upon several exclusionary criteria. Households were excluded if they moved during the pilot, or if they actively opted-out of the program. Households were also excluded if they exhibited many consecutive missing hourly measurements. Households exhibiting missing data generally did so for several months or longer, thus a minimum threshold of one month of missing data was set for exclusion (see Section 4.2.4 Issues or Concerns for more information). Lastly, households were excluded if their mean hourly consumption was deviant relative to other households (i.e., they were classified as 'outliers', and thus not representative of a 'typical' household within the service territory). The operational definition of an outlier was any household that exhibited hourly consumption greater than 15 kWh or less than 0.05 kWh at any hour (i.e., hours 1-24, averaged across day) during the reporting period. Households that qualified under any exclusionary criteria were indexed and subsequently removed prior to statistical analyses.

4.2.3 Estimated Elasticities

The purpose of the Estimated Price Elasticity analysis is to measure the percent change in consumption relative to a percent change in price. Both own-price (daily) elasticity and inter-period substitution elasticity are computed:

- Own-Price Elasticity: Daily means in kW for each household

- Inter-Period Substitution Elasticity: Hourly means in kW for each Peak period, for each month, for each household

4.2.4 Issues or Concerns

There were issues concerning the completeness of the *Technology* data. Data was available from Alectra on households who had purchased a smart thermostat through their thermostat incentive program offerings, but this does not cover households who purchased a smart thermostat outside of Alectra and did not register those devices with Alectra at the commencement of the pilot. Households were asked about the presence of a smart thermostat in the baseline, interim, and end-of-pilot surveys. However, smart thermostats not registered with Alectra were not eligible for load curtailment. This means that all analyses related to the incremental impacts owing to smart thermostats will be restricted only to customers with registered devices that are capable of some form of load curtailment.

There was a disproportionate incidence of 'missing data' for the Dynamic Treatment (this issue only pertains to 'new' Dynamic Treatment customers, not Legacy Dynamic Treatment customers). Upon investigation, there was not enough historical baseline data for a number of customers in this group. As a result of the fact that historical data for at least one year prior to the unprotected period of the current pilot is required in order to employ our difference-in-difference methodology, customers with insufficient historical baseline data were excluded from analysis. The missing data in question was simply delivered to the evaluator by Alectra's operational data store as 'NA' values for the requested baseline period and so the evaluator cannot shed any further light on why customers were allowed to participate in the pilot without the requisite historical consumption data. We speculate, however, that customers opted-in to the pilot, not through direct solicitation by Alectra (since only customers within the eligible sample frame were subject to direct marketing) but instead through referral by neighbours, friends, or family members. Further investigation by Alectra Utilities would be required to unequivocally determine how these customers opted-in to the pricing Treatment plans offered under APP. The loss in sample size due to missing data within the 'new' Dynamic Treatment group was approximately 9.3% for the Winter 2018-2019 and Summer 2019 impact analyses.

4.3 Dependent Variables

In this section, we present the three main dependent variable categories:

- Time-of-Use Period Impacts (including Critical Peak)
- Average Conservation Impacts
- Estimated Price Elasticities

Next, we present a definition and impact estimation model specifications for each dependent variable category.

4.3.1 Time-of-Use Period Impacts

The purpose of the TOU period impact analysis is to measure the change in energy consumption for a Treatment group relative to a Control group during specific TOU periods as a function of pricing Treatment and/or non-price intervention.

We define Time-of-Use Period Impacts as: The year-over-year difference in the average hourly consumption per month, attributable to the pilot program intervention, calculated separately for each TOU period. The exception to this is the Legacy Dynamic pilot impact estimations. The primary reason for this is that no appropriate historical baseline period existed for all Legacy Dynamic participants. Consequently, Legacy Dynamic impacts were derived by simply comparing Treatment and Control customer consumption within the 17-month pilot period.

The weekdays and hours associated with each TOU period for the Dynamic pricing structure are shown below in Table 18.

Table 18: Dynamic Pricing kWh Prices (applicable for Dynamic and Legacy Dynamic)

Price Period	Hours	Price (cents/kWh)	
		Nov - April	May - Oct
Off-Peak	Weekdays: 12am-3pm and 9pm-12am Weekends: All day	4.9	4.9
Low On-Peak	50% of Weekdays: 3pm-9pm	10.0	9.9
Medium On-Peak	30% of Weekdays: 3pm-9pm	19.9	19.8
High On-Peak	20% of Weekdays: 3pm-9pm	39.8	39.7
Critical Peak	On the top six system peak days in Summer 2018 and Winter 2018-2019, and the top nine such days in Summer 2019, each event lasting four hours. Start time of events determined by peak demand hour of event day	49.8	49.8
System-Coincident Peak Impact	Nov-April	May-Oct	
	1pm-7pm (June, July, August) Weekdays and is based on the IESO's analysis of peak hourly load	6pm – 8pm (December, January, and February) Weekdays, and is based on the IESO's analysis of peak hourly load	

There was a slight deviation from the prescribed breakdown of Low, Medium, and High On-Peak days. The way Alectra determines the rate per day is based on the IESO's overall demand forecast – which is highly correlated to the weather forecast – which is variable and hard to predict. Alectra sets a threshold on the demand forecast that will determine if a day is Low, Medium, or High. Alectra adjusts the threshold to ensure that the correct number of day-types occur in each season while trying to be mindful of creating a consistent experience for customers. This means that, for example, if Alectra anticipates a very hot day late in the Summer season, they will plan to call a 'High' On-Peak price, but if it turns out to be a fairly mild day in reality, Alectra will instead call a 'Low' or 'Medium' On-Peak price in order to maintain consistency (from a customer's point of view) between actual experienced weather fluctuation and variable peak prices. For this reason, the realized percentages of Low, Medium, and High On-Peak days may differ slightly from what is prescribed by the OEB. The actual distribution of On-Peak and CPP days are presented in Table 19 through Table 21. Critical Peak day dates are listed in Table 22.

Table 19: Dynamic On-Peak and CPP Days (Summer 2018)

Dynamic On-Peak	Number of Days	% of Total	Prescribed by OEB
High	26	20%	20%
Medium	35	28%	30%
Low	66	52%	50%
CPP	6	n/a	n/a

Days are counted beginning May 1st, 2018

Table 20: Dynamic On-Peak and CPP Days (Winter 2018-2019)

Dynamic On-Peak	Number of Days	% of Total	Prescribed by OEB
High	27	22%	20%
Medium	34	27%	30%
Low	63	51%	50%
CPP	6	n/a	n/a

Days are counted beginning November 1st, 2018

Table 21: Dynamic On-Peak and CPP Days (Summer 2019)

		Dynamic 6		Dynamic 9	
On-Peak Pricing	Prescribed by OEB	Number of Days	% of Total	Number of Days	% of Total
High	20%	25	24%	24	23%
Medium	30%	38	36%	39	37%
Low	50%	42	40%	42	40%
CPP		6	n/a	9	n/a

Days are counted beginning May 1st, 2019

Table 22: Dates of Critical Peak Days

	Summer 2018	Winter 2018-19	Summer 2019
CPP Day 1	2018-06-18	2019-01-21	2019-07-04
CPP Day 2	2018-07-04	2019-01-31	2019-07-05
CPP Day 3	2018-07-05	2019-02-13	2019-07-16
CPP Day 4	2018-07-16	2019-02-19	2019-07-19
CPP Day 5	2018-08-07	2019-02-27	2019-08-13
CPP Day 6	2018-08-28	2019-03-04	2019-08-20
CPP Day 7			2019-08-21
CPP Day 8			2019-09-11
CPP Day 9			2019-09-20

4.3.2 Dynamic Pricing Pilot Analytic Approach

A difference-in-difference (DID) approach was used to measure the effect of TOU period on household energy consumption for all Dynamic pricing TOU peak impact estimations. In order to employ a DID approach for TOU period impact estimations for the Dynamic pilot, there is an additional step required in order to determine the appropriate historical baseline consumption period. This additional step deals with the fact that Dynamic pricing customers were not exposed to Dynamic On-Peak TOU periods under Status-Quo TOU pricing in the historical baseline period. We solve for this issue here by capitalizing on the fact that there was a Legacy Dynamic pricing program in effect for a separate group of Alectra customers during the historical baseline period. As a result, we are able to compute historical baseline consumption for Dynamic customers separately for High, Medium, and Low On-Peak days based on whether the weekdays contained within the historical baseline period were called as High, Medium, or Low On-Peak days for the Legacy Dynamic pricing customers at that time.

Estimated TOU period impacts are averages and were calculated separately for the Summer (May – October) and Winter (November – April) periods. Estimated impacts were calculated based on mean hourly kW consumption using linear regression models (Equations 4.1 and 4.2), with estimations of the impact as a corresponding percentage change derived from the mean hourly kW impact (discussed further below). Consumption impacts deriving from pricing manipulation, communication (i.e., Nudge Report) manipulation, and the interaction of the price and communication manipulation are estimated, as relevant.

The Dynamic pilot assessed the impact of TOU period pricing and the Nudge Report in a duel-factor model (Equations 4.1). The Nudge Reports that were distributed to randomly selected households within the Dynamic pricing pilot contained monthly consumption feedback and personalized conservation tips to recipients. The consumption feedback was delivered as a visual depiction of On-Peak electricity consumption that benchmarked households to their On-Peak consumption at the same time in the previous year. For this reason, we hypothesized that even though personalized conservation tips were not TOU period specific, the On-Peak specificity of the consumption feedback may result in Nudge Reports imparting a differential effect on On-Peak consumption. We might expect therefore, that when pricing signals are sufficient to drive motivations to reduce On-Peak consumption (as was the intention of Dynamic pricing) that Nudge Reports would convey particularly useful consumption feedback information for participants. For this reason, we may expect that the effect of Nudge Reports interacts with the effect of pricing condition *only* for higher-priced TOU periods.

Because we hypothesized a potential interaction between price Treatment and Nudge Report, we calculated models with the inclusion of an interaction term Equation 4.1. We outlined an a priori analytical procedure in (a) the case that the interaction would be significant, in which case we report all lower order factor results from the interaction model (Equation 4.1), and (b) the case that the interaction would be non-significant, in which case we re-calculate the models including only the main effects and no interaction term (Equation 4.2), and we report main effects from this model. This is a reasonable approach because the coefficients of the predictors represent difference values depending on whether the model includes or does not include an interaction term. In regression, adding interaction terms changes the coefficients of the lower order predictors from main effects to *conditional effects*[24]. Main effects describe the impact of one predictor across all levels of the other, while a conditional effect means that the effect of one predictor is conditional on the value of the other. In our models, this means that the coefficient associated with the conditional effect of Price Treatment ($\beta_1\ Price_P$) describes the impact of Price Treatment only for the No Nudge Report households (i.e. $Price_P | Communication_C$=0). This makes intuitive sense when you consider that a significant interaction indicates that $Price_P$ varies depending on $Communication_C$; therefore, it would not also be appropriate to interpret a main effect of $Price_P$ that would be consistent across all levels of $Communication_C$. Following the same rationale in the case of a non-significant $Price_P * Communication_C$ interaction, interpretation of the conditional effect of the lower order effects as the full story of the impact of those factors is obviously incomplete. In this case, it is appropriate to drop the interaction term and calculate a model with only main effects, which describe the effect of one factor independent of the other factors in the model. To minimize confusion, coefficients from non-significant interactions are not reported in the results tables to clarify that reported main effects were derived from a model that did not include the interaction. To foreshadow, none of the Price by Communication interactions reached statistical significance for any TOU period analysis for either pilot (i.e., Dynamic and Legacy Dynamic). As such, all impact estimates for the effect of Price and Communication derive from linear models that did not include the interaction term. All models calculated with and without interactions are included in Appendix I for reference, regardless of statistical significance.

$$(4.1) \quad (PostTOUUsage_i - PreTOUUsage_i) = \alpha + \beta_1\ Price_P + \beta_2\ Communication_C + \beta_3\ Price_P * Communication_C + \varepsilon_i$$

[24] Stevens, J. (1996). *Applied Multivariate Statistics for the Social Sciences* (3rd ed.). Lawrence Erlbaum Associates.

(4.2) $(PostTOUUsage_i - PreTOUUsage_i) = \alpha + \beta_1 \, Price_P + \beta_2 \, Communication_C + \beta_3 + \varepsilon_i$

Where,

PostTOUUsage	=	Average hourly TOU-period kW consumed during experimental period by household *i*
PreTOUUsage	=	Average hourly TOU-period kW consumed during pre-experiment period by household *i*
Price	=	Dummy indicator denoting presence of price manipulation
Communication	=	Dummy indicator denoting presence of communication manipulation
i	=	Indicates individual household
ε	=	Indicates regression error term

It is also worth noting that the TOU period DID regression models do not cluster standard errors, compared to what has sometimes become common practice in certain disciplines when dealing with panel regression data. Clustering standard errors, and other corrections for possible biases in standard error estimation, are common in two econometric circumstances. The first is when the experimental design is such that there are within-condition sub-groups or clusters[25]. A common example of this is when researchers are examining the effects of a law compared to some States without the same law, usually by employing a difference-in-difference model. Because of the high within-State correlation in dependent variable scores, it is important to adjust the standard errors by these geographic clusters. Secondly, some researchers, such as Bertrand and colleagues[26] describe that although standard error correction in difference-in-difference studies without geographical or other a priori clusters was not common at the time of publication, it is advisable because the serial correlation of many data points in a timeseries may underestimate the true standard error. We did not make any adjustments to the standard errors in our analyses because our models do not fulfill either of these criteria. We did compute a difference-in-difference; however, we did not fit a regression line to a timeseries in order to model change across time, as would be cautioned by Bertrand. Our approach calculates one timepoint change from baseline to Treatment period for the Treatment and Control groups, aggregating over all measurements within the given time window. In this method, each participant has one difference score, and these difference scores are compared between Treatment and Control groups. The potential for standard error bias becomes apparent as the number of timepoints in the model increases to levels not modelled in the present study. Finally, Abadie and his collaborators[27] have recently argued that standard error correction as a default choice in a broad range of circumstances without strong theoretical basis is overly conservative.

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[25] Cameron, A. C., & Miller, D. (2015). A Practitioner 's Guide to Cluter-Robust Inference. *The Journal of Human Resources*, *50*(2), 317–372.
[26] Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How Much Should We Trust Differences-in-Differences Estimates? Quarterly Journal of Economics, 119(1), 249–275.
[27] Abadie, A., Athey, S., Imbens, G., & Wooldridge, J. (2017). When Should You Adjust Standard Errors for Clustering? *National Bureau of Economic Research, Working Paper No. 24003.*

4.3.3 Legacy Dynamic Pricing Pilot Analytic Approach

The approach used to estimate TOU period consumption impacts amongst Legacy Dynamic pricing participants differed from the difference-in-difference (DID) approach used for 'new' Dynamic pilot impact estimations. The Legacy Dynamic program began in 2014, meaning that the employment of a DID approach to impact estimation is problematic. Mainly, in order to compare consumption in the current pilot period (May 01, 2018 – April 30, 2019) to a pre-Treatment historical baseline period, a historical data set that is (in many cases) over four years old would have to be used. Aside from the fact that hourly consumption data dating back this far was not provided to the evaluator for both Legacy Dynamic Treatment and matched Control participants at the time of impact evaluation, the logistics of employing a DID approach is further complicated by the fact that Legacy Dynamic pricing customers enrolled into Dynamic pricing at three different historical time periods, meaning that different historical baseline periods would have to be used for different groups of customers within the Legacy Dynamic customer group (this is discussed further below). It is for these reasons that we compare Legacy Dynamic households with Status-Quo TOU Control households in each year on record separately, without using the DID approach. Given this, caution should be used when making qualitative or quantitative comparisons between Dynamic and Legacy Dynamic impacts. Legacy Dynamic participants have been exposed to the Dynamic pricing structure for (in some cases) up to four years, whereas newly enrolled Dynamic participants have only been exposed to Dynamic pricing for a little over a year and a half. Even with this in mind, any comparisons made between these two groups of customers would not provide an accurate picture of the effect of exposure duration to Dynamic pricing on electricity consumption behaviour. This is because Legacy Dynamic participants enjoyed full price protection for the entirety of the Legacy program. Thus, because of differences in the analytical approach, differential exposure durations to Dynamic pricing, and differences in the length of exposure to price protection, making any comparisons between the Legacy and newly enrolled Dynamic customer groups inappropriate.

Because of the inherited legacy nature of the Legacy Dynamic group, none of the Status-Quo TOU Control participants received Nudge Reports (recall that premise IDs for Summer and Winter matched Control households for the Legacy group were not available in time to generate custom reports for this group). Therefore, the effect of TOU price structure (Dynamic vs. Status-Quo TOU) was examined between Treatment and Control participants (Equation 4.3), and separate linear analyses examined the effect of Nudge Reports within the Legacy Dynamic Treatment group only (Equation 4.4). Full results of all models are reported in Appendix I.

(4.3) $$PostTOUUsage_i = \alpha + \beta_1 \, Price_P + \varepsilon_i$$

(4.4) $$PostTOUUsage_i = \alpha + \beta_1 \, Communication_C + \varepsilon_i$$

Where,

PostTOUUsage	=	Average hourly TOU-period kW consumed during experimental period by household *i*
Price	=	Dummy indicator denoting presence of price manipulation

Communication	=	Dummy indicator denoting presence of communication manipulation
i	=	Indicates individual household
ε	=	Indicates non-clustered regression error term

Estimated impacts are averages and are calculated separately for the Summer 2018 (May – October), Winter 2018-19 (November – April) and Summer 2019 (June-October 2019) periods.

4.3.4 Average Conservation Impacts

The purpose of the Average Conservation Impact analysis is to measure the difference in electricity consumption between the Treatment and Control groups during each seasonal period and the entire duration of the pilot as a function of TOU price plan and/or non-price intervention.

We define Average Conservation Impact for the Dynamic pilot as the year-over-year difference in the average hourly consumption per month, calculated in the Summer 2018, Winter 2018-19, Summer 2019, and 17-month pilot period. For the Legacy Dynamic pilot, Average Conservation Impact is calculated within the 17-month Treatment period only (i.e., not a year-over-year change as per the DID approach used for 'new' Dynamic). The Summer period is defined as May 1st to October 31st (Summer 2019 analysis begins in June), and the Winter period is November 1st – April 30th. Average Conservation Impacts are collapsed across TOU periods. Note that the use of different Legacy Dynamic matched Control groups during the different seasonal periods precludes a year-round or full 17-month analysis of average conservation.

The analytical approach mirrored that of the TOU period impact estimation for each pilot. Impacts for Summer, Winter, 12-months, and 17-months are estimated based on mean kW consumption differences for pricing Treatment, communication Treatment (i.e., Nudge Reports), and the interaction between price and communication Treatments, as relevant for each pilot. The linear regression models for the Dynamic pilot used to estimate average conservation impacts with and without interaction terms are represented algebraically in Equations 4.5 and 4.6, and Legacy Dynamic linear models are represented in Equations 4.7 and 4.8.

(4.5) $$\left(PostAvgHourlyUsage_i - PreAvgHourlyUsage_{i,}\right) = \alpha + \beta_1\,Price_P + \beta_2\,Communication_C + \beta_3\,Price_P * Communication_C + \varepsilon_i$$

(4.6) $$\left(PostAvgHourlyUsage_i - PreAvgHourlyUsage_{i,}\right) = \alpha + \beta_1\,Price_P + \beta_2\,Communication_C + \varepsilon_i$$

(4.7) $$PostAvgHourlyUsage_i = \alpha + \beta_1\,Price_P + \varepsilon_i$$

(4.8) $$PostAvgHourlyUsage_i = \alpha + \beta_1\,Communication_C + \varepsilon_i$$

Where,

PostAvgHourlyUsage	=	Average kWs consumed per hour in each month for household *i*, averaged over all experimental period months
PreAvgHourlyUsage	=	Average kWs consumed per hour in each month for household *i*, averaged over all pre-experimental period months
Price	=	Dummy indicator denoting presence of price manipulation
Communication	=	Dummy indicator denoting presence of communication manipulation
i	=	Indicates individual household
ε	=	Indicates regression error term

4.3.5 Smart Thermostat Technology

Separate analyses are performed to assess the impacts of smart thermostat technology within each of the pricing pilots. Our estimation of consumption impacts owing to smart thermostats is completed using verified thermostat registration data obtained from Alectra. However, exact timing of smart thermostat installation for each household remains unknown; therefore, Technology impacts are analyzed with linear models (Equation 4.9) comparing mean hourly kW consumption of households with and without registered smart thermostats during the Treatment period only, and we did not employ a difference-in-difference approach.

Since we do not have data regarding thermostat acquisition dates for many of the customers classified as belonging to the 'Technology' groups in this pilot, it means that 'Technology' customers (those who registered a device as part of the pilot) fall into three distinct categories during the relevant historical baseline period:

1. Households who did not possess a smart thermostat at any point during the baseline (pre-pilot) period but acquired one for the start of the pilot period

2. Households who acquired a smart thermostat at some point during the baseline period, meaning they could benefit from programmable settings for some but not all of the baseline period used for differencing

3. Households who possessed a smart thermostat for the entirety of the baseline period, and simply registered that device at the commencement of the pilot

Given the heterogeneity of smart thermostat ownership status for the Technology group in the historical baseline period, we wanted to avoid introducing this 'noise' into the analysis via a difference-in-difference methodology. Put another way, if we employed a DID approach, then for some individuals, the estimated Treatment effect would be that of thermostat ownership AND registration, for others it would represent the effect of thermostat ownership AND registration for some but not all time periods, and yet for others, the DID method would deliver an effect solely of thermostat registration. By simply comparing customers with registered devices during the pilot period to customers without registered devices it ensures that at least our Treatment group consumption derives entirely from both thermostat ownership AND registration. The linear model used to estimate Technology impacts is shown algebraically in Equation 4.9.

(4.9) $PostTOUUsage_i = \alpha + \beta_1\, Technology_T + \varepsilon_i$

PostAvgHourlyUsage	=	Average hourly kW consumed during experimental period by household *i*
Technology	=	Dummy indicator denoting presence of smart thermostat technology
i	=	Indicates individual household
ε	=	Indicates regression error term

4.3.6 Estimated Price Elasticity

The purpose of the Estimated Price Elasticity analysis is to measure the percent change in consumption relative to a percent change in price. Both own-price (daily) elasticity and inter-period substitution elasticity will be measured over the 17-month Treatment period.

We define Own-Price (Daily) Elasticity as: The percent change in hourly electricity consumption relative to the percent change in hourly electricity price.

We define Inter-Period Substitution Elasticity as: The percent change in the ratio of On-Peak to Off-Peak electricity consumption relative to the percent change in the ratio of On-Peak to Off-Peak electricity price.

The regression models for the Estimated Price Elasticity analysis is represented algebraically in Equation 4.14 for own-price elasticity and Equation 4.15 for inter-period substitution elasticity.

(4.14) $ln\,(Q_d) = \alpha + \eta\, ln\,(P_d) + \delta_1\, CDH_d + \delta_2\, HDH_d + \sum_{i=1}^{N} \theta_i D_i + \varepsilon_{i,d}$

(4.15) $ln\left(\frac{Q_{on-peak,d}}{Q_{off-peak,d}}\right) = \alpha + \sigma\, ln\left(\frac{P_{on-peak,d}}{P_{off-peak,d}}\right) + \delta_1\,(CDH_{on-peak,d} - CDH_{off-peak,d}) + \delta_2\,(HDH_{on-peak,d} - HDH_{off-peak,d}) + \sum_{i=1}^{N} \theta_i D_i + \varepsilon_{i,d}$

Where,

Q	=	kW consumed per hour averaged across day *d*
P	=	Electricity Price per hour averaged across day *d*
CDH	=	Cooling Degree hours per hour averaged across day *d*
HDH	=	Heating Degree hours per hour averaged across day *d*
D	=	Dummy indicator for each individual day
i	=	Indicates individual household
ε	=	Indicates regression error term

4.3.7 Estimated Percentage Impacts

In all Dynamic pilot results summary tables, mean hourly kW Treatment estimates represent the difference in year-over-year kW consumption in each TOU period for participants receiving a price/non-price Treatment, relative to participants in the appropriate Control group. We extrapolate percent impact from these mean hourly kW consumption estimates by dividing the impact coefficient by the relevant Treatment group's counterfactual consumption, which we derived by subtracting the impact coefficient from the Treatment group's observed consumption in the unprotected pilot period. From Equation 4.1:

$$\%\ impact = \frac{\widehat{\beta_1}}{\left(PostTOUUsage_i - \widehat{\beta_1}\right)}$$

As such, percent impact estimates represent the percentage in the pilot period by which the observed consumption in the Treatment group differs from their counterfactual consumption had they not been exposed to the Treatment.

4.3.8 Estimation of Dynamic Pilot Summer vs. Winter Impacts Analysis

Beginning in October 2017, eligible households from the sample frame were contacted via direct marketing efforts to voluntarily sign up for the Dynamic pricing plan (again, marketed as Advantage Power Pricing). All Advantage Power Pricing (APP) participants were then placed into a full price protection period meaning that bill savings accrued as a result of participation in the APP program (relative to what charges for consumption would have been under Status-Quo TOU pricing) were credited to their subsequent electricity invoices, but any additional costs owing to APP participation were not charged. This protected period lasted until March 31, 2018 (Table 23).

Due to the difference-in-difference methodology employed to estimate consumption impacts for the Dynamic pilot, pre-Treatment baseline consumption data is required for each household. The Summer 2018 Treatment and the Summer 2019 Treatment extension period use the pre-Treatment period of Summer 2017 as baseline for the DID calculations. For example, a household's On-Peak consumption during May 2018 is compared to their consumption in May 2017, when they were not in the pilot. Since the price protection period ran from October 2017 to March 2018, this time period could not be used as a pre-Treatment baseline period for the Winter impact analysis (which covers November 2018 to April 2019). In order to circumvent this issue, we obtained consumption data from the year previous to the protected period for all participants (November 2016 – April 2017). In short, this means that the pre-Treatment historical baseline data used for the DID impact estimation for the Summer periods is one year prior to the current pilot, whereas for the Winter impact estimation, the pre-Treatment historical baseline data is two years prior to the current pilot.

Winter impact analyses derive from a comparison of consumption data from the unprotected-Treatment period (Nov 2018 – April 2019) to the pre-Treatment period (Nov 2016 – April 2017). However, we do not present data from the protected-Treatment period (Nov 2017 – April 2018) as we do not have any a priori hypotheses regarding the effects of the pricing pilots on price-protected consumption and due to the fact that the duration of the protected period is variable across customers in the Dynamic pilot depending on enrollment date (since enrollment continued throughout the entire protected period).

Table 23: Treatment period names

Winter Season Analysis		
Pre-Treatment Period	Protected-Treatment Period	Unprotected-Treatment Period
November 2016 – April 2017	November 2017 – April 2018	November 2018 – April 2019

5. Results

5.1 Bill Savings

Here we present customers' bill savings (or additional costs) owing to APP participation (shown in Table 24). These values are calculated by taking the difference between Dynamic and Legacy Dynamic customers' APP bill amounts and what customers would have paid if they exhibited the same consumption behaviour but had been billed as per Status-Quo TOU. Monetary savings are denoted as positive and costs are denoted as negative. This method of calculating bill savings is how Alectra determined whether or not a given customer was saving money as a result of pilot participation (which would appear as a bill credit on the next billing cycle) or is paying more (which was reflected as the billable amount on their billing cycle invoice). Average monthly bill savings indicate that Dynamic participants experienced small savings in the Summer period and moderate savings in the Winter period, with Legacy Dynamic customers seeing slightly larger savings. However, all participants experienced costs in Summer months (July and August), indicating that electricity-saving behaviours in particularly hot months, during On-Peak times of day were less frequent. Figures showing the distribution of the total bill savings amounts per pricing pilot are shown in Appendix D.

Table 24: Monthly Bill Savings

Summer 2018	May	June	July	August	September	October	Average Monthly Savings
Dynamic	$11.93	$4.99	-$17.80	-$12.64	$2.37	$12.81	$0.28
Legacy Dynamic	$11.73	$5.22	-$16.45	-$11.01	$2.99	$12.34	$0.81
Winter 2019-19	**November**	**December**	**January**	**February**	**March**	**April**	**Average Monthly Savings**
Dynamic	$13.98	$10.14	-$0.79	-$14.42	-$3.19	$10.54	$2.71
Legacy Dynamic	$14.54	$10.43	-$1.31	-$16.16	-$3.84	$11.01	$2.45
Summer 2019	**May**	**June**	**July**	**August**	**September**	**October**	**Average Monthly Savings**
Dynamic CPP 6	--	$12.25	-$12.04	-$22.28	-$2.46	$8.78	-$3.15
Dynamic CPP 9	--	$11.40	-$13.19	-$21.56	-$1.21	$8.96	-$3.12
Legacy Dynamic CPP 6	--	$11.44	-$12.51	-$19.64	-$0.36	$9.06	-$2.40
Legacy Dynamic CPP 9	--	$11.57	-$12.53	-$19.67	-$0.16	$9.27	-$2.30

Bill Savings are Denoted as Positive

5.2 Seasonal Temperatures

Average seasonal temperatures for each Dynamic TOU price period are presented in Table 25.

Table 25: Average seasonal temperature in degrees Celsius per Time-of-Use Pricing Period

Average temperature in degrees Celsius	Summer 2018	Winter 2018-19	Summer 2019	
			Dynamic 6[28]	Dynamic 9
High On-Peak	27.38	-6.35	23.17	23.07
Medium On-Peak	24.06	-0.88	19.41	19.41
Low On-Peak	16.34	4.8	13.25	13.25
Off-Peak	18.16	-0.81	18.49	18.54
Total CPP	26.63	-10.35	23.49	
CPP Day 1	27.3	-13	25.35	
CPP Day 2	28.03	-17.03	25.73	
CPP Day 3	25.68	-4.5	24.53	
CPP Day 4	23.45	-6.23	26.9	
CPP Day 5	26.3	-10.9	22.5	
CPP Day 6	29.03	-10.43	23	
CPP Day 7	--	--	23.95	
CPP Day 8	--	--	19.8	
CPP Day 9	--	--	19.65	

5.3 Dynamic Pricing Pilot

5.3.1 Sample Size and Summary Statistics

The number of participants in the Dynamic pricing pilot is displayed in Table 26. The Dynamic pilot began with 1,540 participants evenly distributed between the four Treatment and Control groups. At the end of the pilot extension period (October 30th, 2019) the number of participants was 1,076. Participant drop off was due to either households moving out of the service territory, households opting out of the program, missing data[29], or the household consumption was deemed to be an outlier[30]. In addition, there were a small number of households participating in a

[28] Note that for the Dynamic 6 group, CPP days 4, 5, & 7 were called as High On-Peak days, whereas for the Dynamic 9 group all CPP days (1 through 9) were called as Critical Peak Pricing events.
[29] See Section 4.2.4 Issues or Concerns for further explanation.
[30] An outlier was defined as any household who consumed more than 15kWh or less than 0.05kWh during any hour in the analysis period

separate Electric Vehicle (EV) usage pilot that began in September 2019, these households were also excluded from impact analyses pertaining to Dynamic pricing.

Table 27 through Table 29 present a summary of average hourly kW consumption for the Dynamic pilot for the pre-Treatment baseline periods of 2016-17 and the Treatment period of 2018-19.

Table 26: Number of Participants for Dynamic Pilot

Summer 2018 Reporting Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data[31]	Outliers	Total Exclusions	Final N
Dynamic Pricing, No Nudge Report	385	34	9	0	0	4	47	338
Dynamic Pricing + Nudge Report	385	29	6	0	0	5	40	345
Status-Quo TOU Pricing, No Nudge Report	385	0	14	0	1	6	21	364
Status-Quo TOU Pricing + Nudge Report	385	1	17	0	0	5	23	362
Total	1540	64	46	0	1	20	131	1409
Winter 2018-19 Reporting Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data	Outliers	Total Excls.	Final N
Dynamic Pricing, No Nudge Report	338	25	8	0	70	0	103	235
Dynamic Pricing + Nudge Report	345	38	4	0	67	1	110	235

Winter 2018-19 Reporting Period

[31] See Section 4.2.4 Issues or Concerns for further explanation.

	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data	Outliers	Total Excls.	Final N
Status-Quo TOU Pricing + Nudge Report	362	4	14	0	0	3	21	341
Total	1409	67	46	0	137	6	256	1153
Summer 2019 Extension Period								
	Starting N	Opt-Outs	Move-Outs	EVs	Missing Data	Outliers	Total Excls.	Final N
Dynamic 6 Pricing, No Nudge Report	120	2	9	1	0	1	13	107
Dynamic 9 Pricing, No Nudge Report	108	5	4	1	0	0	10	98
Dynamic 6 Pricing + Nudge Report	115	3	5	2	0	0	10	105
Dynamic 9 Pricing + Nudge Report	127	6	2	1	0	0	9	118
Status-Quo TOU Pricing, No Nudge Report	342	0	12	0	0	4	16	326
Status-Quo TOU Pricing + Nudge Report	341	4	13	0	0	2	19	322
Total	1153	20	45	5	0	7	77	1076

Table 27: Summary of Consumption in Mean Hourly kW per Condition for Dynamic Pilot (Summer 2017/18 Periods)

Summer Period (kWh)	Status-Quo TOU Pricing, No Nudge Report	New Dynamic Pricing, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	New Dynamic Pricing + Nudge Report

High-Peak 2017	Mean	1.185	1.225	1.252	1.175
	SD	0.855	0.974	1.012	0.736
High-Peak 2018	Mean	1.974	1.802	2.072	1.688
	SD	1.204	1.276	1.319	0.994
Medium-Peak 2017	Mean	1.243	1.276	1.301	1.212
	SD	0.817	0.972	0.986	0.702
Medium-Peak 2018	Mean	1.647	1.509	1.718	1.427
	SD	1.011	1.100	1.175	0.852
Low-Peak 2017	Mean	1.102	1.145	1.154	1.078
	SD	0.710	0.870	0.866	0.607
Low-Peak 2018	Mean	1.088	1.053	1.131	0.995
	SD	0.722	0.803	0.860	0.607
Off-Peak 2017	Mean	0.851	0.902	0.892	0.850
	SD	0.545	0.706	0.725	0.475
Off-Peak 2018	Mean	0.966	1.021	1.017	0.971
	SD	0.608	0.726	0.781	0.588
Total 2017	Mean	1.084	1.126	1.137	1.068
	SD	0.750	0.892	0.911	0.648
Total 2018	Mean	1.397	1.331	1.462	1.256
	SD	0.994	1.042	1.131	0.828

Table 28: Summary of Consumption in Mean Hourly kW per Condition for Dynamic Pilot (Winter Period)

Winter Period (kWh)	Status-Quo TOU Pricing, No Nudge Report	New Dynamic Pricing, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	New Dynamic Pricing + Nudge Report

High-Peak 16-17	Mean	1.194	1.170	1.181	1.104
	SD	0.754	0.829	0.799	0.599
High-Peak 18-19	Mean	1.198	1.059	1.216	1.008
	SD	0.733	0.703	0.905	0.523
Medium-Peak 16-17	Mean	1.121	1.085	1.126	1.030
	SD	0.667	0.727	0.760	0.521
Medium-Peak 18-19	Mean	1.154	1.041	1.175	0.985
	SD	0.698	0.699	0.831	0.515
Low-Peak 16-17	Mean	1.047	1.028	1.082	0.986
	SD	0.615	0.723	0.732	0.527
Low-Peak 18-19	Mean	1.096	1.019	1.125	0.949
	SD	0.663	0.696	0.771	0.492
Off-Peak 16-17	Mean	0.864	0.838	0.854	0.800
	SD	0.531	0.604	0.583	0.416
Off-Peak 18-19	Mean	0.918	0.896	0.922	0.865
	SD	0.566	0.578	0.670	0.454
Total 16-17	Mean	1.040	1.014	1.046	0.966
	SD	0.646	0.725	0.725	0.524
Total 18-19	Mean	1.076	0.996	1.094	0.944
	SD	0.666	0.669	0.790	0.496

Table 29: Summary of Consumption in Mean Hourly kW per Condition for Dynamic Pilot (Summer 2019 Period)

Summer Period 2019 (kWh)	Status-Quo TOU Pricing, No Nudge Report	Dynamic 6, No Nudge Report	Dynamic 9, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	Dynamic 6 + Nudge Report	Dynamic 9+ Nudge Report

High-Peak 2019	Mean	1.696	1.568	1.542	1.696	1.479	1.387
	SD	1.077	1.343	1.171	1.077	0.964	0.823
Medium-Peak 2019	Mean	1.33	1.238	1.223	1.33	1.17	1.098
	SD	0.89	1.203	1.008	0.89	0.71	0.688
Low-Peak 2019	Mean	0.991	0.992	0.956	0.991	0.93	0.886
	SD	0.629	0.977	0.689	0.629	0.513	0.508
Off-Peak 2019	Mean	0.926	0.986	0.969	0.926	0.938	0.896
	SD	0.618	0.925	0.737	0.618	0.534	0.522
Total 2019	Mean	1.232	1.196	1.149	1.232	1.13	1.046
	SD	0.882	1.146	0.933	0.882	0.739	0.663

5.3.2 Time-of-Use Period Impacts, Seasonal Impacts, and Elasticities

Because of the difference-in-difference methodology employed here to estimate consumption impacts, there is an additional step required in order to determine the appropriate historical baseline consumption period for the estimation of TOU period impacts for Dynamic pricing customers. During the pilot period, customers participating in Dynamic pricing experienced either a High, Medium, or Low On-Peak price on any given day according to the breakdown in Table 19 and Table 20. This slightly complicates the derivation of historical baseline consumption for each of these three variants of On-Peak pricing since, of course, these customers were not exposed to Dynamic On-Peak prices under Status-Quo TOU pricing in the historical baseline period. We solve for this issue here by capitalizing on the fact that there was a Legacy Dynamic pricing program in effect for a separate group of Alectra customers (results of which are reported in the next section) during the historical baseline period. As a result, we are able to compute historical baseline consumption for Dynamic customers separately for High, Medium, and Low On-Peak days based on whether the weekdays contained within the historical baseline period were called as High, Medium, or Low On-Peak days for the Legacy Dynamic pricing customers at that time.

TOU period impacts owing to Dynamic pricing are displayed in Table 30 to Table 32. For the Summer 2018 period during the three On-Peak periods (High, Medium, and Low), the estimated consumption impacts for participants exposed to Dynamic pricing are -0.260 kW, -0.186 kW, and -0.069 kW per hour, respectively. For the Winter 2018-19 period during the three On-Peak periods (High, Medium, and Low), estimated consumption impacts for participants exposed to Dynamic pricing are -0.122 kW, -0.085 kW and -0.069 kW per hour, respectively. During the Summer 2019 extension period, the estimated impact of High On-Peak pricing is -0.148 kW for the Dynamic 6 group and -0.121 kW for the Dynamic 9 group, while the impact of Medium On-

Peak pricing is -0.155 kW (Dynamic 6) and -0.100 kW (Dynamic 9). There was no significant impact of Off-Peak pricing in either Summer 2018, Winter 2018-2019, or Summer 2019.

Any differences in energy consumption associated with the Nudge Report during On- or Off-Peak periods were not found to be statistically significant.

Table 30: Dynamic Pilot Impact Analysis Results – Summer 2018

Summer 2018	Dynamic Pricing (Main Effect)		Nudge Report (Main Effect)	
	Mean Hourly kW	%[32]	Mean Hourly kW	%[33]
High On-Peak Effects	**-0.26*****	-12.968	-0.015	-0.792
Medium On-Peak Effects	**-0.186*****	-11.245	-0.002	-0.127
Low On-Peak Effects	**-0.069*****	-6.313	0.000	0
Off-Peak Effects	0.000	0	0.007	0.709
System-Coincident Peak	**-0.161*****	-10.651	-0.003	-0.207

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 31: Dynamic Pilot Impact Analysis Results – Winter 2018-19

Winter 2018-19	Dynamic Pricing (Main Effect)		Nudge Report (Main Effect)	
	Mean Hourly kW	%	Mean Hourly kW	%

[32] % impacts are calculated as kW impact / (PostTOUUsage - kW impact), where PostTOUUsage is the average consumption between the Dynamic Pricing + Nudge Report and Dynamic Pricing + No Nudge Report groups from table 27.

[33] % impacts are calculated as kW impact / (PostTOUUsage - kW impact), where PostTOUUsage is the average consumption between the Dynamic Pricing + Nudge Report and Standard TOU Pricing + Nudge Report groups from table 27.

High On-Peak Effects	**-0.122*** **	-10.558	0.024	2.206
Medium On-Peak Effects	**-0.085*** **	-7.741	0.009	0.84
Low On-Peak Effects	**-0.069*** **	-6.553	-0.016	-1.519
Off-Peak Effects	0.001	0.114	0.011	1.246
System-Coincident Peak	-0.027	-2.738	0.008	0.824

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 32: Dynamic Pilot Impact Analysis Results - Summer 2019

Summer 2019		High On-Peak Effects	Medium On-Peak Effects	Low On-Peak Effects	Off-Peak Effects	System-Coincident Peak
Dynamic 6 Pricing (Main Effect)	Mean Hourly kW	**-0.148*** **	**-0.115*** **	-0.045	-0.002	**-0.159*** **
	%	-8.528	-8.719	-4.473	-0.207	-11.015
Dynamic 9 Pricing (Main Effect)	Mean Hourly kW	**-0.121*** **	**-0.1*** **	-0.038	-0.003	**-0.133*** **
	%	-7.632	-7.933	-3.962	-0.321	-9.661
Nudge Report (Main Effect)	Mean Hourly kW	-0.066	-0.036	-0.005	-0.01	**-0.057***
	%	-4.16	-2.914	-0.532	-1.075	-4.169

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

During the System-Coincident Peak hours, results differed between Summer and Winter (Table 30 to Table 32). In the Summer 2018 period, we estimated a -0.161 kW average hourly consumption impact attributable to Dynamic pricing. Similarly, Summer 2019 yielded -0.159 kW and -0.133 kW mean hourly impacts for the Dynamic 6 & 9 groups respectively during the System-Coincident Peak hours. In the Winter 2018-19 Period, consumption during System-

Coincident Peak hours did not differ between Dynamic pricing and Status-Quo TOU Control households. System-Coincident Peak hours during the Summer were from 1-7pm whereas they were from 6-8pm in the Winter. We postulate that individuals are more likely to be home between the hours of 6-8pm (vs. 1-7pm) resulting in a lower likelihood of conserving energy during these hours.

The Nudge Reports delivered consumption reductions of -0.057 kW per hour during the Summer 2019 System-Coincident Peak hours.

Seasonal Average Conservation Impacts are shown in Table 33. Overall, there was a marginally significant main effect of Dynamic pricing on total Summer 2018 electricity consumption amounting to approximately -0.024 kW per hour, and no significant effect during the Winter 2018-2019 or Summer 2019 seasons. Overall impacts of Dynamic pricing across the entire 17-month Treatment period, amount to significant consumption savings of approximately -0.025 kW per hour. The 12-month and 17-month impacts were calculated for participants who remained in the pilot for the full relevant period. Participants who left the pilot were removed from these multi-season analyses. Details are included in Appendix I.

In comparing Dynamic pricing pilot participants who received monthly Nudge Reports to those who did not receive Nudge Reports over the entire 17-month Treatment period, there were no significant differences in electricity consumption.

Table 33: Dynamic Pilot Seasonal Average Conservation Impact Analysis Results

		Dynamic Pricing		Nudge Report	
	n[34]	Mean Hourly kW	%	Mean Hourly kW	%

[34] The 17-month impact is larger than the un-weighted average of the seasonal averages because the 17-month impact is calculated for only the households who continued through the full 17-month duration of the program. For example, if the 12-month impact were calculated only for the 1076 households who continued to the end of the

Summer 2018 Impact	1409	-0.024^	-2.256	0.005	0.478
Winter 2018-19 Impact	1153	-0.014	-1.528	0.01	1.094
12-Month Impact	1153	-0.021	-2.126	0.007	1.226
Dynamic 6 Pricing Summer 2019	1076	-0.023	-2.242	-0.014	-1.398
Dynamic 9 Pricing Summer 2019	1076	-0.022	-2.219		
17-Month Impact	1076	**-0.025****	-2.47	0.000	0

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

Average hourly kW consumption for each CPP event is presented in Table 34. In order to compute the appropriate historical baseline consumption required to employ a difference-in-difference approach to the calculation of consumption impacts owing to CPP events, we once again capitalize on the existence of the Legacy Dynamic pricing pilot that was being run with a separate group of customers during the historical baseline period. This means that consumption impacts were calculated for each specific CPP day in the present pilot by first computing the difference between consumption for a given customer during a given CPP day in the current pilot (e.g., Winter, CPP Day 1) and their consumption during the corresponding CPP day in the baseline period. The three extra days marked as CPP for the Dynamic 9 group were marked as High On-Peak pricing for the Dynamic 6 group.

Table 34: Summary of Consumption in Mean Hourly kW per Dynamic Pilot Critical Peak Day (Summer 2018 Period)

Summer 2018 CPP		Status-Quo TOU Pricing, No Nudge Report	New Dynamic Pricing, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	New Dynamic Pricing + Nudge Report
CPP Day 1	Mean	1.977	1.696	2.077	1.582
	SD	1.441	1.600	1.568	1.254
CPP Day 2	Mean	2.500	2.181	2.556	2.014
	SD	1.664	1.636	1.62	1.346

program (not the 1153 households who were still enrolled at the end of the 12-monht reporting period), the 12-month impact estimate would be -0.27 kW.

CPP Day 3	Mean	2.113	1.819	2.075	1.676
	SD	1.473	1.503	1.58	1.242
CPP Day 4	Mean	1.562	1.309	1.804	1.26
	SD	1.277	1.246	1.571	1.044
CPP Day 5	Mean	1.914	1.612	2.068	1.562
	SD	1.461	1.391	1.588	1.326
CPP Day 6	Mean	2.208	1.906	2.346	1.777
	SD	1.523	1.65	1.663	1.295
Total	Mean	2.046	1.754	2.154	1.645
	SD	1.505	1.534	1.616	1.276

Table 35: Summary of Consumption in Mean Hourly kW per Dynamic Pilot Critical Peak Day (Winter 2018-19 Period)

Winter 2018-2019 CPP		Status-Quo TOU Pricing, No Nudge Report	New Dynamic Pricing, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	New Dynamic Pricing + Nudge Report
CPP Day 1	Mean	1.488	1.269	1.583	1.23
	SD	1.125	0.949	1.359	0.91
CPP Day 2	Mean	1.454	1.265	1.497	1.193
	SD	1.096	0.983	1.255	0.776
CPP Day 3	Mean	1.289	1.062	1.333	1.064
	SD	0.966	0.833	1.177	0.741
CPP Day 4	Mean	1.228	1.103	1.322	1.039
	SD	0.956	0.866	1.062	0.704
CPP Day 5	Mean	1.33	1.108	1.347	1.135
	SD	1.222	0.872	1.129	0.786
CPP Day 6	Mean	1.201	1.097	1.245	1.04
	SD	0.894	0.955	1.14	0.746
Total	Mean	1.326	1.146	1.383	1.113
	SD	1.052	0.911	1.193	0.783

Table 36: Summary of Consumption in Mean Hourly kW per Dynamic Pilot Critical Peak Day (Summer 2019 Period)

Summer 2019 CPP		Status-Quo TOU Pricing, No Nudge Report	Dynamic 6 Pricing, No Nudge Report	Dynamic 9 Pricing, No Nudge Report	Status-Quo TOU Pricing + Nudge Report	Dynamic 6 Pricing + Nudge Report	Dynamic 9 Pricing + Nudge Report
CPP Day 1	Mean	2.303	1.76	1.893	2.429	1.839	1.759
	SD	1.494	1.677	1.438	1.48	1.194	1.173
CPP Day 2	Mean	2.324	1.901	1.908	2.49	1.805	1.709
	SD	1.475	1.722	1.385	1.47	1.292	1.161
CPP Day 3	Mean	2.029	1.633	1.69	2.138	1.427	1.426
	SD	1.308	1.46	1.457	1.501	0.964	0.99
CPP Day/ High On-Peak	Mean	2.262	1.828	1.889	2.374	1.774	1.652
	SD	1.339	1.721	1.526	1.447	1.095	1.148
CPP Day 5/ High On-Peak	Mean	1.944	1.68	1.551	2.086	1.535	1.433
	SD	1.323	1.604	1.416	1.456	1.131	1.141
CPP Day 6	Mean	1.834	1.572	1.477	1.908	1.577	1.434
	SD	1.307	1.309	1.358	1.428	1.162	1.074
CPP Day 7/ High On-Peak	Mean	2.006	1.674	1.716	2.155	1.636	1.427
	SD	1.294	1.397	1.407	1.435	1.119	0.98
CPP Day 8	Mean	1.397	1.279	1.222	1.523	1.276	1.088
	SD	1.126	1.359	1.23	1.305	0.852	0.756
CPP Day 9	Mean	1.093	1.052	0.995	1.212	0.915	0.939
	SD	0.896	1.282	0.968	1.153	0.769	0.683
Total	Mean	1.91	1.598	1.593	2.035	1.531	1.43
	SD	1.353	1.528	1.39	1.467	1.108	1.053

The results for CPP events are shown in Table 37 to Table 39, and graphical representations of mean hourly consumption on each individual of the CPP event day are shown in Appendix G. Total CPP event impacts are show for both groups for both the 6 and the 9 CPP days. Calculating the average impact of the Dynamic 6 and Dynamic 9 groups over the 9 days allows for examination of the effect of the 3 additional CPP days over and above them being called as High On-Peak days. Impact estimates owing to Dynamic pricing during CPP hours amounted to -0.354 kW per hour on average in the Summer 2018 period and -0.168 kW per hour in the Winter period. In the Summer 2019 period, we looked at impact of Dynamic CPP pricing for the Dynamic 6 and the Dynamic 9 groups over both 6 days that were commonly CPP days, as well as for both groups over the additional 3 days that were marked as High On-Peak for the Dynamic 6 group and CPP events for the Dynamic 9 group. Over the 6 common CPP days, Dynamic 6 and Dynamic 9 pricing yielded significant average impacts of -0.367 and -.328 kW per hour, respectively. Impacts over the 9 days was -.382 kW per hour for the Dynamic 6 group and -0.349 kW per hour for the Dynamic 9 pricing. Importantly the two pricing Treatment groups did not significantly differ from each other (non-significant analyses comparing Dynamic 6 and 9 are included in Appendix I).

Nudge Reports delivered additional consumption impacts only on CPP Day 3 (-0.136 kW per hour) in Summer 2018. No other significant impacts were estimated owing to Nudge Reports. All Nudge Report impacts for CPP days can be found in Appendix I.

Table 37: Dynamic Pilot Critical Peak Day Impact Analysis Results (Summer 2018)

Summer 2018 CPP	Dynamic Pricing (Main Effect)	
	Mean Hourly kW	%
CPP Day 1	**-0.375*** **	-18.62
CPP Day 2	**-0.329*** **	-13.559
CPP Day 3	**-0.282*** **	-13.895
CPP Day 4	**-0.407*** **	-24.061
CPP Day 5	**-0.361*** **	-18.532
CPP Day 6	**-0.365*** **	-16.542
Total	**-0.354*** **	-17.239

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 38: Dynamic Pilot Critical Peak Day Impact Analysis Results (Winter 2018-19)

Winter 2018-2019 CPP	Dynamic Pricing (Main Effect)

	Mean Hourly kW	%
CPP Day 1	**-0.319*** **	-20.338
CPP Day 2	**-0.113***	-8.42
CPP Day 3	**-0.139*** **	-11.564
CPP Day 4	**-0.189*** **	-15
CPP Day 5	**-0.158*** **	-12.349
CPP Day 6	-0.094^	-8.086
Total	**-0.168*** **	-12.948

**** p < 0.001; ** p < 0.01; * p < 0.05; ^ p < 0.1*

For Summer 2019 CPP event impact estimates, (Table 39) CPP days 4, 5, and 7 were CPP days only for households assigned to the Dynamic 9 group. These three CPP days were called as High On-Peak days for households assigned to the Dynamic 6 group. CPP days 1, 2, 3, 6, 8, and 9 were called as CPP event days for households in both the Dynamic 6 and Dynamic 9 groups.

Table 39 : Dynamic Pilot Critical Peak Day Impact Analysis Results (Summer 2019)

Summer 2019 CPP	Main Effects of Price

	Dynamic 6 Pricing		Dynamic 9 Pricing	
	Mean Hourly kW	%	Mean Hourly kW	%
CPP Day 1	**-0.496*****	-21.607	**-0.42*****	-18.7
CPP Day 2	**-0.467*****	-20.129	**-0.433*****	-19.317
CPP Day 3	**-0.54*****	-26.087	**-0.405*****	-20.632
CPP Day 4	**-0.484*****	-20.903	**-0.405*****	-15.967
CPP Day 5	**-0.391*****	-20.217	**-0.416*****	-18.617
CPP Day 6	**-0.426*****	-21.295	**-0.436*****	-23.05
CPP Day 7	**-0.360*****	-17.866	**-0.358*****	-15.609
CPP Day 8	**-0.206*****	-13.886	**-0.218****	-15.878
CPP Day 9	-0.069	-6.556	-0.057	-5.566
Dynamic 6, 6 CPP Days	**-0.367*****	-19.001	**--**	---18.802
Dynamic 9, 9 CPP Days	**--**	--	**-0.349*****	-18.758
Total Impact Over 6 Common CPP Days	**-.367*****	-19.001	**-.328*****	-17.831
Total Impact Over 9 CPP Days	**-0.382*****	-19.625	**-0.349*****	-18.802

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$;

5.3.3 Elasticity

Daily and Substitution Elasticities for the full 17-month pilot Treatment period are reported in Table 40. Daily elasticity of demand was estimated at -0.107, whereas substitution elasticity of demand was estimated at -0.019; small changes in percent consumption per percent increase in price.

Table 40: Dynamic Pilot Daily and Substitution Elasticities of Demand

	Elasticity Estimate
Daily Elasticity	**-0.107*****
Substitution Elasticity On/Off-Peak	**-0.019*****

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

5.3.4 Technology Impacts

Dynamic pricing households were designated as "*Technology*" if they participated in a smart thermostat incentive program offered by Alectra Utilities. Exact timing of smart thermostat installation for each household remains unknown, therefore Technology is only analyzed comparing kWh consumption of households with and without registered smart thermostats (capable of receiving automatic load curtailment during On-Peak and CPP event periods) during the Treatment period, and we did not employ a difference-in-difference approach. Analyzing Technology only during the Treatment period avoids any noise introduced by potential smart thermostat usage during the pre-Treatment pricing period.

The distribution of registered smart thermostats as a function of pilot group and device type is presented in Table 41. Due to sample size restrictions, the Summer 2019 Dynamic 6 and 9 groups were combined into one Dynamic pricing group for all Technology analyses. Registered Honeywell and Nest thermostats were not capable of receiving load curtailment signals from Alectra for the Summer 2019 reporting period and therefore the 'Technology' group for Summer 2019 impact estimates includes only customers with registered Energate or Nest devices. Honeywell and Nest customers with registered devices were excluded entirely from the Summer 2019 Technology impact analysis, that is, they were not added to the control group. Summaries of average electricity consumption for Technology households are presented in Table 42, and the results of the Technology impact analysis are shown in Table 43, with Technology impacts during CPP events presented in Table 44 to Table 46.

Table 41: Number of Dynamic Pilot participants with registered smart thermostats

Summer 2018	Energate	Ecobee	Nest	Honeywell	Unknown[35]
Dynamic Pricing + Nudge Report	35	22	29	0	3

[35] A small number of households had duplicate smart thermostat registrations for different thermostat types. These households were included a single time in all analyses comparing households with and without smart thermostats but are classified as unknown when the evaluator was certain of registration but unable to determine the exact model.

Dynamic Pricing, No Nudge Report	37	9	24	0	1
Status-Quo TOU Pricing + Nudge Report	6	2	0	0	0
Status-Quo TOU Pricing, No Nudge Report	2	0	0	0	0
Winter 2018-2019	Energate	Ecobee	Nest	Honeywell	Unknown
Dynamic Pricing + Nudge Report	24	14	10	0	1
Dynamic Pricing, No Nudge Report	24	5	13	0	0
Status-Quo TOU Pricing + Nudge Report	6	2	0	0	0
Status-Quo TOU Pricing, No Nudge Report	2	0	0	0	0
Summer 2019	Energate	Ecobee			
Dynamic Pricing + Nudge Report	20	13	--	--	--
Dynamic Pricing, No Nudge Report	23	5	--	--	--
Summer 2019	Energate	Ecobee			
Status-Quo TOU Pricing + Nudge Report	4	2	--	--	--
Status-Quo TOU Pricing, No Nudge Report	2	0	--	--	--

Table 42: Dynamic Pricing Technology (smart thermostats) Consumption Summary Statistics

		Summer 2018		Winter 2018-19		Summer 2019	
		Mean Hourly kW	SD	Mean Hourly kW	SD	Mean Hourly kW	SD
High-Peak	Technology	1.710	1.052	0.927	0.488	1.488	0.976
	No Technology	1.912	1.234	1.156	0.769	1.508	1.046
Medium-Peak	Technology	1.454	0.884	0.931	0.498	1.192	0.807
	No Technology	1.595	1.068	1.119	0.728	1.191	0.896
Low-Peak	Technology	1.005	0.649	0.904	0.489	0.897	0.455
	No Technology	1.076	0.769	1.074	0.691	0.955	0.700
Off-Peak	Technology	0.979	0.608	0.790	0.392	0.926	0.481
	No Technology	0.996	0.690	0.915	0.595	0.965	0.671
Total	Technology	1.272	0.866	0.883	0.469	1.126	0.749
	No Technology	1.376	1.026	1.053	0.694	1.155	0.871

We estimated small impacts on electricity consumption associated with Technology ownership/registration during On- and Off-Peak periods; however, these impacts were only reached statistical significance during Winter 2018-19 (-0.145 kW per hour; Table 43). Similar results were obtained during CPP events (Table 44 to Table 46) with estimated impacts in the range of 0.089 kW to -0.370 kW per hour on average and only reaching significance or marginal significance ($p < .10$) on a few occasions.

Table 43: Dynamic Pricing Technology Impact Analysis Results (Mean Hourly kW)

Technology Impacts (kWh)	Summer 2018		Winter 2018/2019		Summer 2019	
	Mean Hourly kW	%	Mean Hourly kW	%	Mean Hourly kW	%
High-Peak Effects	-0.062	-3.541	**-0.145***	-13.704	-0.021	-1.363
Medium-Peak Effects	-0.023	-1.538	**-0.110***	-10.626	0.002	0.137
Low-Peak Effects	-0.022	-2.131	**-0.110***	-10.894	-0.057	-6.061
Off-Peak Effects	-0.015	-1.527	**-0.110****	-12.241	-0.038	-3.951

Total Effects	-0.031	-2.347	**-0.114***	-11.531	-0.029	-2.488

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 44: Dynamic Pricing CPP Days Technology Impact Analysis (Summer 2018)

Summer 2018 CPP Consumption (Mean Hourly kW)						
	Technology		No Technology		Technology Impact Analysis Results	
	Mean	SD	Mean	SD	kWh	%
CPP Day 1	1.573	1.231	1.875	1.514	-0.107	-6.379
CPP Day 2	1.966	1.42	2.367	1.605	-0.227^	-10.351
CPP Day 3	1.683	1.296	1.959	1.487	-0.109	-6.1
CPP Day 4	1.15	0.993	1.536	1.352	**-0.177***	-13.321
CPP Day 5	1.5	1.321	1.835	1.475	-0.146	-8.876
CPP Day 6	1.765	1.477	2.106	1.563	-0.118	-6.276
Total	1.606	1.322	1.946	1.523	-0.150	-8.544

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 45: Dynamic Pricing CPP Days Technology Impact Analysis (Winter 2018-19)

Winter 2018-19 Consumption (Mean Hourly kW)						
	Technology		No Technology		Technology Impact Analysis Results	
	Mean	SD	Mean	SD	kWh	%
CPP Day 1	1.190	0.853	1.441	1.159	-0.071	-5.613
CPP Day 2	1.131	0.742	1.399	1.099	-0.139	-10.43
CPP Day 3	0.939	0.630	1.236	1.000	**-0.169***	-15.216

CPP Day 4	0.976	0.733	1.212	0.947	-0.137^	-12.323
CPP Day 5	1.047	0.744	1.270	1.078	-0.133	-11.301
CPP Day 6	0.904	0.711	1.184	0.980	**-0.219***	-19.523
Total	1.027	0.745	1.286	1.048	-0.145^	-12.344

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 46: Dynamic Pricing CPP Days Technology Impact Analysis (Summer 2019)

Summer 2019 CPP Consumption (Mean Hourly kW)						
	Technology		No Technology		Technology Impact Analysis Results	
	Mean	SD	Mean	SD	kWh	%
CPP Day 1	1.678	1.292	1.859	1.399	-0.181	-9.727
CPP Day 2	1.531	1.313	1.900	1.425	-0.370^	-19.462
CPP Day 3	1.357	1.122	1.584	1.278	-0.227	-14.355
CPP Day 4	1.520	1.183	1.862	1.444	-0.342^	-18.360
CPP Day 5	1.529	1.183	1.559	1.372	-0.029	-1.891
CPP Day 6	1.360	1.174	1.538	1.236	-0.178	-11.566
CPP Day 7	1.464	1.236	1.642	1.251	-0.178	-10.821
CPP Day 8	1.287	1.075	1.198	1.082	0.089	7.437
CPP Day 9	0.935	0.694	0.986	0.994	-0.052	-5.235
Total	1.407	1.005	1.570	1.114	-0.163	-10.387

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

5.3.5 Pledge Analysis

Finally, we examined consumption impacts between households who responded to the On-Peak conservation pledge on the Nudge Report versus households who received the Nudge Reports but did not respond to the pledge. Recall that households had the option to respond to the pledge via SMS text message to commit to reducing their On-Peak electricity consumption. Households who chose to respond to the pledge were offered a $5 rebate. The number of participants in each of the comparison groups and the resulting impacts are shown in Table 47. Unfortunately, there were insufficient numbers of pledge participants to conduct an analysis that would allow for the derivation of meaningful impacts.

Table 47: Pledge Numbers

	Status-Quo TOU Control, Pledge Not Signed	Status-Quo TOU Control, Pledge Signed	Dynamic Pricing, Pledge Not Signed	Dynamic Pricing, Pledge Signed
Summer 2018	362	0	318	27
Winter 2018-19	341	0	219	16
Summer 2019	648	0	414	14

5.3.6 Summary of Dynamic Pricing Impacts

Given that the ratio of Off-Peak price to High On-Peak and CPP event kWh price is quite high relative to Status-Quo TOU pricing, it was hypothesized that this would provide a strong incentive for Dynamic pricing customers to curtail their electricity consumption behaviour in order to realize bill savings. The estimated impacts were highly consistent with this hypothesis as customers in Dynamic pricing exhibited lower electricity consumption relative to matched Control participants during all High and Medium Peak periods, with Summer 2018 and Winter 2018-19 seeing additional consumption savings during Low-Peak periods. Impacts during these periods ranged between -0.069 kW and -0.260 kW per hour on average. Estimated consumption impacts were not significant during the Off-Peak hours.

Significant conservation impacts were estimated during the initial six CPP events, in which Dynamic pricing Treatment customers exhibited -0.069 kW to -0.540 kW per hour relative to matched Controls during those same hours. Additionally, the electricity consumption impacts owing to Dynamic pricing during On-Peak and CPP events yielded net savings in overall average hourly consumption of 1.5% over the entire 17-month Treatment period.

In terms of non-price communications, impact estimates owing to Nudge Reports did not reach statistical significance.

Finally, Dynamic pricing customers who registered a smart thermostat through participation in Alectra's thermostat incentive program exhibited additional incremental consumption reductions relative to Dynamic pricing customers who did not report smart thermostat ownership; however, those reductions were statistically significant during only the Winter 2018-19 season (-0.145 kW per hour). Similar results were obtained during CPP events: small impacts of smart thermostat ownership/registration, with those impacts only reaching significance on a few occasions.

Overall, Dynamic pricing resulted in dramatic reductions in On-Peak electricity consumption relative to Status-Quo TOU pricing. These impacts were largest during High On-Peak days and CPP event days, indicating that strong pricing signals can act as a meaningful incentive for the curtailment of residential electricity consumption. Importantly, these savings were enhanced in some instances as a result of non-price communications, in the form of Nudge Reports, as well as ownership of smart thermostat Technology. These peak reductions were not offset by increases in Off-Peak consumption, resulting in relatively small but reliable overall conservation impacts.

With respect to the 5-month extension period (June – October 2019), there were two primary research questions that the extension period pilot was designed to address:

1. ***Would the On-Peak and CPP event impacts estimated for the Summer 2018 season still be present a year later in Summer 2019?*** Consumption impacts during High On-Peak TOU periods did in fact persist from Summer 2018 to Summer 2019. The magnitude of these impacts is observed to be smaller in Summer 2019 however, likely owing to cooler High On-Peak temperatures in Summer 2019 relative to Summer 2018. In terms of CPP event responsiveness, we see very similar impacts across the Summer 2018 and Summer 2019 seasons.

2. ***Would an increase in the frequency of CPP events from 6 to 9 impact responsiveness to CPP events?*** In assessing consumption impacts across each of the CPP events called in the Summer 2019 season, we see that consumption impacts for the six events that the Dynamic 6 and Dynamic 9 groups shared in common, are very similar. In addition, while we also see significant consumption impacts on the 3 CPP days that were unique to the Dynamic 9 group, the magnitude of these impacts is not statistically different from those obtained for the Dynamic 6 group on those three days (despite the fact that those days were called as High On-Peak days for the Dynamic 6 group).

5.4 Legacy Dynamic Pricing Pilot

5.4.1 Sample Size and Summary Statistics

The results of the Dynamic pilot estimated the effects of Dynamic pricing on 'newly' enrolled households during the enrollment period beginning in November 2017 and ending in March 2018. These "new" Dynamic participants were recruited via APP marketing materials, and Dynamic pricing impacts related to these newly enrolled customers were described in detail in the previous section. However, there existed approximately 1,500 households who enrolled in Dynamic pricing between 2015-2016 as part of previous instantiations of Alectra's APP program ('Legacy Dynamic' customers) and have been exposed to Dynamic pricing over a longer period of time. These Legacy Dynamic customers were encouraged to remain in Dynamic pricing as part of the 17-month pilot reported here. We analyze Legacy Dynamic pricing impacts independently of 'new' Dynamic pricing impacts for three important reasons:

1. The former (Legacy) Dynamic pricing initiative offered to customers by Alectra was run with full price protection. This means that as of their enrollment date in Dynamic pricing until the beginning of the most recent pilot reporting period, all participants were not financially penalized if their APP bill amounts were greater than what they would have been billed under Status-Quo TOU. Because it is unknown how extended exposure to price protection affects customer responsiveness to alternative pricing schemes, we consider Legacy Dynamic customers to be a qualitatively distinct group relative to new Dynamic customers.

2. The Legacy Dynamic pricing program began in 2014, meaning that the employment of a difference-in-difference approach to impact estimation is problematic. Mainly, in order to compare consumption in the pilot period (May 01, 2018 – October 31, 2019) to a pre-Treatment historical baseline period, a historical data set that is (in many cases) over five years old would have to be used. This is further complicated by the fact that Legacy Dynamic pricing customers enrolled into Dynamic pricing at three different historical time periods, meaning that different historical baseline periods would have to be used for different groups of customers within the Legacy Dynamic customer group (this is discussed further below).

3. Legacy Dynamic customers are compared to a separate matched Control group than the "new" Dynamic customers. Moreover, whereas the new Dynamic customers are compared to a single matched Control group, the Legacy Dynamic customers are compared to distinct matched Control groups in the Summer and Winter seasons.

The longevity of Legacy Dynamic pricing customers in the program affords us the opportunity to estimate how Dynamic pricing affects customers over an extended period of time in order to determine whether consumption impacts were sustained, increased, or decreased over time. Due to missing data, impact estimates for Winter seasons 2015-2016 and 2016-2017 were not available.

As discussed throughout this report, (e.g. Section 4.3.3), the procedure for measuring effects of Dynamic pricing on consumption for the Legacy households is distinct form the difference-in-difference methodology employed for the estimation of "new" Dynamic pricing impacts. Instead, the Legacy Dynamic impact estimates derive from a comparison of consumption between the Treatment and Control groups for each year between 2014-2019. Furthermore, as participants in the Legacy Dynamic pricing group enrolled into the pilot at different time-points, a procedure for measuring the varying durations of exposure to Dynamic pricing within the Legacy group is required. Registration dates for Legacy Dynamic customers are shown in Table 48**.**

Table 48: Breakdown of Registration Dates for Legacy Dynamic Participants

	On or Before May 1st, 2015	October 1st, 2015 – May 4th, 2016	After June 1st, 2016
Number of Registrations	978	787	55

The observed registration dates in Table 48 reveal three natural groups, or 'waves', of customer enrollment. 992 households enrolled on or before May 1st, 2015 (the first instantiation of

Dynamic pricing offered to customers by Alectra). The next major registration period was between October 1st, 2015 – May 4th, 2016. These 816 households would not have been exposed to Dynamic pricing in the Summer of 2015 but would have been exposed to Dynamic pricing during the Summer of 2016. The remaining 55 households signed up after June 1st, 2016, meaning that 2017 would have been the earliest full summer exposure to Dynamic pricing for this group. Based on these observations, we define two distinct bins of households for which consumption impacts will be estimated: **Registration Bin 1** (registration date on or before May 1st, 2015) and **Registration Bin 2** (registration date between October 1st, 2015 and May 4th, 2016). Households in **Registration Bin 3** (registration after June 1st, 2016) were excluded from the analysis as the sample size was too small to allow for the derivation of meaningful impacts.

The sample sizes used for impact estimation for the Legacy Dynamic pilot are displayed in Table 49 for Bin 1 and Table 50 for Bin 2. These tables also the breakdown of attrition rates due to either households moving out of the service territory, households opting out of the program, missing data[36], or because household consumption was deemed to be an outlier[37]. Furthermore, we observed that some households signed up for, or were erroneously assigned to, more than one pilot group (i.e. overlap with other RPP pilots being conducted by Alectra during the relevant reporting period). As a result of this, these "conflict with other pilot" households were removed from the present impact analysis; however, the number of these households was relatively small. Note that unlike in the "new" Dynamic pilot, separate matched Control groups were created for Summer and Winter periods (as per Potter et al., 2016)[38]. We conducted Control and Treatment pairwise elimination. This means that if a Treatment participant was removed, we removed their corresponding matched Control, and vice versa. In the present case, this method led to higher numbers of Legacy Dynamic pricing participants in the Winter 2018-19 period compared to Summer 2018, and Summer 2019. These participants were excluded when their Summer matched Control was removed and were added back into the Winter analysis with a new matched Control. Due to the reduction in sample size after subdividing the Treatment group into Legacy 6 and Legacy 9 for the extension period, analysis of the Summer 2019 extension period combined the two Registration Date Bins. For clarity, the final number of participants for the Summer 2019 extension period with bins combined is presented in Table 51.

Table 49: Number of Participants for Legacy Dynamic Pilot Bin 1

Bin 1 (registration date on or before May 1st, 2015)									
	Initial N	Opt-Outs	Move-Outs	Conflict with Other Pilots	Missing Data	Outliers	Removal of Matched Exclusions	Total Exclusions	Final N

[36]See Section 4.2.4 Issues or Concerns for further explanation.
[37]An outlier was defined as any household who consumed more than 15kWh per hour, less than 0.05kWh per hour during any hour in the analysis period
[38] Potter, Candice., Jain, Ankit., Thompson, Daniel., and Cumming, Trevor., (2016) "peaksaverPLUS Program 2015 Load Impact Evaluation" *Nexant, Inc.*

Summer 2018 Reporting Period									
Legacy Dynamic	778	3	34	5	15	4	53	114	664
Status-Quo TOU Control	778	4	0	30	13	9	58	114	664
Winter 2018-19 Reporting Period									
Legacy Dynamic	839	2	36	7	18	6	42	111	728
Status-Quo TOU Control	839	7	2	26	6	5	65	111	728
Summer 2019 Extension Period									
Legacy Dynamic 6 CPP Days	327	47	7	0	1	0	1	56	271
Legacy Dynamic 9 CPP Days	336	40	6	0	2	0	0	48	288
Status-Quo TOU Control	663	1	0	0	0	1	102	104	559

Table 50: Number of Participants for Legacy Dynamic Pilot Bin 1

Bin 2 (registration date between October 1st, 2015 and May 4th, 2016)									
	Initial N	Opt-Outs	Move-Outs	Conflict with Other Pilots	Missing Data	Outliers	Removal of Matched Exclusions	Total Exclusions	Final N
Summer Period									
Legacy Dynamic	650	41	34	6	9	16	41	147	503
Status-Quo TOU Control	650	2	2	21	9	19	94	147	503

Winter Period									
Legacy Dynamic	639	36	37	8	13	8	39	141	498
Status-Quo TOU Control	639	1	1	29	10	9	91	141	498
Summer 2019 Extension Period									
	Initial N	Opt-Outs	Move-Outs	Conflict with Other Pilots	EVs	Missing Data	Outliers	Removal of Matched Exclusions	Total Exclusions	Final N
Legacy Dynamic 6 CPP Days	253	34	10	0	3	0	0	2	49	204
Legacy Dynamic 9 CPP Days	250	36	4	0	4	0	1	1	46	204
Status-Quo TOU Control	503	0	0	0	0	1	2	92	95	408

Table 51: Final Number of Summer Extension Period Legacy Dynamic Participants

Summer 2019 Legacy Dynamic Participants	Final N
Legacy Dynamic 6	475
Legacy Dynamic 9	492
Status-Quo TOU Control	967
Total	1934

Next, we present a summary of average hourly kW consumption for the Legacy Dynamic pilot from 2014 through 2018 shown separately for the two registration bins for Summer (Table 52) and Winter (Table 53). Despite the fact that we do not employ a difference-in-difference approach to impact estimation for Legacy Dynamic customers, we present summary statistics for consumption in the year(s) prior to program participation (the 'baseline' year) for customers in both registration bins. Note that for Registration Bin 1, the Summer baseline year was 2014 and the Winter baseline year was 2014-2015, whereas for Registration Bin 2, the Summer baseline years were 2014 and 2015, and the Winter baseline year was 2014-2015. Summary statistics for the Summer 2019 period are presented in
Table 54.

Table 52: Legacy Dynamic Pilot Summary Statistics of Mean Hourly Consumption (kW) (Summer 2018 Period)

Summer 2014-2018 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
High-Peak 2014	Mean	1.217	1.316	1.257	1.178	1.254	1.190
	SD	0.700	0.822	0.726	0.775	0.822	0.805
High-Peak 2015	Mean	1.860	1.538	1.489	1.750	1.844	1.820
	SD	0.939	0.914	0.858	1.012	1.096	1.055
High-Peak 2016	Mean	2.032	1.702	1.671	1.887	1.747	1.729
	SD	1.056	1.005	1.002	1.065	1.112	1.134
High-Peak 2017	Mean	1.535	1.232	1.285	1.463	1.426	1.340
	SD	0.845	0.795	0.829	0.874	0.997	0.928
High-Peak 2018	Mean	1.921	1.759	1.795	1.811	1.775	1.718
	SD	1.044	1.036	1.077	1.050	1.235	1.090
Medium-Peak 2014	Mean	1.273	1.376	1.316	1.223	1.295	1.237
	SD	0.725	0.846	0.750	0.795	0.855	0.832

Summer 2014-2018 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
Medium-Peak 2015	Mean	1.327	1.247	1.193	1.264	1.384	1.328
	SD	0.828	0.820	0.754	0.881	0.961	0.922
Medium-Peak 2016	Mean	1.553	1.431	1.389	1.452	1.407	1.403
	SD	0.907	0.909	0.869	0.926	0.965	0.985
Medium-Peak 2017	Mean	1.134	1.013	1.038	1.113	1.146	1.061
	SD	0.707	0.671	0.661	0.749	0.821	0.786
Medium-Peak 2018	Mean	1.570	1.489	1.502	1.488	1.488	1.410
	SD	0.894	0.892	0.889	0.910	1.046	0.909
Low-Peak 2014	Mean	1.190	1.283	1.225	1.159	1.235	1.161
	SD	0.675	0.790	0.700	0.752	0.803	0.779
Low-Peak 2015	Mean	1.030	1.038	1.008	1.002	1.116	1.045
	SD	0.631	0.659	0.630	0.691	0.769	0.754
Low-Peak 2016	Mean	1.017	1.046	0.992	0.974	1.021	0.992
	SD	0.639	0.702	0.630	0.656	0.720	0.731
Low-Peak 2017	Mean	0.916	0.881	0.881	0.909	0.963	0.898
	SD	0.540	0.573	0.534	0.585	0.644	0.662
Low-Peak 2018	Mean	0.996	1.028	1.021	0.970	1.044	0.982
	SD	0.613	0.638	0.617	0.647	0.733	0.680
Off-Peak 2014	Mean	0.852	0.902	0.876	0.853	0.903	0.840
	SD	0.480	0.569	0.511	0.577	0.596	0.591
Off-Peak 2015	Mean	0.875	0.961	0.953	0.872	0.949	0.887
	SD	0.500	0.569	0.574	0.590	0.610	0.608
Off-Peak 2016	Mean	0.941	1.053	1.035	0.912	1.021	0.963
	SD	0.542	0.653	0.601	0.593	0.656	0.639
Off-Peak 2017	Mean	0.796	0.914	0.925	0.799	0.905	0.848
	SD	0.465	0.609	0.536	0.520	0.600	0.610

Summer 2014-2018 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
Off-Peak 2018	Mean	0.909	1.022	1.013	0.905	1.005	0.952
	SD	0.527	0.626	0.582	0.590	0.662	0.620
Total Consumption 2014	Mean	1.116	1.200	1.150	1.088	1.156	1.091
	SD	0.664	0.777	0.691	0.737	0.782	0.765
Total Consumption 2015	Mean	1.325	1.178	1.142	1.263	1.356	1.305
	SD	0.937	0.834	0.792	0.957	1.011	1.011
Total Consumption 2016	Mean	1.502	1.361	1.319	1.410	1.364	1.341
	SD	1.032	0.954	0.913	1.015	1.006	1.030
Total Consumption 2017	Mean	1.145	1.040	1.060	1.115	1.141	1.066
	SD	0.786	0.729	0.721	0.799	0.856	0.824
Total Consumption 2018	Mean	1.412	1.361	1.373	1.355	1.378	1.307
	SD	0.939	0.909	0.922	0.945	1.036	0.935

Table 53: Legacy Dynamic Pilot Summary Statistics of Mean Hourly Consumption (kW) (Winter 2018-19 Period)

Winter 2018-19 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
High-Peak 2014-2015	Mean	1.224	1.211	1.182	1.6	1.7	1.62
	SD	0.623	0.626	0.555	1.35	1.45	1.268
High-Peak 2015-2016	Mean	1.027	1.063	1.021	1.27	1.24	1.208
	SD	0.501	0.559	0.528	0.96	0.88	0.831
High-Peak 2016-2017	Mean	0.995	0.992	0.979	1.24	1.2	1.2
	SD	0.482	0.551	0.496	1.02	0.92	0.908
High-Peak 2017-2018	Mean	1.068	1.087	1.079	1.4	1.4	1.347
	SD	0.571	0.706	0.613	1.32	1.2	1.135
High-Peak 2018-2019	Mean	1.076	1.07	1.071	1.41	1.43	1.389
	SD	0.559	0.586	0.598	1.34	1.26	1.21

Winter 2018-19 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
Medium-Peak 2014-2015	Mean	1.216	1.23	1.188	1.55	1.61	1.544
	SD	0.615	0.626	0.555	1.23	1.32	1.167
Medium-Peak 2015-2016	Mean	--	--	--	--	--	--
	SD	--	--	--	--	--	--
Medium-Peak 2016-2017	Mean	--	--	--	--	--	--
	SD	--	--	--	--	--	--
Medium-Peak 2017-2018	Mean	1.023	1.062	1.051	1.29	1.3	1.275
	SD	0.504	0.601	0.555	1.12	0.99	0.966
Medium-Peak 2018-2019	Mean	1.032	1.05	1.049	1.27	1.3	1.274
	SD	0.54	0.583	0.584	1.11	1.03	1.056
Low-Peak 2014-2015	Mean	1.112	1.14	1.091	1.35	1.41	1.349
	SD	0.559	0.591	0.522	0.98	1.03	0.934
Low-Peak 2015-2016	Mean	--	--	--	--	--	--
	SD	--	--	--	--	--	--
Low-Peak 2016-2017	Mean	--	--	--	--	--	--
	SD	--	--	--	--	--	--
Low-Peak 2017-2018	Mean	0.956	1.008	1.005	1.15	1.16	1.144
	SD	0.485	0.577	0.564	0.92	0.81	0.813
Low-Peak 2018-2019	Mean	0.997	1.022	1.023	1.18	1.21	1.181
	SD	0.52	0.57	0.551	0.95	0.89	0.886
Off-Peak 2014-2015	Mean	0.923	0.933	0.904	1.24	1.28	1.233
	SD	0.489	0.481	0.44	1.14	1.19	1.095
Off-Peak 2015-2016	Mean	0.807	0.891	0.857	1.06	1.09	1.059
	SD	0.404	0.48	0.427	0.9	0.86	0.858
Off-Peak 2016-2017	Mean	0.788	0.873	0.85	1.03	1.09	1.073
	SD	0.392	0.506	0.403	0.94	0.92	0.933

Winter 2018-19 Period (kWh)		Registration Bin 1			Registration Bin 2		
		Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report	Status-Quo TOU Control, No Nudge Report	Dynamic Pricing, No Nudge Report	Dynamic Pricing + Nudge Report
Off-Peak 2017-2018	Mean	0.812	0.896	0.89	1.08	1.17	1.137
	SD	0.408	0.539	0.453	1.06	1	1.037
Off-Peak 2018-2019	Mean	0.826	0.883	0.883	1.08	1.17	1.164
	SD	0.432	0.511	0.462	1.05	1.03	1.069
Total 2014-2015	Mean	1.065	1.073	1.038	1.38	1.44	1.37
	SD	0.585	0.597	0.549	1.2	1.28	1.13
Total 2015-2016	Mean	0.932	0.974	0.939	1.2	1.19	1.154
	SD	0.488	0.549	0.509	1.01	0.94	0.913
Total 2016-2017	Mean	0.916	0.948	0.93	1.17	1.16	1.164
	SD	0.48	0.562	0.479	1.04	0.94	0.953
Total 2017-2018	Mean	0.965	1.011	1.004	1.24	1.27	1.228
	SD	0.507	0.613	0.56	1.14	1.03	1.012
Total 2018-2019	Mean	0.999	1.019	1.02	1.26	1.3	1.269
	SD	0.545	0.584	0.579	1.16	1.1	1.091

Table 54: Legacy Dynamic Pilot Summary Statistics of Mean Hourly Consumption (kW) (Summer 2019 Period)

Summer 2019 Period (kWh)	Status-Quo TOU Control, No	Legacy Dynamic 6 Pricing, No	Legacy Dynamic 9 Pricing, No	Legacy Dynamic 6 Pricing +	Legacy Dynamic 9 Pricing +

		Nudge Report	Nudge Report	Nudge Report	Nudge Report	Nudge Report
High-Peak 2019	Mean	1.547	1.533	1.516	1.403	1.445
	SD	0.972	1.014	1.058	0.902	0.99
Medium-Peak 2019	Mean	1.187	1.228	1.198	1.112	1.181
	SD	0.78	0.84	0.846	0.726	0.795
Low-Peak 2019	Mean	0.887	0.982	0.953	0.864	0.932
	SD	0.534	0.62	0.58	0.536	0.603
Off-Peak 2019	Mean	0.85	0.981	0.965	0.896	0.965
	SD	0.55	0.681	0.626	0.557	0.655
Total 2019	Mean	1.115	1.181	1.159	1.071	1.133
	SD	0.785	0.837	0.834	0.729	0.803

5.4.2 Time-of-Use Period Impacts and Seasonal Results with Elasticities

Impact estimates for On-Peak (High, Medium, Low) and Off-Peak TOU periods, CPP Days, and System-Coincident Peak hours are displayed in Table 55 to Table 59. In order to derive impacts for High, Medium, and Low On-Peak hours during the baseline (pre-pilot) years, we used the following approach: For Registration Bin 1, we used temperature data for Summer and Winter weekdays in the baseline year to rank order the days and then assigned the warmest 20% to 'High On-Peak', the next warmest 30% to 'Medium On-Peak', and the next warmest 50% to 'Low On-Peak' for Summer months (for Winter months, the days were ranked in reverse from coldest to warmest). For Registration Bin 2, we capitalized on the pre-existing assignment of On-Peak days to Low, Medium, and High for the Legacy Dynamic participants in Registration Bin 1 where possible, and where this was not possible, we again relied on temperature data to infer whether a given day would have been assigned to Low, Medium, or High On-Peak.
Legacy Dynamic households consumed less Summer 2018 High On-Peak electricity than Status-Quo TOU Control households during all Treatment years (Bin 1 - 2015-2019; Bin 2 - 2016-2019). For Registration Bin 1, households in the Treatment group consumed on average -0.35kW, -0.35kW, -0.28kW, and -0.14kW less energy per hour on average (relative to Control) during High-Peak hours in 2015, 2016, 2017, and 2018 respectively. For Registration Bin 2, the effect was -0.15kW, -0.08kW, and -0.07kW in 2016, 2017, and 2018 respectively. Summer 2019 did not see significant differences in High On-Peak energy consumption between Legacy Dynamic customers and matched Controls. We did however observe a significant difference during the Summer baseline periods between Control and Treatment groups. In both Registration Bins, High On-Peak consumption was higher in the Treatment group before the program began. This would suggest that the derived impacts of Dynamic pricing on Legacy Dynamic customers could be underestimates the true Treatment impact. No differences between pricing groups were observed for any of the High On-Peak Winter periods.

With respect to the Summer Medium On-Peak hours in Registration Bin 1, the effects were similar to those estimated during the High On-Peak hours. Treatment households had higher electricity consumption at baseline than the Control group, followed by lower consumption for the Legacy Dynamic Treatment customers relative to Control in all Treatment years (-0.075 to 0.143 kW per hour). However, there were no significant differences in consumption between Legacy Dynamic pricing Treatment and Control households during Summer 2018 or 2019 Medium On-Peak TOU periods. Similar to the High On-Peak results, there was only one impact estimate reaching statistical significance during the Winter Medium On-Peak periods for either Registration Bin (i.e. only +0.034 kW per hour in Bin 1 during 2017-2018).

With respect to Low On-Peak electricity consumption, both registration bins had higher consumption than Status-Quo TOU Control household during the Summer baseline year. Differences between Treatment and Control customers during all three Summer and Winter Treatment periods ranged between -0.035 kW per hour and +0.076 kW per hour, with estimated consumption impacts being positive more often than negative for Legacy Dynamic Treatment households relative to Control households, and most years showing no significant differences between pricing groups.

Legacy Dynamic households exhibited higher consumption (ranging between +0.037 to +0.123 kW per hour on average) during Off-Peak TOU periods in most Treatment years.

Table 55: Legacy Dynamic Pricing TOU Peak Impact Analysis Results (Mean Hourly kW, Summer 2014-18)

Summer 2014-18 Period	Baseline	Bin 1 Dynamic Pricing / Bin 2 Baseline	Dynamic Pricing Main Effect		
	2014	2015	2016	2017	2018
High-Peak - Bin 1	0.070^	**-0.347*** **	**-0.345*** **	**-0.276*** **	**-0.144** **
High-Peak - Bin 2	0.042	0.081	**-0.149* **	-0.082	-0.065
Medium-Peak - Bin 1	0.073^	**-0.107** **	**-0.143** **	**-0.109** **	-0.075^
Medium-Peak – Bin 2	0.042	0.091^	-0.048	-0.012	-0.041
Low-Peak - Bin 1	0.064	-0.007	0.002	-0.035	0.028
Low-Peak - Bin 2	0.037	0.076^	0.032	0.020	0.041
Off-Peak - Bin 1	0.037	**0.082** **	**0.103*** **	**0.123*** **	**0.108*** **
Off-Peak - Bin 2	0.017	0.044	**0.078* **	**0.076* **	**0.072* **
CPP - Bin 1	--	**-0.756*** **	**-0.721*** **	**-0.421*** **	**-0.241*** **
CPP - Bin 2	--	0.029	**-0.37*** **	**-0.159** **	**-0.152* **
System-Coincident-Peak - Bin 1	0.009	**-0.162*** **	**-0.256*** **	-0.064^	**-0.087* **
System-Coincident-Peak – Bin 2	0.011	0.035	**-0.118* **	-0.037	-0.060

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

Table 56: Legacy Dynamic Pricing TOU Peak Impact Analysis Results (Summer, % Difference in Mean Hourly kW)

Summer 2018 Period (%)	Baseline	Bin 1 Dynamic Pricing / Bin 2 Baseline	Dynamic Pricing Main Effect (Mean Hourly %)		
	2014	2015	2016	2017	2018
High-Peak - Bin 1	5.752	-18.653	-16.98	-17.986	-7.496
High-Peak - Bin 2	3.564	4.627	-7.897	-5.607	-3.59
Medium-Peak - Bin 1	5.732	-8.061	-9.206	-9.609	-4.776
Medium-Peak – Bin 2	3.435	7.202	-3.305	-1.078	-2.755
Low-Peak - Bin 1	5.379	-0.679	0.197	-3.821	2.81
Low-Peak - Bin 2	3.192	7.583	3.286	2.2	4.225
Off-Peak - Bin 1	4.344	9.367	10.951	15.447	11.878
Off-Peak - Bin 2	1.993	5.044	8.548	9.507	7.959
CPP - Bin 1	--	-35.383	-28.749	-22.868	-11.996
CPP - Bin 2	--	1.466	-15.865	-9.195	-7.851
System-Coincident-Peak - Bin 1	4.556	-13.034	-16.98	-5.405	-6.019
System-Coincident-Peak – Bin 2	0.95	2.931	-7.897	-3.212	-4.336

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

Table 57: Legacy Dynamic Pricing TOU Peak Impact Analysis Results (Average Hourly kW, Winter 2014-19)

Winter 2018-19 Periods	Baseline	Bin 1 Dynamic Pricing / Bin 2 Baseline	Dynamic Pricing Main Effect		
	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
High-Peak – Bin 1	-0.028	0.016	-0.01	0.015	-0.005
High-Peak – Bin 2	0.057	-0.045	-0.043	-0.026	-0.005
Medium-Peak – Bin 1	-0.007	--	--	0.034	0.018
Medium-Peak – Bin 2	0.032	--	--	-0.005	0.014
Low-Peak – Bin 1	0.004	--	--	**0.05***	0.025
Low-Peak – Bin 2	0.03	--	--	0.003	0.02
Off-Peak – Bin 1	-0.004	**0.068****	**0.074*****	**0.081*****	**0.057***
Off-Peak – Bin 2	0.016	0.012	0.048	0.07	0.091
CPP – Bin 1	--	**-0.067***	**-0.076***	0.006	-0.03
CPP – Bin 2	--	-0.095	-0.146^	-0.029	-0.021
System-Coincident-Peak – Bin 1	-0.007	0.01	-0.007	0.028	0.014
System-Coincident-Peak - Bin 2	0.033	-0.071	-0.064	-0.02	-0.004

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 58: Legacy Dynamic Pricing TOU Peak Impact Analysis Results (Winter, % Difference in Mean Hourly kW)

Winter 2018-19 Period (%)	Baseline	Bin 1 Dynamic Pricing / Bin 2 Baseline	Dynamic Pricing Main Effect (Mean Hourly %)		
	2014	2015	2016	2017	2018
High-Peak - Bin 1	-2.287	1.558	0.812	1.405	-0.465
High-Peak - Bin 2	3.554	-3.552	-4.63	-1.858	-0.354
Medium-Peak - Bin 1	-0.575	--	--	3.324	1.745
Medium-Peak – Bin 2	2.071	--	--	-0.387	1.1
Low-Peak - Bin 1	0.36	--	--	5.231	2.507
Low-Peak - Bin 2	2.225	--	--	0.261	1.702
Off-Peak - Bin 1	-0.434	8.427	9.389	9.97	6.898
Off-Peak - Bin 2	1.289	1.129	4.644	6.468	8.447
CPP - Bin 1	--	-6.227	-6.305	0.589	-2.475
CPP - Bin 2	--	-6.808	-9.165	-2.076	-1.321
System-Coincident-Peak - Bin 1	-0.487	0.812	-0.59	2.351	1.17
System-Coincident-Peak – Bin 2	1.807	-4.63	-4.259	-1.329	-0.267

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

Table 59: Legacy Dynamic Pricing TOU Peak Impact Analysis Results (Summer 2019; Mean Hourly kW and % differences)

Summer 2019 Period	Dynamic Pricing Main Effect (Mean Hourly kW)			
	Dynamic Pricing (6 CPP)		Dynamic Pricing (9 CPP)	
	Mean Hourly kW	%	Mean Hourly kW	%
High-Peak	-0.079	-5.133	-0.067	-4.306
Medium-Peak	-0.018	-1.533	0.002	0.169
Low-Peak	0.036	4.004	0.056	6.267^
Off-Peak	**0.089****	10.418	**0.116*****	13.599
CPP	**-0.24*****	-13.337	**-0.225*****	-12.511
System-Coincident-Peak	-0.068	-5.123	-0.055	-4.108

**** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$*

CPP events occurred at different frequencies across each year and season of Legacy Dynamic pricing (Table 60).

Table 60: Number of Critical Peak Events by Year

	Summer	Winter
Year 1	--	--
Year 2	5	4
Year 3	5	1
Year 4	7	3
Year 5	6	6
Year 6	6/9	NA

With respect to CPP events in the Summer months across years, the pattern was consistent across the two Registration Bins, and the two CPP pricing groups during Summer 2019. We estimated lower electricity consumption (-0.152 to -0.756 kW per hour) for Legacy Dynamic Treatment customers relative to Control customers during CPP event hours across all Treatment years.

CPP events were less impactful in the Winter months across the years analyzed here, with small effects in mean hourly kW consumption only obtained during Treatment Years 1 and 2 for Registration Bin 1(-0.067 kW and -0.076 kW respectively), and no differences between Treatment and Control for Registration Bin 2.

The differential distribution of the number of CPP events and their duration limits potential inferences of about the effects of CPP impacts across different years. Specifically, the larger number of CPP events in Year 5 (the most recent instantiation of Dynamic pricing) relative to Years 2 and 3, likely yield better estimates of the impact of CPP events on consumption relative to historical impact estimates derived from smaller sets of observations. This is further complicated by the fact that only in Year 5 was price protection removed. Again, while it is possible, and potentially insightful to examine CPP responsiveness over time for Legacy Dynamic pricing households given the data available, caution should be used when interpreting the reduction in magnitude of these effects over time (i.e., in the Summer CPP impact estimates across year).

There were no significant differences between Legacy Dynamic pricing Treatment and Control households during any of the Summer or Winter System-Coincident Peak periods.

From a descriptive perspective, we do observe that the magnitude of Summer Legacy Dynamic pricing consumption effects (for High On-Peak, Medium On-Peak, and CPP events) between Treatment and Control households diminish across time (

Table 55 to Table 59). For example, the High On-Peak registration Bin 1 impacts for Treatment years 2015-2018 are -0.347 kW, -0.345 kW, -0.276 kW, and -0.144 kW mean hourly consumption, respectively, with significant consumption impact estimates obtained for Legacy Dynamic Treatment households relative to Control households in all years. It is important to note that inferential statistical modelling of pricing Treatment impacts over time, incorporating seasonal variations in temperature, are necessary to confirm that these magnitude changes in Summer impacts represent a significant trend rather than natural variability in the data. The magnitudes of all other periods of measurement, including Low On-Peak, Off-Peak, as well as overall Summer do not exhibit this descriptive trend. The effects of Summer 2019 appear descriptively similar to Summer 2018; however, a direct comparison is made more difficult because Summer 2019 analyses combined the Registration Bins. Further discussion of this potential effect is included in Section 5.4.7.

Seasonal average conservation impacts are shown in Table 61 and Table 62. Overall, Legacy Dynamic pricing Treatment customers consumed slightly more electricity than Status-Quo TOU Control customers, and this effect only reached significance for Bin 1 (and in the Summer 2019 period in which Bin 1 and 2 were combined). The use of different matched Control groups during the Summer and Winter periods precludes a year-round or full 17-month analysis of average conservation impacts.

Table 61: Legacy Dynamic Seasonal Average Hourly kW Consumption Impacts

	2014 Summer 2014-15 Winter	2015 Summer 2015-16 Winter	2016 Summer 2016-17 Winter	2017 Summer 2017-18 Winter	2018 Summer 2018–19 Winter	Summer 2019	
Summer Bin 1	0.042	0.051^	**0.063***	**0.081****	**0.084****	Legacy Dynamic 6	**0.068***
Summer Bin 2	0.02	0.049	0.057	0.06^	0.059		
Winter Bin 1	-0.004	**0.059****	0.059	**0.073****	**0.05***	Legacy Dynamic 9	**0.0932****
Winter Bin 2	0.02	0.003	0.032	0.058	0.077		

**** p < 0.001; ** p < 0.01; * p < 0.05; ^ p < 0.1; ^ p < .10*

Table 62: Legacy Dynamic Seasonal Average Hourly % Consumption Impacts

	2014 Summer 2014-15 Winter	2015 Summer 2015-16 Winter	2016 Summer 2016-17 Winter	2017 Summer 2017-18 Winter	2018 Summer 2018–19 Winter	Summer 2019	
Summer Bin 1	4.615	5.433	6.165	9.459	8.601	Legacy Dynamic 6	7.436
Summer Bin 2	2.208	5.278	5.787	7.025	6.115		
Winter Bin 1	-0.415	6.983	7.163	8.634	5.809	Legacy Dynamic 9	10.236
Winter Bin 2	1.562	0.273	2.993	5.215	6.949		

**** p < 0.001; ** p < 0.01; * p < 0.05; ^ p < 0.1; ^ p < .10*

5.4.3 Elasticity

Daily and Substitution Elasticities are reported for the 17-month Treatment period in Table 63. Daily elasticity of demand was estimated at -0.072. The daily elasticity of demand was negative and less than 1, indicating only a small change in percent consumption per percent change in price. Substitution elasticity of demand was estimated at -0.004 again indicating a relatively small change in percent consumption per percent change in price.

Table 63: Legacy Dynamic Pilot Daily and Substitution Elasticities of Demand

	Elasticity Estimate
Daily Elasticity	**-0.072*** **
Substitution Elasticity On/Off-Peak	**-0.004*** **

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

5.4.4 Communication Analysis

In this section, we report consumption impacts attributable to the Nudge Reports that were distributed to households in the Legacy Dynamic Group. Starting in May 2018, we randomly selected half of the Legacy Dynamic Treatment group to receive Nudge Reports (Table 64). We report the effects of the Nudge Reports between Legacy Dynamic households who did not receive Nudge Reports to the households who did receive Nudge Reports. To preserve statistical power, we combined both Registration Date Bins (1 and 2). In addition, we did not use a difference-in-difference methodology (for the same rationale outlined in the analytic approach to TOU period impact estimates) but instead analyzed consumption behaviour during the Treatment period only.

Summary statistics of hourly consumption for Legacy Dynamic households with and without Nudge Reports were previously shown in Table 55 to Table 59. Consumption impacts owing to Nudge Reports are shown in Table 65. None of the estimated impacts of Nudge Reports reached statistical significance.

Table 64: Number of Legacy Dynamic participants who received Nudge Reports

	Summer 2018 Final N	Winter 2018-19 Final N	Summer 2019 Final N
Legacy Dynamic, No Nudge Report	574	615	--
Legacy Dynamic + Nudge Report	593	611	--
Legacy Dynamic 6, No Nudge Report	--	--	235
Legacy Dynamic 9, No Nudge Report	--	--	240
Legacy Dynamic + Nudge Report	--	--	242
Legacy Dynamic + Nudge Report	--	--	250

Table 65: Legacy Dynamic Nudge Report Communication Impact Analysis Results

	Nudge Report Main Effect (Mean Hourly kW)					
	Summer 2018 Period		Winter 2018-19 Period		Summer 2019	
	Mean Hourly kW	%	Mean Hourly kW	%	Mean Hourly kW	%
High-Peak	-0.005	-0.279	-0.005	-0.404	-0.1^	-6.564
Medium-Peak	-0.027	-1.842	-0.005	-0.424	-0.065	-5.387
Low-Peak	-0.031	-2.997	-0.007	-0.628	-0.068^	-7.053
Off-Peak	-0.029	-2.865	0.005	0.494	-0.042	-4.306
CPP	-0.03	-1.71	-0.013	-0.986	-0.098	-6.061
System-Coincident-Peak	-0.011	-0.815	0.007	0.562	-0.063	-4.869
Total	-0.024	-1.772	-0.004	-0.352	-0.047	-4.615
12-Month Total	-	-	-0.012	-1.641	-	-
17-Month Total	-	-	-	-	-0.035	-3.328

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

5.4.5 Technology Impacts

As with the Dynamic pricing pilot, Legacy Dynamic pricing households were designated as "Technology" if they participated in a smart thermostat incentive program offered by Alectra Utilities. Objectively verifiable data on smart thermostat ownership exists only for customers who registered their devices through Alectra and therefore our estimation of consumption impacts owing to smart thermostats could only be completed using this verified data. Recall that registered devices were equipped with some form of load curtailment during peak pricing events and so the estimated impacts of smart thermostats (i.e., "Technology") reported here are a measure of the (likely) additive effects of both owning a smart thermostat *and* receiving automatic load curtailment signals. For the Technology analysis, we again combined both Registration date bins.

Frequency of smart thermostat ownership/registration is presented in Table 66. None of the Status-Quo TOU matched Control households owned registered smart thermostats with Alectra Utilities; therefore, we compared Technology and No Technology within the Legacy Dynamic pricing Treatment group only. Registered Honeywell and Nest thermostats were not capable of receiving load curtailment signals from Alectra for the Summer 2019 reporting period and therefore the 'Technology' group for Summer 2019 impact estimates includes only customers with registered Energate or Nest devices. Honeywell and Nest customers with registered devices were excluded entirely from the Summer 2019 Technology impact analysis, that is, they were not added to the control group.

Table 66: Frequency of registered smart thermostat ownership by Legacy Dynamic condition

	Energate	Ecobee	Nest	Honeywell	Unknown
Summer Period					
Legacy Dynamic Pricing	690	5	4	62	38
Status-Quo TOU Control	0	0	0	0	0
Winter Period					
Legacy Dynamic Pricing	731	6	7	66	36
Status-Quo TOU Control	0	0	0	0	0
Summer 2019 Period					
Legacy Dynamic Pricing	615	4	--	--	--
Status-Quo TOU Control	0	0	0	0	0

For the Legacy Dynamic pricing pilot, results of the Technology impact analysis are shown in Table 67 to Table 69. For Summer 2018 High On-Peak hours, we estimated a statistically significant mean hourly consumption effect of -0.127kW owing to smart thermostat possession/registration. Technology was associated with lower electricity consumption for all of the Winter Legacy Dynamic TOU periods, ranging between -0.151 kW (Low On-Peak) and -0.281 kW (High On-Peak), including an overall effect of -0.208 kW for the Winter months. Analysis of the Summer 2019 consumption data yielded an estimated consumption impact of -0.082 kw during High On-peak hours. In this period, the effects of technology ranged from 0.012 kw (during Off-Peak hours) to -0.082 kw during the High On-Peak hours.

Table 67: Legacy Dynamic Technology Impact Analysis Results (Mean Hourly kW; Summer 2018)

Summer Period (Mean Hourly kW)		Technology	No Technology	Estimates	
				Mean Hourly kW	%
High-Peak	Mean	1.723	1.85	**-0.127***	-6.887
	SD	1.058	1.191		
Medium-Peak	Mean	1.449	1.529	-0.08	-5.211
	SD	0.894	0.998		
Low-Peak	Mean	1.014	1.03	-0.016	-1.59
	SD	0.645	0.698		
Off-Peak	Mean	1.016	0.964	0.052	5.383
	SD	0.613	0.636		
Total	Mean	1.336	1.397	-0.061	-4.379
	SD	0.91	1.017		

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 68: Legacy Dynamic Technology Impact Analysis Results (Mean Hourly kW; Winter 2018-19)

Winter Period (Mean Hourly kW)		Technology	No Technology	Estimates	
				Mean Hourly kW	%
High-Peak	Mean	1.12	1.402	**-0.281*** **	-20.078
	SD	0.706	1.261		
Medium-Peak	Mean	1.081	1.291	**-0.21*** **	-16.289
	SD	0.652	1.073		
Low-Peak	Mean	1.046	1.197	**-0.151*** **	-12.628
	SD	0.605	0.907		
Off-Peak	Mean	0.946	1.117	**-0.171*** **	-15.283
	SD	0.621	1.04		
Total	Mean	1.062	1.27	**-0.208*** **	-16.363
	SD	0.672	1.111		

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

Table 69: Legacy Dynamic Technology Impact Analysis Results (Mean Hourly kW; Summer 2019)

Summer 2019 Period			Technology	No Technology	Estimates	
					Mean Hourly kW	%
Legacy Dynamic	High-Peak	Mean	1.46	1.545	-0.082	-5.33
		SD	0.957	1.003		
	Medium-Peak	Mean	1.181	1.192	-0.031	-2.59
		SD	0.783	0.805		
	Low-Peak	Mean	0.93	0.901	-0.024	-2.54
		SD	0.573	0.558		
	Off-Peak	Mean	0.966	0.865	0.012	4.51
		SD	0.614	0.582		
	Total	Mean	1.136	1.124	-0.064	-6.09
		SD	0.778	0.808		

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ^ $p < 0.1$

5.4.6 Pledge Analysis

We sought to examine consumption impacts between households who responded to the On-Peak conservation pledge on the Nudge Report versus households who received the Nudge Reports but did not respond to the pledge. Recall that households had the option to respond to the pledge via SMS text message to commit to reducing their On-Peak electricity consumption. Households who chose to respond to the pledge were offered a $5 rebate. The number of participants in each of the comparison groups is shown in Table 70. Unfortunately, there is insufficient cell size to derive statistically meaningful impacts owing to customers signing versus not signing the pledge within the Legacy Dynamic pricing Treatment group.

Table 70: Pledge Numbers – Legacy Dynamic Customers Who Received Nudge Reports

	Pledge Not Signed	Pricing Pledge Signed
Summer 2018	555	38
Winter 2018-19	571	40
Summer 2019	462	28

5.4.7 Overall Summary of Legacy Dynamic Impacts

Overall, Legacy Dynamic participants consumed less High On-Peak, Medium On-Peak, and CPP electricity during Summer months than the Status-Quo TOU Control households. However, these differences appear to decrease across time and there were no significant differences between Treatment and Control households during On-Peak periods in Summer 2019. Similar to the "new" Dynamic pricing pilot, large consumption impacts were estimated during CPP events, but no overall differences were observed between impact estimates for those Legacy Dynamic participants who received six CPP events or those who received 9 CPP events. Diminished On-Peak hour savings were partially offset by higher Low and Off-Peak usage, leading to some increases in seasonal consumption in the Treatment relative to the Control group.

In terms of non-price interventions, Nudge Reports were not associated with significant consumption impacts and smart thermostat ownership/registration yielded significant electricity consumption impacts for Summer High On-Peak periods and all Winter On-Peak periods.

In terms of the diminishing magnitude of the impact estimates during High On-Peak and Critical Peak events in the Summer months, we offer two interpretations of this hypothesized diminishing behavioural response to peak pricing:

Hypothesis 1 - Impact of prior extended price protection: Customers in Legacy Dynamic pricing have been enrolled in Advantage Power Pricing since 2015 or 2016 (depending on whether they are in registration bin 1 or 2) and have been enjoying full price protection until the start of the current pilot program in April 2018. It is therefore possible that these customers decreased responsiveness to pricing signals over time precisely because there was no material financial penalty associated with doing so. In other words, customers may have learned that failure to maintain On-Peak consumption reductions would not end up costing them more (at least in terms of total bill amount) than they were used to paying under Status-Quo TOU.

Hypothesis 2 - Impact of declining technology use: Over the course of the Legacy Dynamic pricing initiatives undertaken by Alectra Utilities, formerly branded and marketed as Advantage Power Pricing, as well as in the current instantiation, participating customers have been offered subsidized smart thermostats (including procurement and installation). The rationale behind these thermostat incentive programs was that customers would exhibit greater demand response to High On-Peak and Critical Peak pricing events. Response to these events for customers owning eligible devices (i.e., Energate) could be achieved by adjusting the devices 'comfort' settings during programming, and/or by consenting to load curtailment. The latter involves allowing the utility to remotely adjust thermostat settings to lower consumption during high-demand times of day, thus allowing the customer to realize bill savings without having to take any action. The decline in the magnitude of estimated consumption impacts owing to Dynamic pricing for Legacy customers, may therefore be driven, at least in part, by differential use/acquisition of smart thermostat devices over the four to five years in which participating Legacy customers have been enrolled.

There are two ways in which differential use of Technology may have mitigated behavioural response to CPP events:

1. *Lower uptake of devices across the three Dynamic pricing enrollment periods:* While it is true that update of the smart thermostat incentives offered in the current instantiation of Dynamic pricing is lower than the historical uptake observed in the Legacy programs, this is unlikely to be a major factor in driving lower CPP responsiveness. If lowered behavioural response was due to a drop-in device acquisition, we would expect to see sharp declines in behavioural response to CPP events that coincide with the program registration periods. Instead we see a fairly steady decline over the course of the program.

2. *Increasing use of thermostat comfort settings:* It is possible that as time in the Dynamic pricing program increases, customers become increasingly likely to increase the comfort settings on their thermostats, thus increasing consumption during Peak hours in order to enjoy warmer or cooler homes (in Winter and Summer respectively). At the time of the submission of this report, we do not possess thermostat settings data from registered devices and so cannot speak to the reality of this hypothesis.

In summary, the apparent change in impact of Dynamic pricing across time is an interesting potential area of future investigation and should include statistical evaluation of any such effects. Note that such an analysis would not be particularly informative here owing to the fact that the switch from full price protection to unprotected participation in Year 5 represents a significant qualitative change in program design. In addition, differential exposure duration to Dynamic pricing (owing to different registration periods) and inconsistency in the frequency of CPP events across season and year further complicates what would otherwise be a simple time-series analysis. Although we have posited several potential mechanisms to explain a potential reduction in behavioural response to Dynamic pricing over time, a detailed analysis of these mechanisms is not possible at present.

With respect to the 5-month extension period (June – October, 2019), there were two primary research questions that the extension period pilot was designed to address:

1. ***Would the On-Peak and CPP event impacts estimated for the Summer 2018 season still be present a year later in Summer 2019?*** We observed that the trend towards diminished High On-Peak consumption savings observed from 2015-2018 continued into 2019 for Legacy Dynamic households, with consumption impacts failing to reach statistical significance in Summer 2019. With respect to CPP event responsiveness, we estimated similar impacts in the Summer 2018 and Summer 2019 seasons.

2. ***Would an increase in the frequency of CPP events from 6 to 9 impact responsiveness to CPP events?*** In assessing consumption impacts across each of the CPP events called in the Summer 2019 season, we see that consumption impacts for the six events that the Dynamic 6 and Dynamic 9 groups shared in common, are very similar. Thus, as with the 'new' Dynamic pilot, increasing the frequency of CPP events does not seem to impact behavioural response to any one particular CPP event.

6. Survey Findings

In service of the broader objectives of the RPP Pilot Program, customer-facing surveys were administered to all Dynamic and Legacy Dynamic customers along with households in the matched Control groups. The purpose of the surveys was to measure overall levels of comprehension of TOU pricing plans, motivation to change behaviour, subjective experience with APP price plans, and to capture relevant demographic data and household characteristics (e.g. electric vehicle (EV) ownership and use of a programmable thermostat).

To estimate the effects of participation in Dynamic pricing over time on the above metrics, surveys were deployed at the beginning of the pilot (April 2018) (*baseline*), at the six-month mark (October 2018) (*midterm/interim*), and at the end of the Dynamic pilot extension period (November 2019) (*final*). Each of these surveys remained active for approximately one month in order to gather as much participant response data as possible without sacrificing the temporal specificity of each survey (i.e., if the baseline survey were active for too long, it would no longer be a valid 'baseline' survey). Unfortunately, a single survey link was distributed to all Dynamic pricing pilot participants regardless of whether they were newly enrolled or part of the Legacy Dynamic program. This means that survey results for the Dynamic pricing plan comprise a mixture of responses from both "new" and Legacy participants. This section of the report will discuss the results of all three surveys in order to assess potential changes in comprehension, motivation, and self-reported behaviour change (1) across time, and (2) between Treatment and Control groups within Dynamic pricing, where applicable and feasible. Note that survey responses were solicited via direct mail and email marketing initiatives undertaken by Alectra and therefore the evaluator had no control over the response rate. In some instances (particularly for Control participants within each pilot), response rates were too low to allow for any meaningful analyses.

Since survey data was provided in an anonymous form, we cannot determine how many households provided unique responses. That is, some households may have responded to surveys at just a single time-point, any two of the three time-points, or all three time-points. Table 71 shows the number of survey completions across all conditions. Table 72 shows the number of survey completions across all conditions *and* survey timepoints.

Table 71: Total Number of Survey Responses per Condition Overall

Pricing Pilot Group	No Nudge Report	Nudge Report	**Total**
Dynamic Pricing Control	17	8	**25**
Dynamic Pricing Treatment	541	58	**599**
Total			**624**

Table 72: Number of Survey Responses per Condition Baseline, Midterm, and Final

Number of Completions for Baseline Survey

Treatment Group	No Nudge Report	Nudge Report	**Total**
Dynamic Pricing Control	12	8	**20**
Dynamic Pricing Treatment	83	58	**141**
Total			**161**
Number of Completions for Midterm Survey			
Dynamic Pricing Control	5	0	**5**
Dynamic Pricing Treatment	235	166	**401**
Total			**406**
Number of Completions for Final Survey			
Dynamic Pricing Control	0	0	**0**
Dynamic Pricing Treatment	223	0	**223**
Total			**223**

6.1 Comprehension

The first research question was whether households who received a Nudge Report had higher levels of comprehension regarding electricity prices and the TOU period structure in the Province of Ontario relative to those who did not receive Nudge Reports. It was hypothesized that with prolonged exposure to Nudge Reports over the duration of the pilot, that customers would increase their level of comprehension of prices and TOU period times relative to customers who were not exposed to these reports. To answer this question, households were asked the same four comprehension questions on the baseline (before Treatment), midterm (six months after receiving pricing Treatment/Nudge Report), and final surveys (17 months after receiving pricing Treatment/Nudge Report). The four comprehension questions that appeared on all three surveys are listed below as well as in Appendix K:

1. Please select the pricing model that you think best describes how electricity is currently priced for the majority of residential customers in Ontario **(Answer: "Time-Of-Use: The price of electricity varies depending on the time of day")**

2. Electricity usage is split into different Time-Of-Use periods. The cost of electricity varies between these periods. What do you think the daily Time-Of-Use Periods are called in Ontario? **(Answer: "Three different TOU periods: Off-Peak, Mid-Peak, On-Peak")**

3. Select the top 3 household items that you believe consume the most electricity **(Answer: "Washing machine / Dryer, Heating and Cooling unit, Fridge")**

4. What do you think is the most effective way to reduce your electricity bill in the Summertime? **(Answer: Raise the temperature on your A/C unit by 2 degrees Celsius between the hours of 1pm and 7pm during hot months)**

Each survey response was coded as correct or incorrect and a comprehension score out of 4 was obtained for each respondent. Survey respondents were given one mark for correct answers on questions 1, 2, and 4 and 1/3 of a mark for each correctly listed item in question 3. The final comprehension score was then converted into a percentage.

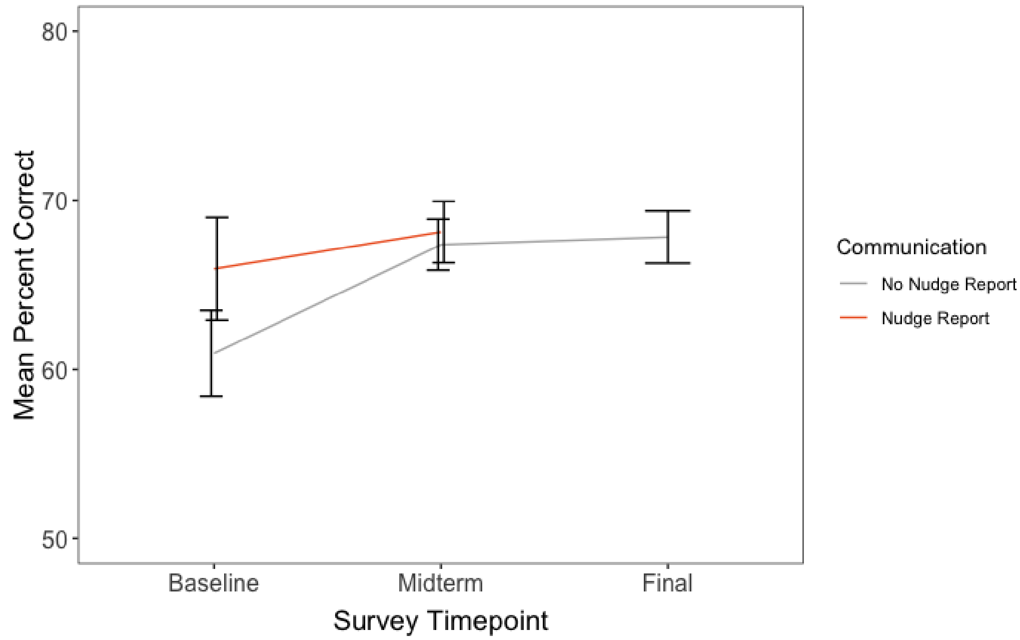
This section will compare percentage of correct responses between the Baseline, Midterm (Interim), and Final Surveys by communication condition (i.e. whether or not they received a Nudge Report).

Table 73 and Figure 1 show the comprehension scores (mean percent correct responses) for the Dynamic pricing pilot. There were too few survey completes for Dynamic pricing Controls at baseline and midterm, therefore comprehension was analyzed in the Dynamic pricing Treatment group only. There was a significant effect of timepoint on comprehension scores for all participants in the Dynamic pricing Treatment group. Overall, participants performed significantly better on comprehension at the midterm and final timepoints compared to baseline. There was no effect of communication (i.e. Nudge Report) on comprehension scores.
In summary, participants in the Dynamic pricing pilot performed significantly better on the comprehension portion of the survey over time. Results of the statistical model for the Dynamic pricing pilot are shown in Table 1 of Appendix J.

Table 73: Comprehension Scores for Dynamic Pricing Pilot (Mean Percent Correct)

	Dynamic Pricing Control		Dynamic Pricing Treatment	
Survey Timepoint	No Nudge	Nudge	No Nudge	Nudge
Baseline	70.8%	78.1%	60.9%	65.9%
Midterm	68.3%	N/A	67.4%	68.1%
Final	N/A	N/A	67.8%	N/A

Figure 1: Comprehension Scores for the Dynamic Pricing Pilot (Mean Percent Correct)



6.2 Motivation

The second research question addressed by the customer-facing surveys pertains to whether pricing Treatment and/or the Nudge Report were able to increase household motivation to alter electricity consumption behaviour. Households were asked for their opinions regarding their motivation to either shift or not shift their electricity usage in accordance with their TOU schedule (APP TOU schedule for pricing Treatment customers and Status-Quo TOU schedule for pricing Control customers). The purpose of this assessment was to determine whether any of pricing Treatments and/or Nudge Report communications had any effect on these motivations. To measure motivation, respondents were asked the following six questions (note: questions are also listed in Appendix K):

1. Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I don't think it is fair for the utility company to ask me to change my energy consumption behaviour.

2. Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I feel like I am already doing everything I can to conserve energy.

3. Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I feel motivated to conserve On-Peak electricity and/or shift my electricity usage to Off-Peak.

4. Respond with "Yes" or "No": Has TOU pricing affected how you consume energy?

5. How much do you agree or disagree with each of the following reasons for why you have NOT shifted your consumption behaviour from On-peak to Off-peak (on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree")?

    a. I didn't know Ontario had a Time-of-use pricing structure for electricity consumption
    b. It is too difficult for me to schedule electricity consuming activities during Off-Peak hours (such as overnight)
    c. I don't think the cost savings are worth the effort
    d. I don't think it contributes much to the province's electricity conservation efforts
    e. I'm not too concerned about the environmental impact of my electricity consumption
    f. I don't think anyone else does it, so I don't either
    g. It's too complicated for me to understand

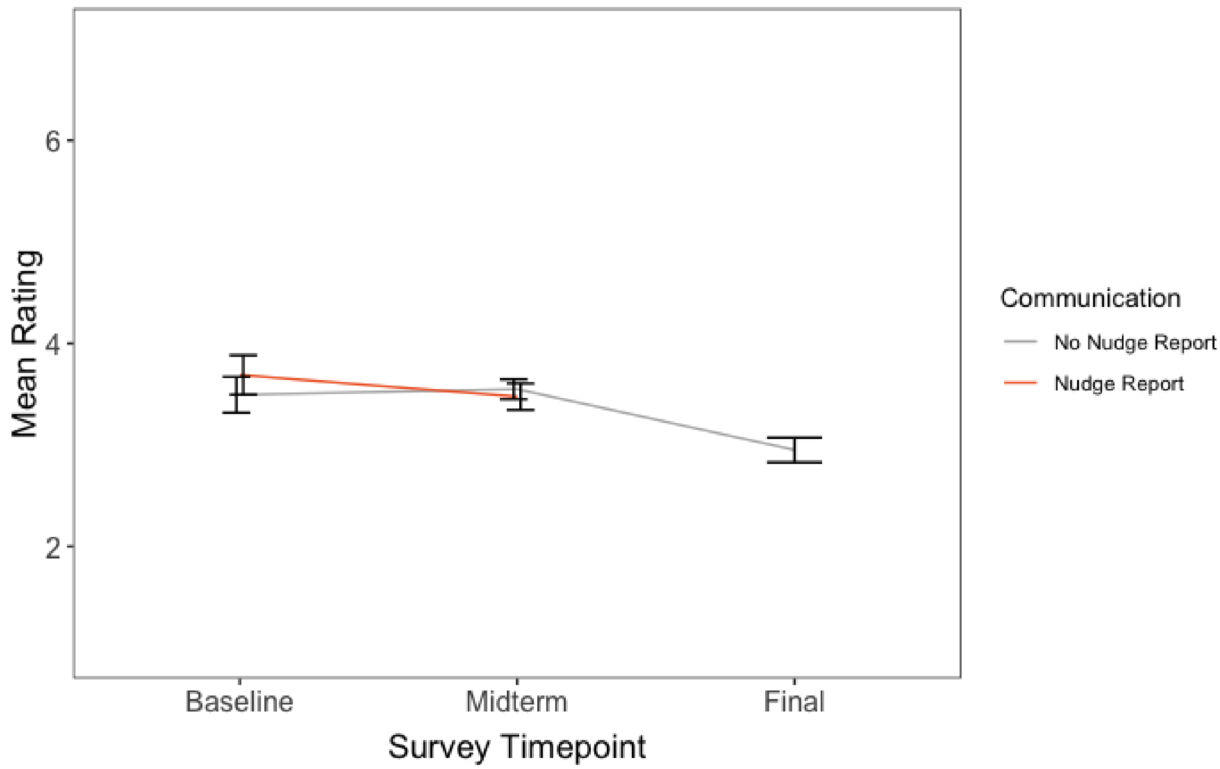
6. How much do you agree or disagree with each of the following reasons for why you have shifted your consumption behaviour from On-peak to Off-peak? (on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree"):
    a. To save money on my monthly bills
    b. It was the environmentally responsible thing to do
    c. To be a good role model for others
    d. Because others I know were also doing it
    e. It was convenient for me to shift my electricity consumption
    f. I purchased smart thermostats to automatically shift my electricity consumption

There were not enough survey completions at the baseline and midterm survey timepoints for Dynamic pricing Control households, and therefore we only analyzed survey responses for the Dynamic pricing Treatment respondents over time.

Question 1: *Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I don't think it is fair for the utility company to ask me to change my energy consumption behaviour.*

Participants in the Dynamic pricing Treatment group had lower ratings of agreement with the statement 'I don't think it is fair for the utility company to ask me to change my energy consumption behaviour' at the final survey timepoint compared to baseline (Figure 2; Table 2 of Appendix J).

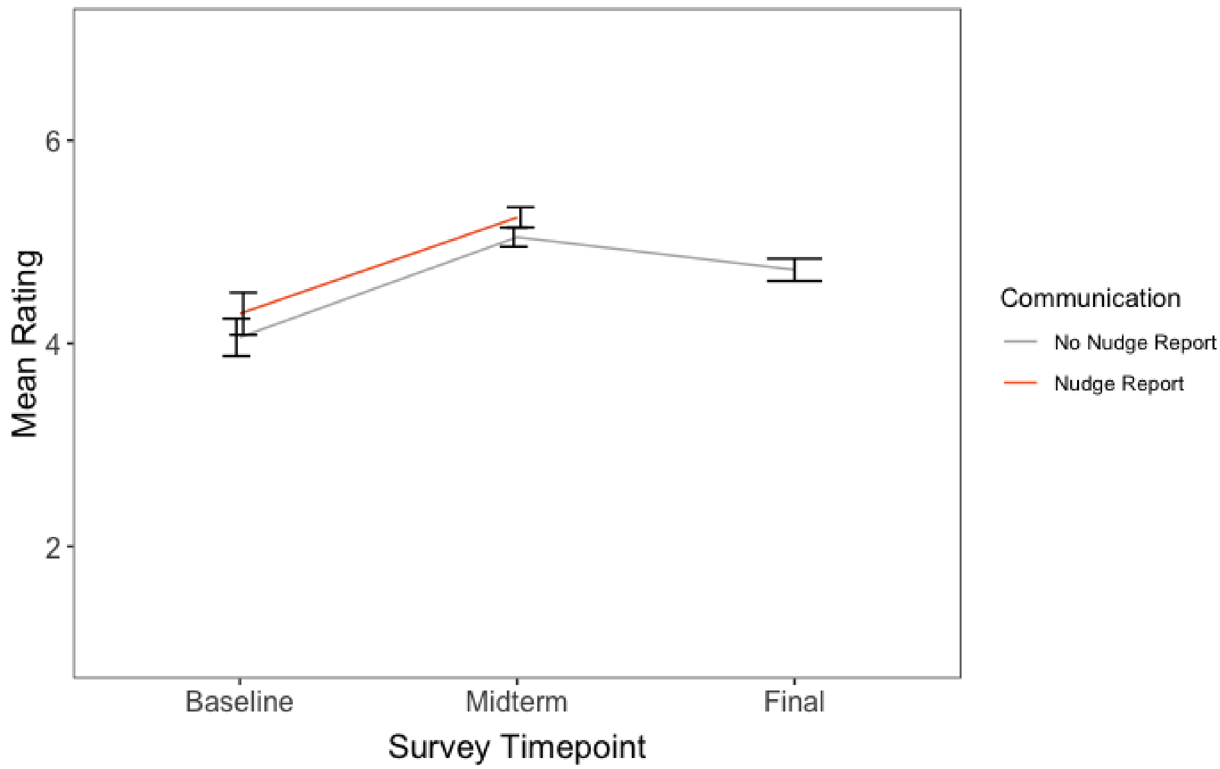
Figure 2: Participants mean ratings for agreement with the statement 'I don't think it is fair for the utility company to ask me to change my energy consumption behaviour' (1-7 scale)



Question 2: *Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I feel like I am already doing everything I can to conserve energy.*

There was a significant effect of timepoint on level of agreement with the statement 'I feel like I am already doing everything I can to conserve energy' whereby participants in the Dynamic pricing Treatment group had higher levels of agreement with this statement at the midterm and final survey timepoints compared to baseline (Figure 3; Table 3 of Appendix J).

Figure 3: Participants mean ratings for agreement with the statement 'I feel like I am already doing everything I can to conserve energy' (1-7 scale)



Question 3: *Rate your level of agreement with the following statement on a scale from 1: "Strongly Disagree" to 7: "Strongly Agree": I feel motivated to conserve On-Peak electricity and/or shift my electricity usage to Off-Peak.*

There were no differences between Dynamic pricing groups on responses to Question 3. Participants agreed with this statement on average, with a mean level of agreement of 5.70 (+/- 1.25) on a scale of 1 to 7.

Question 4: *Has TOU affected your energy consumption?*

There were no significant differences between groups in terms of likelihood of reporting that TOU pricing affected electricity consumption. Proportion who reported 'Yes' for each group/condition are recorded in Table 74.

Table 74: Percentage of participants for each condition who responded that TOU pricing has affected their energy consumption

	Dynamic Pricing Control		Dynamic Pricing Treatment	
Survey Timepoint	No Nudge	Nudge	No Nudge	Nudge
Baseline	100.0%	100.0%	95.2%	86.2%
Midterm	100.0%	N/A	90.2%	85.5%
Final	N/A	N/A	91.0%	N/A

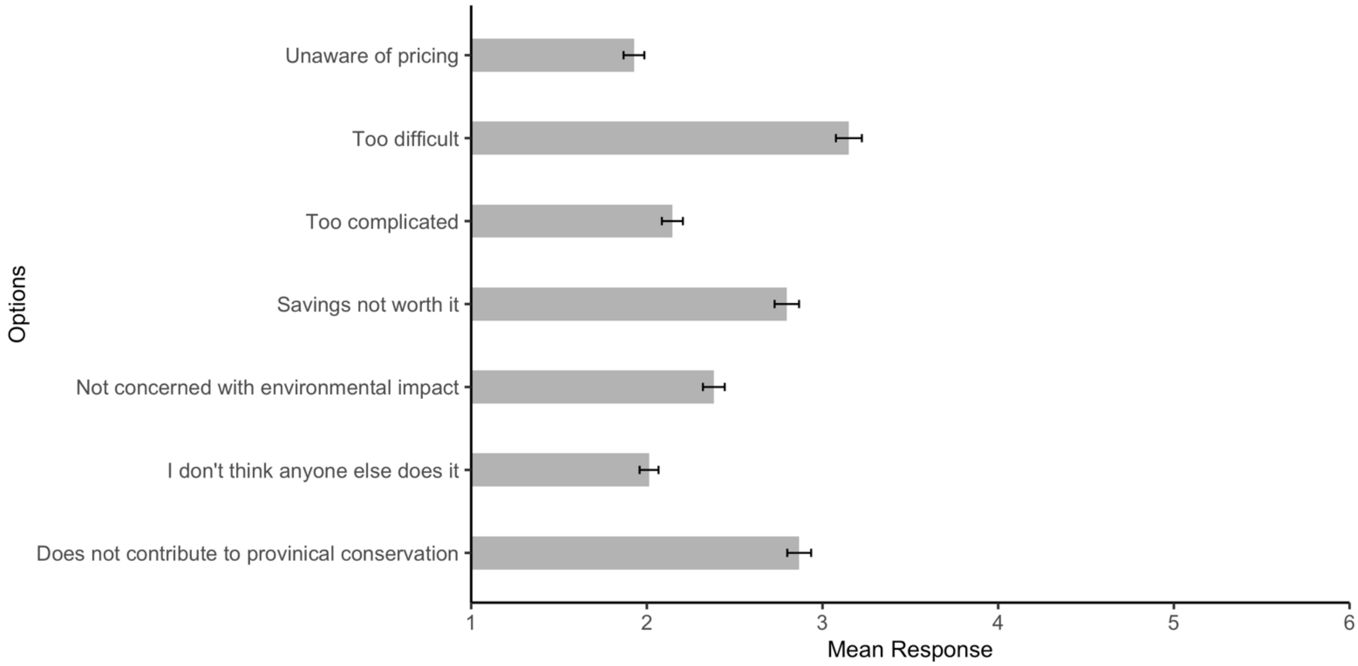
Question 5: *Factors that influence why participants reported that they did not shift their energy consumption behaviour.*

Overall, mean ratings for various motivational factors affecting why Dynamic pricing Treatment participants claim they did not shift their electricity consumption behaviour in response to Dynamic pricing significantly differed from one another (Table 6 of Appendix J). Difficulty in shifting energy consumption behaviour was rated most highly as a factor for why participants did not shift their behaviour followed by Provincial reasons (i.e. does not contribute to Provincial energy conservation). Mean ratings for each factor are displayed in Figure 4 and summarized in Table 75.

Table 75: Mean levels of agreement (1-7 scale) with motivational factors for not shifting energy behaviour in Dynamic Pricing Treatment participants

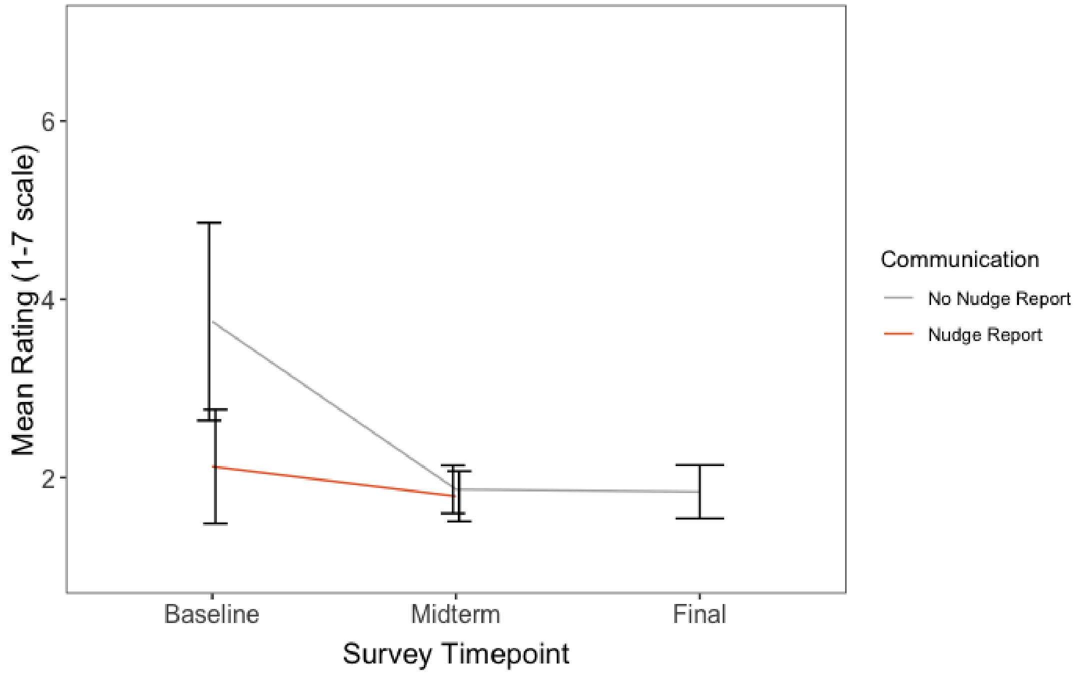
Motivation	Timepoint	Dynamic Pricing Treatment
Awareness	Baseline	2.7
	Midterm	1.8
	Final	1.8
Difficulty	Baseline	3.0
	Midterm	3.9
	Final	3.7
Cost	Baseline	2.5
	Midterm	3.8
	Final	3.7
Provincial	Baseline	3.3
	Midterm	3.7
	Final	3.8
Environment	Baseline	2.3
	Midterm	3.1
	Final	2.3
Social	Baseline	2.0
	Midterm	2.3
	Final	2.1
Comprehension	Baseline	2.8
	Midterm	3.0
	Final	2.5

Figure 4: Participants mean ratings for how much each factor influenced them to not shift energy consumption behaviour (1-7 scale)



Participants in the Dynamic pricing pilot had reduced feelings of 'lack of awareness' as a motivation for why they did not shift their electricity consumption behaviour over the course of the Dynamic pricing pilot. Specifically, their level of agreement with the statement 'I didn't know Ontario had a Time-of-use pricing structure for electricity consumption' decreased at the midterm and final survey timepoints compared to baseline (Figure 5; Table 7 of Appendix J).

Figure 5: Participants mean ratings for how much 'lack of awareness' influenced them not to shift energy consumption behaviour (1-7 scale)



No other responses to Question 5 differed significantly different between groups (Nudge Report, no Nudge Report) or across time in the Dynamic pricing pilot.

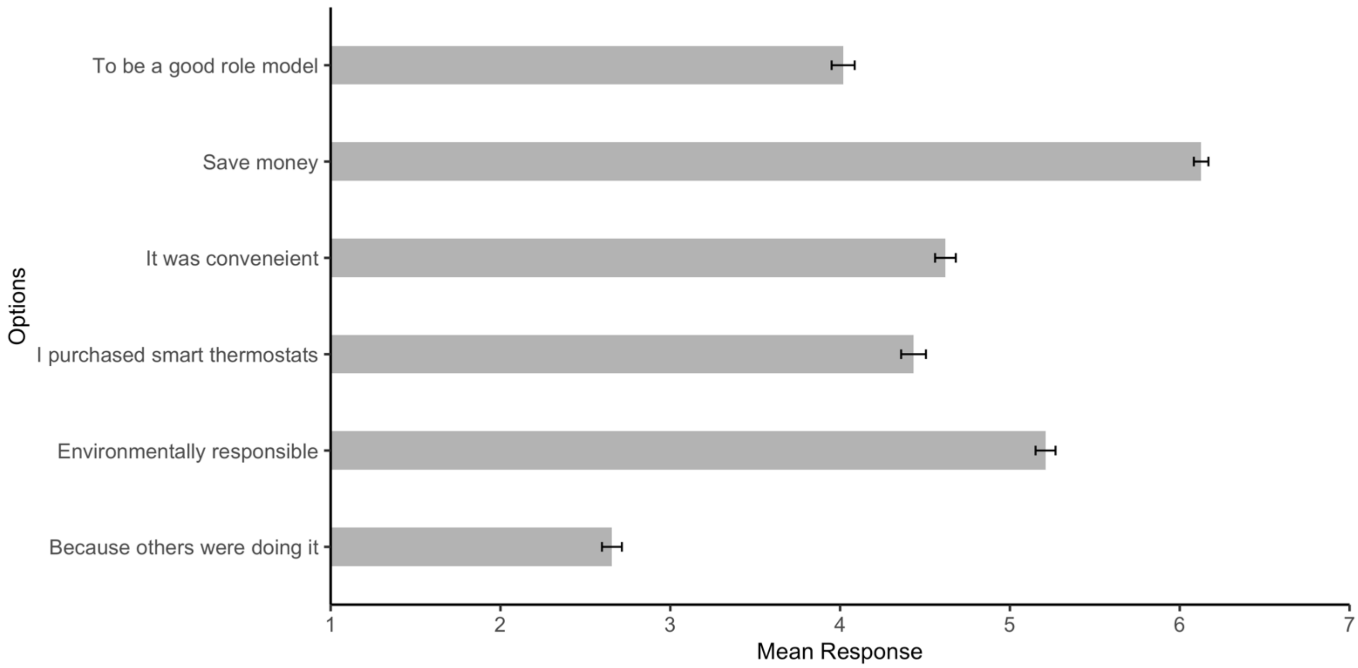
Question 6: *Factors that influence why participants reported that they did shift their energy consumption behaviour.*

Overall, mean ratings for various motivational factors affecting why Dynamic pricing pilot Treatment participants feel they *did* shift their electricity consumption behaviour significantly differed from one another (Table 14 of Appendix J). 'Saving money' was rated most highly as factor for why participants shifted their behaviour followed by environmental responsibility. Mean ratings for each factor are presented in Figure 6 and summarized in Table 76.

Table 76: Mean levels of agreement (1-7 scale) with motivational factors for shifting energy behaviour in Dynamic Pricing Treatment participants

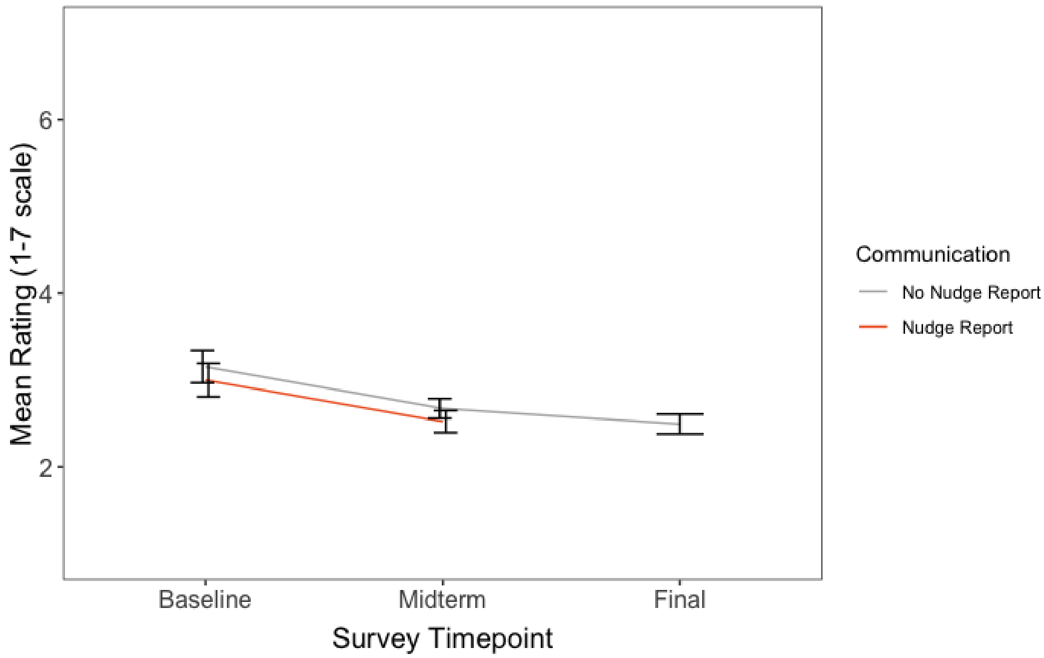
Motivation	Timepoint	Dynamic Pricing Treatment
Cost	Baseline	6.2
	Midterm	6.1
	Final	6.3
Environment	Baseline	5.3
	Midterm	5.1
	Final	5.4
Role model	Baseline	4.2
	Midterm	4.0
	Final	4.1
Social	Baseline	3.1
	Midterm	2.6
	Final	2.5
Convenience	Baseline	4.8
	Midterm	4.4
	Final	5.1
Smart Thermostat	Baseline	4.8
	Midterm	4.3
	Final	4.6

Figure 6: Participants mean ratings for how much each factor influenced them to shift energy consumption behaviour (1-7 scale)



There was a significant effect of timepoint on agreement levels with social motivation (i.e. ‘because others I know were also doing it’) as a reason for why participants in the Dynamic pricing pilot shifted their electricity consumption behaviour (Table 18 of Appendix J). Participants in the Dynamic pricing Treatment group had significantly lower agreement ratings for this factor at the midterm survey compared to baseline and even lower agreement at the final survey timepoint compared to baseline (Figure 7).

Figure 7: Participants mean ratings for how much social factors influenced them to shift energy consumption behaviour (1-7 scale)



There was a significant effect of timepoint on agreement with convenience (i.e. 'it was convenient for me to shift my energy consumption') and purchasing smart thermostats as motivational factors for why participants in the Dynamic pricing Treatment group shifted their electricity consumption behaviour. Agreement ratings with both of these factors were lower at the midterm survey timepoint compared to baseline (Figure 8, Table 19 of Appendix J, and Figure 9, Table 20 of Appendix J).

Figure 8: Participants mean ratings for how much convenience influenced them to shift energy consumption behaviour (1-7 scale)

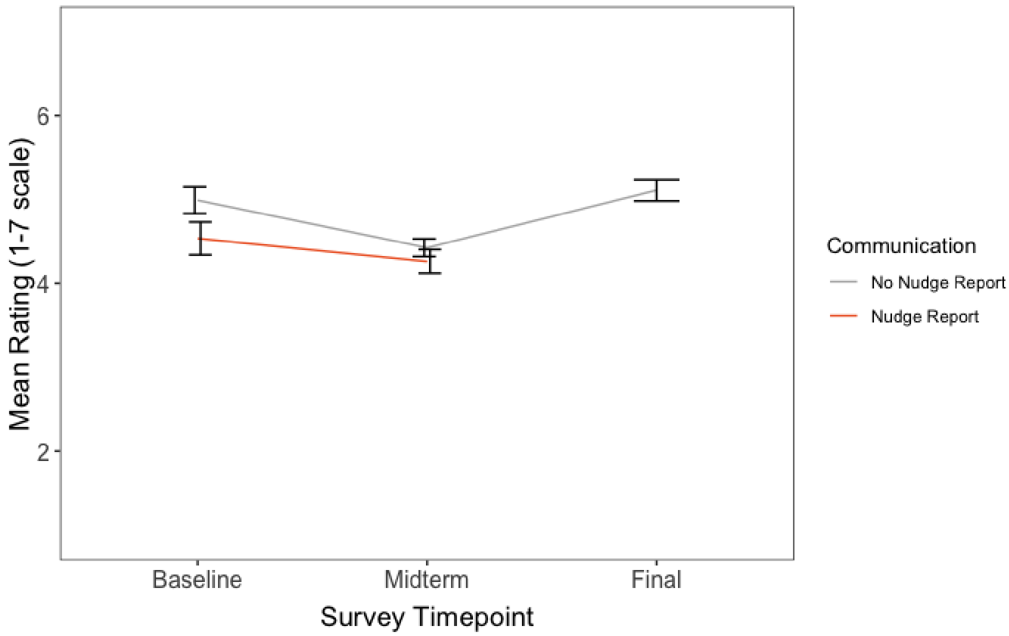
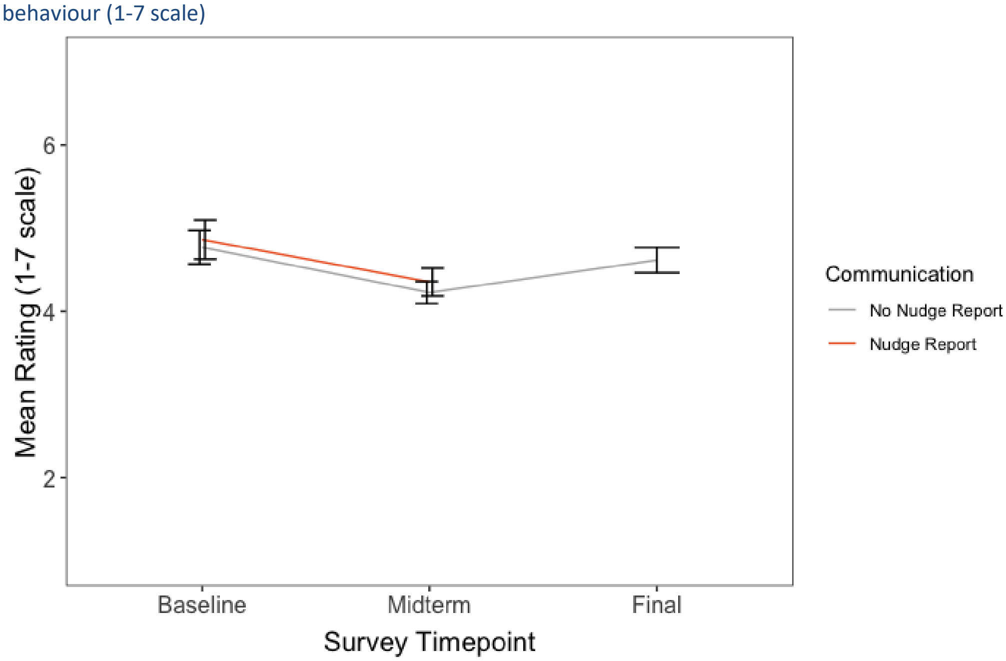


Figure 9: Participants mean ratings for how much purchasing a smart thermostat influenced them to shift energy consumption behaviour (1-7 scale)



Based on the small number of surveys completed by the Dynamic pricing Control group, we were only able to examine Dynamic pricing Treatment participant responses *over time*. Dynamic pricing Treatment participants had lower agreement with the statement 'I don't think it is fair for the utility company to ask me to change my energy consumption behaviour' over time and also felt more strongly that they were 'doing everything they can' to conserve electricity over the course of the Dynamic pilot. Most Dynamic pricing participants felt that TOU pricing did affect their consumption behaviour. For those who reported that TOU pricing did not affect their consumption behaviour, 'difficulty shifting energy consumption to Off-Peak hours' and 'doesn't contribute to provincial energy conservation' were rated most highly as motivations for not shifting their behaviour.

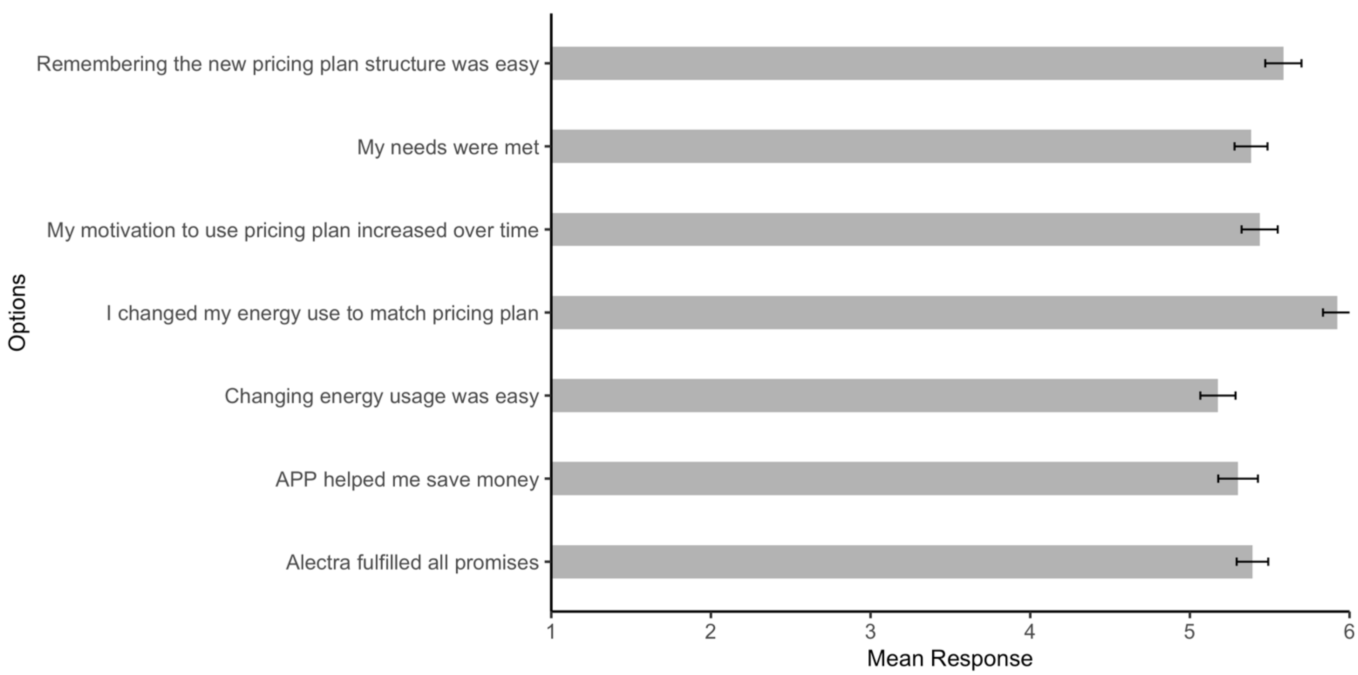
In terms of what Dynamic pricing participants felt *did* affect their electricity consumption behaviour, saving money and environmental responsibility were rated most highly as reasons for shifting behaviour. Participants rated social reasons for shifting their behaviour lower over the course of the pilot, and also reported convenience and the use of smart thermostats lower at the midterm survey timepoint compared to baseline and final survey timepoints.

6.3 Participant Experience

Participants in Dynamic pricing were asked several questions related to their experience in the APP program at the final survey timepoint (questions are listed in Appendix K). Here we review responses to these questions in order to quantify participants' subjective experience with APP.

There were significant differences in the degree to which participants in the Dynamic pricing pilot agreed with the seven statements related to their subjective experience (Figure 10; Table 21 of Appendix J). Overall, participants had the highest ratings of agreement with the statement 'I changed my energy use behaviour to match my new pricing plan' and 'Remembering the new pricing plan structure was easy' suggesting that they were able to successfully remember and adopt new electricity consumption behaviours.

Figure 10: Dynamic Pricing participant mean levels of agreement with key subjective aspects of Alternative Pricing Plan participation



Overall, the participants exposed to Dynamic pricing had the high numerical levels of satisfaction with their experience in APP, with a mean rating of 5.64 (+/- 1.55) on a scale of 1 to 7. Participants in the Dynamic pricing Treatment group were also likely to recommend (i.e. above neutral) APP to others, with a mean rating of 5.64 (+/- 1.66) on a 1 to 7 scale. Most survey respondents (76.7%) in the Dynamic pricing Treatment group did not contact Alectra with any issues over the course of the pilot.

6.4 Participant Demographics

Dynamic pricing participants were asked a series of demographic questions at the end of each survey. The primary purpose of these questions was to provide a comprehensive picture of the make-up of the APP participants. These demographic responses should provide useful information for the scalability of the APP price plans to other markets. As with any pilot project, the interpretability and generalizability of the behavioural findings are limited to the characteristics of the sample with whom the pilot was conducted. A few of the noteworthy observations from the demographic questionnaire: (1) 89% of respondents report owning some type of programmable thermostat, (2) less than 6% of respondents indicate heating their homes primarily with electricity, (3) over 90% of respondents indicate having central Air Conditioning, and (4) only 7% of respondents indicate owning an electric vehicle, indicating that Dynamic pricing is perhaps not optimized to attract this particular sub-population. We note that since survey responses were completely voluntary, sample characteristic data from respondents may be somewhat skewed due to selection bias; caution should be used when interpreting the demographic responses as well as all other survey-derived insights reported here. A full list of demographic survey questions can be found in Appendix K.

Table 77: Dynamic Pricing Pilot Demographics

	Dynamic Pricing Control (N=25)	Dynamic Pricing Treatment (N=765)	Total (N=790)
Residence			
N-Missing	0 (0.0%)	1 (0.1%)	1 (0.1%)
Duplex or two-family home	0 (0.0%)	28 (3.7%)	28 (3.5%)
High-rise apartment or condo building	0 (0.0%)	3 (0.4%)	3 (0.4%)
Low-rise apartment or condo building	0 (0.0%)	6 (0.8%)	6 (0.8%)
Other (please enter)	0 (0.0%)	12 (1.6%)	12 (1.5%)
Single-family home	22 (88.0%)	613 (80.1%)	635 (80.4%)
Townhouse or row-house	3 (12.0%)	100 (13.1%)	103 (13.0%)
Other (please indicate)	0 (0.0%)	2 (0.3%)	2 (0.3%)
Year Home Built			
N-Missing	0 (0.0%)	1 (0.1%)	1 (0.1%)
1920 or before	0 (0.0%)	13 (1.7%)	13 (1.6%)
1921 - 1945	0 (0.0%)	3 (0.4%)	3 (0.4%)
1946 - 1960	2 (8.0%)	20 (2.6%)	22 (2.8%)
1961 - 1970	2 (8.0%)	42 (5.5%)	44 (5.6%)
1971 - 1980	3 (12.0%)	89 (11.6%)	92 (11.6%)

	Dynamic Pricing Control (N=25)	Dynamic Pricing Treatment (N=765)	Total (N=790)
1981 - 1985	1 (4.0%)	64 (8.4%)	65 (8.2%)
1986 - 1990	2 (8.0%)	90 (11.8%)	92 (11.6%)
1991 - 1995	2 (8.0%)	45 (5.9%)	47 (5.9%)
1996 - 2000	2 (8.0%)	89 (11.6%)	91 (11.5%)
2001 - 2005	1 (4.0%)	103 (13.5%)	104 (13.2%)
2006 - 2011	4 (16.0%)	110 (14.4%)	114 (14.4%)
2012 - 2016	4 (16.0%)	24 (3.1%)	28 (3.5%)
2012 - 2017	1 (4.0%)	65 (8.5%)	66 (8.4%)
Unsure	1 (4.0%)	7 (0.9%)	8 (1.0%)
Thermostat			
N-Missing	0 (0.0%)	1 (0.1%)	1 (0.1%)
No	2 (8.0%)	84 (11.0%)	86 (10.9%)
Yes	23 (92.0%)	680 (88.9%)	703 (89.0%)
Thermostat Type			
N-Missing	1 (4.0%)	46 (6.0%)	47 (5.9%)
ecobee	4 (16.0%)	96 (12.5%)	100 (12.7%)
Energate Foundation	0 (0.0%)	246 (32.2%)	246 (31.1%)
Honeywell UtilityPRO or ExpressStat	6 (24.0%)	133 (17.4%)	139 (17.6%)
Nest	6 (24.0%)	130 (17.0%)	136 (17.2%)
Other (please enter)	8 (32.0%)	114 (14.9%)	122 (15.4%)
Primary Heating Method			
N-Missing	0 (0.0%)	6 (0.8%)	6 (0.8%)
Boiler with hot water or steam radiators	0 (0.0%)	4 (0.5%)	4 (0.5%)
Primary Heating Method			
Electric baseboard heaters	0 (0.0%)	20 (2.6%)	20 (2.5%)
Electric furnace	1 (4.0%)	25 (3.3%)	26 (3.3%)
Natural gas furnace	24 (96.0%)	693 (90.6%)	717 (90.8%)
Other	0 (0.0%)	7 (0.9%)	7 (0.9%)
Propane furnace	0 (0.0%)	3 (0.4%)	3 (0.4%)
Other (please indicate)	0 (0.0%)	7 (0.9%)	7 (0.9%)
Appliances			
Central air conditioning	23 (92.0%)	694 (90.7%)	717 (90.8%)
Electric clothing dryer	17 (68.0%)	526 (8.8%)	543 (68.7%)
Electric water heater	9 (36.0%)	190 (24.8%)	199 (25.2%)
Room or window air conditioner	0 (0%)	0 (0%)	0 (0%)
Electric space heater	0 (0%)	155(20.3%)	155 (19.6%)
Swimming Pool	0 (0%)	0 (0%)	61 (8.0%)
Electric Vehicle Ownership			
N-Missing	0 (0.0%)	6 (0.8%)	6 (0.8%)
No	24 (96.0%)	702 (91.8%)	726 (91.9%)
Yes	1 (4.0%)	57 (7.5%)	58 (7.3%)
Number of Adults 18+			

	Dynamic Pricing Control (N=25)	Dynamic Pricing Treatment (N=765)	Total (N=790)
N-Missing	0	1	1
Mean (SD)	2.400 (0.707)	2.356 (0.987)	2.357 (0.979)
Range	1.000 - 4.000	0.000 - 7.000	0.000 - 7.000
Number of Adults 60+			
N-Missing	0	6	6
Mean (SD)	0.320 (0.690)	0.705 (0.887)	0.693 (0.883)
Range	0.000 - 2.000	0.000 - 3.000	0.000 - 3.000
Number of Children			
N-Missing	1	2	3
Mean (SD)	0.542 (0.884)	0.699 (0.999)	0.694 (0.996)
Range	0.000 - 2.000	0.000 - 9.000	0.000 - 9.000
Income Level			
N-Missing	0 (0.0%)	7 (0.9%)	7 (0.9%)
$10,000 to less than $20,000	2 (8.0%)	9 (1.2%)	11 (1.4%)
Income Level			
$100,000 to less than $150,000	5 (20.0%)	120 (15.7%)	125 (15.8%)
$150,000 or more	4 (16.0%)	122 (15.9%)	126 (15.9%)
$20,000 to less than $30,000	0 (0.0%)	19 (2.5%)	19 (2.4%)
$30,000 to less than $40,000	0 (0.0%)	31 (4.1%)	31 (3.9%)
$40,000 to less than $75,000	1 (4.0%)	103 (13.5%)	104 (13.2%)
$75,000 to less than $90,000	3 (12.0%)	83 (10.8%)	86 (10.9%)
$90,000 to less than $100,000	0 (0.0%)	53 (6.9%)	53 (6.7%)
Less than $10,000	2 (8.0%)	5 (0.7%)	7 (0.9%)
Prefer not to say	8 (32.0%)	213 (27.8%)	221 (28.0%)
Education			
N-Missing	1 (4.0%)	7 (0.9%)	8 (1.0%)
College or other non-university certificate or diploma	5 (20.0%)	140 (18.3%)	145 (18.4%)
None, or grade 1-8	0 (0.0%)	5 (0.7%)	5 (0.6%)
Post-graduate or professional schooling after university (e.g., Master's degree or Ph.D; law or medical school)	8 (32.0%)	197 (25.8%)	205 (25.9%)
Registered Apprenticeship or other trades certificate or diploma	0 (0.0%)	19 (2.5%)	19 (2.4%)
Secondary (high) school graduate	0 (0.0%)	56 (7.3%)	56 (7.1%)
Secondary (high) school incomplete	0 (0.0%)	8 (1.0%)	8 (1.0%)
University certificate, diploma, or degree	11 (44.0%)	333 (43.5%)	344 (43.5%)
What is the last grade or class you completed in school?	0 (0.0%)	0 (0.0%)	0 (0.0%)
Number of People in House			

	Dynamic Pricing Control (N=25)	Dynamic Pricing Treatment (N=765)	Total (N=790)
N-Missing	0 (0.0%)	2 (0.3%)	2 (0.3%)
0	2 (8.0%)	214 (28.0%)	216 (27.3%)
1	5 (20.0%)	240 (31.4%)	245 (31.0%)
2	17 (68.0%)	261 (34.1%)	278 (35.2%)
3	0 (0.0%)	31 (4.1%)	31 (3.9%)
4+	1 (4.0%)	17 (2.2%)	18 (2.3%)
Someone Home Mon-Fri			
N-Missing	0 (0.0%)	1 (0.1%)	1 (0.1%)
No	5 (20.0%)	51 (6.7%)	56 (7.1%)
Yes	20 (80.0%)	713 (93.2%)	733 (92.8%)

7. Summary and Conclusions

This report assessed the impacts of Dynamic pricing in combination with two non-price interventions (communications in the form of Nudge Reports as well as technology in the form of programmable smart thermostats with load curtailment enablement). Originally, Dynamic pricing was intended to run for 12 months, in parallel with two other pricing pilots offered as part of Advantage Power Pricing by Alectra Utilities. However, in May 2019, the Ontario Energy Board opted to extend the reporting period for the Dynamic pricing plan for an additional five months based on a desire to obtain additional insights after reviewing the impacts reported during the interim reporting period (April 2018 – October 2018 inclusive). This extension was also intended to allow for the exploration of customer response to a greater number of CPP events by splitting Dynamic pricing participants into two groups, one receiving six CPP events (which is the number of events called for each of the Summer and Winter seasons in the original 12-month reporting period), and the other receiving nine CPP events. For completeness, the consumption impacts owing to Dynamic pricing as well as the non-price interventions, were reported for the entire 17-month duration of Dynamic pricing (the originally scoped 12-month APP pilot plus the 5-month Dynamic pricing extension period).

Below, we first summarize the key behavioural findings with respect to electricity consumption impacts stemming from Dynamic pricing (both "new" and Legacy Dynamic pilots), followed by the non-pricing interventions. We then summarize the findings obtained from the three customer-facing surveys administered over the course of this pilot. Finally, we make some general conclusions and recommendations pertaining to the future of the Regulated Price Plan in the Province of Ontario.

Summary of Pricing Interventions

Dynamic Pricing

It was hypothesized that the high On- to Off-Peak pricing differential in the Dynamic pricing pilot would provide a strong incentive for customers to reduce their electricity consumption behaviour during On-Peak periods in order to realize bill savings. This could be accomplished either through simple curtailment of On-Peak consumption, or through load shifting behaviours in which customers perform certain actions (such as laundry, pre-cooling air conditioning etc.) during Off-Peak as opposed to On-Peak hours. The estimated consumption impacts were highly consistent with the former, as Dynamic pricing customers exhibited lower electricity consumption relative to matched Control participants during Low, Medium, and High-On-Peak hours, without exhibiting an increase in Off-Peak consumption.

The largest consumption impacts in this pilot owe to the CPP events in which Dynamic pricing customers were subjected to six 4-hour events in each of the Summer 2018 and Winter 2018-2019 reporting periods, and either six or nine such events in Summer 2019. These customers were notified via email or SMS text (according to each customer's preference) of upcoming CPP events, provided a minimum of two hours in advance of such events. Customers were charged an hourly kWh price of 49.8 cents during these event hours. Dynamic pricing Treatment customers substantially less electricity during CPP event hours compared to matched Controls during those same hours. The overall electricity consumption impacts owing to Dynamic pricing during Peak and CPP events also yielded a small net decrease in overall average consumption in the Summer and Winter periods respectively.

Based on preliminary (i.e., 6-month interim) impact analyses showing that Dynamic pricing is an effective means to reduce household electricity consumption during High and Critical Peak TOU periods in Summer months, Dynamic and Legacy Dynamic pilots were extended over a second Summer season. With respect to this 5-month extension period (June – October 2019), there were two primary research questions:

1. Will the responsiveness to High On-Peak and Critical Peak price events by Dynamic and Legacy Dynamic customers in the Summer of 2018 persist a year later (i.e., in the Summer of 2019)?

2. Does the responsiveness to CPP events by Dynamic and Legacy Dynamic customers depend on the frequency of those events (i.e., will increasing the number of CPP events from 6 to 9 per season result in diminished behavioural response to such events)?

With respect to the first research question, there were no qualitative differences in the estimated magnitude of responsiveness to High On-Peak TOU periods between the Summer 2018 and Summer 2019 seasons for either the Dynamic or Legacy Dynamic pilots. The magnitude of the consumption savings owing to High On-Peak pricing was numerically smaller however for the Summer 2019 season relative to Summer 2018. This likely owes in large part to the fact that electricity consumption is variable and highly dependent on weather. High On-Peak average hourly temperatures were approximately 4 degrees Celsius lower in Summer 2019 relative to Summer 2018 (average hourly temperatures as a function of season and TOU period are provided in Table 25 later in this report). Of course, part of the quantitative reduction in High On-Peak impact across the two Summers may reflect diminished behavioural response to Dynamic pricing. It is not possible to ascertain the relative contributions of seasonal weather fluctuations and diminished behavioural response in driving the smaller estimated consumption impact in Summer 2019 relative to Summer 2018. Importantly, CPP event responsiveness was nearly identical in both Summer 2018 and Summer 2019 for households in both Dynamic and Legacy Dynamic pilots. Responsiveness to short, infrequent CPP events, therefore, shows no evidence of diminished behavioural response over a two-Summer reporting period.

With respect to the second research question, consumption impact estimates clearly indicate that average hourly consumption savings during CPP events do not differ between households who received six such events and those who received nine. We can conclude therefore, that for a given CPP event, behavioural response is not affected by the frequency at which such events occur, at least within the range of event frequencies that were manipulated here.

Summary of Non-Pricing Interventions

Nudge Reports

One of the aims of the current RPP Pilot program is to explore the potential impacts of non-price means by which to drive conservation and demand management behaviours. To that end, Alectra and its partner BEworks designed and distributed monthly communications in the form of Nudge

Reports to randomly selected pricing Treatment and Control customers in the Dynamic pricing pilots. These reports featured a mix of (1) conservation pledges, (2) salient TOU schedules, (3) personalized conservation tips (derived from load disaggregation data by Bidgely), and (4) personalized On-Peak consumption feedback. These Nudge Reports were designed based on the principles of behavioural economic theory which holds that individuals do not always respond rationally to pricing signals, act in their own best interests, or follow through with intended actions. For randomly selected customers in the Dynamic pricing Treatment conditions, these Nudge Reports appeared on the back page of the monthly Shadow Bills. For randomly selected Dynamic pricing matched Status-Quo TOU Control participants (i.e., customers who remained on Status-Quo TOU pricing), these reports were distributed via direct mail as single-page monthly communications under the program name Power Insights.

Nudge Reports were not successful at delivering incremental consumption impacts over and above the impacts attributable to Dynamic pricing, except for a -0.057 kW per hour effect during system-coincident peak times of day in Summer 2019 for the Dynamic pilot. Given that the Nudge Reports deployed in the current pilot program contained several behavioural interventions, it is impossible to disentangle the independent or interactive effects of each feature of the Nudge Reports on customer behaviour. Future work would be needed to better understand the potential of behavioural interventions to further impart conservation impacts in pricing schemes in which the pricing manipulation itself delivers large impacts. It is likely the case that Nudge Reports are more appropriate and impactful when price is either not manipulated, or does not function as a sufficient incentive on its own to drive conservation and demand management behaviours among residential consumers.

Smart Thermostats

The effects of programmable smart thermostats on conservation and load shifting behaviours in the present pilot program were assessed quasi-experimentally. That is, these devices were not randomly assigned to Treatment and Control customers, but instead, we relied on data regarding ownership *and* registration of these devices within the pilot population. Importantly, only customers with eligible devices that were registered to receive automatic load curtailment were included in our Technology Treatment group. The Energate Foundation thermostat had the most ability in this regard, being able to respond to varying price levels with different levels of response, with a sophisticated and flexible setting that allowed customers to specify their preferred level of price-response.

Dynamic pricing costumers, both "new" and Legacy, who were registered for automatic load curtailemnt generally exhibited reduced electricity consumption relative to Dynamic pricing customers who did not register an eligible device for load curtailment.

It seems therefore, that smart thermostats provide an additional non-price means of driving electricity consumption reductions among populations who choose to purchase these devices and register them to receive automatic load curtailment. However, we recommend caution when interpreting the effects of smart thermostats on consumption behaviour. Specifically, households were not randomly assigned to receive smart thermostats. Instead, all pricing participants had the opportunity to self-select themselves into smart thermostat ownership by taking advantage of thermostat incentive offers. Due to this inherent selection bias, we cannot attribute a causal relation between smart thermostat ownership and incremental sensitivity to pricing signals displayed by the subset of households designated as 'Technology' households. Indeed, some unknown proportion of the observed variance in consumption behaviour owing to smart thermostat ownership/usage is almost certainly driven by the fact that individuals who choose to acquire such devices are likely different from individuals who do not acquire such devices in many other material ways. Specifically, smart thermostat owners are likely more engaged, motivated, tech-savvy etc. than their non-technology adopting counterparts, and it may be these inherent individual difference characteristics that drive incremental changes in consumption behaviour. Only a true RCT or a recruit-and-deny experimental approach would be able to quantify the unique contribution of smart thermostat technology to demand response among residential electricity consumers.

Summary of Customer-Facing Surveys

Customer-facing surveys were administered to Dynamic and Legacy Dynamic program participants at three time-points during the course of the 17-month reporting period: within the registration period and first two months of the pilot (baseline), at the 6-month mark (mid-term) and at the conclusion of the pilot at the 17-month mark (final). There were three primary objectives of these surveys: (1) to capture relevant demographic and socio-economic information about the samples, (2) to assess whether comprehension of TOU pricing differs among Treatment and Control groups, and whether there are any changes in comprehension of TOU pricing over time, and (3) to assess whether motivations to alter electricity consumption behaviour differs among Treatment and Control groups, and whether there are any changes in stated motivations to alter consumption behaviour over time.

In terms of comprehension of TOU pricing, we found that comprehension scores increased over the duration of the Dynamic pricing pilot, which likely comes as a result of increasing exposure to Nudge Reports and Shadow Bill communications throughout the duration of the pilot. In addition, participants reported an increase in feeling that 'they were doing everything they can' to conserve electricity from the beginning of the pilot to the end, likely owing to sustained attempts to reduce bill amounts under Dynamic pricing. In general, Dynamic pricing participants reported being highly satisfied with their experience in Dynamic pricing over the 17-month duration of the pilot.

Final Conclusions and Recommendations

The current RPP Pilot program undertaken by Alectra Utilities and its partners has produced important and novel insights regarding the future of the Regulated Price Plan in the Province of Ontario. It is clear that strong pricing signals, in the form of the Variable Peak and Critical Peak pricing events that typify Dynamic pricing, are in fact sufficient to drive electricity conservation behaviours during peak-demand times of day. This raises two important considerations when considering the scalability of new pricing structures such as Dynamic pricing. (1) Electricity is a basic commodity to which all Ontario residents have a reasonable expectation of access. Given this, there must be careful consideration given to the use of price as the sole or primary lever to achieve conservation objectives. Specifically, there will be limits on the extent to which LDCs are able or willing to increase the price of peak electricity during certain times of day (even if across all hours of the day pricing remains the same on average) and there are surely limits on consumers' willingness to pay for On-Peak electricity as well as limits on their tolerance to frequent Critical Peak events, despite the fact that the increase in CPP event frequency from 6 to 9 seems to have had no adverse effects on either behavioural response or participant experience. (2) Dynamic pricing, as tested here, required that participants had to actively 'opt-in', suggesting that providing rate-payers with choice regarding their TOU pricing plan may be necessary in the future in order to realize maximum conservation and/or load shifting impacts. In order to further validate this latter point, future pilots could experimentally manipulate whether Variable Peak pricing plans are administered on an opt-in vs. opt-out basis.

Finally, non-price interventions such as behaviourally informed customer communications and availability of smart thermostat technology hold promise as additional, complementary methods for further realizing On-Peak consumption reductions among Ontarians. LDCs should seek to optimize their current customer communications with respect to consumption feedback (either through existing electricity invoices or through separate communications) as well as potentially devoting more resources to the marketing and provision of automated load control devices such as smart thermostats.

How to contact us

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