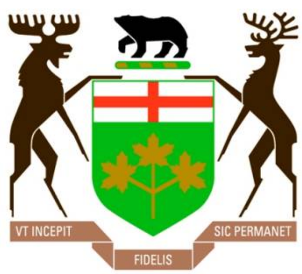
NAVIGANT

TIME OF USE RATES IN ONTARIO

PART 1: IMPACT ANALYSIS

Prepared for the

ONTARIO ENERGY BOARD



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Navigant Consulting Ltd.
Bay Adelaide Centre
333 Bay Street, Suite 1250
Toronto, ON   M5H 2R2
T: 416.777.2440
F: 416.777.2441
www.navigant.com

Executive Summary

Under amendments to the Ontario Energy Board Act, 1998 (the Act) contained in the Electricity Restructuring Act, 2004, the Ontario Energy Board was mandated to develop a Regulated Price Plan (RPP) for electricity prices to be charged to consumers that have been designated by regulation. The first prices were implemented under the RPP effective on April 1, 2005, as set out in regulation by the Ontario Government.

Since the May 2006 price setting, in addition to the standard RPP tiered rates, some customers have been subject to time-of-use (TOU) rates. TOU rates have a three period (On-Peak, Mid-Peak, Off-Peak) two season (November through April, May through October) structure. It is anticipated that by the end of 2014 nearly all of Ontario's RPP customers will have been converted from tiered to TOU rates. As of June 2013, nearly 4.5 million (about 93%) of Ontario's RPP-eligible customers were subject to TOU rates.[1] Ontario is the only jurisdiction in North America with universal mandatory TOU rates for residential customers.

Navigant was engaged in the spring of 2013 by the OEB to undertake a study of TOU rates with two principal goals.

1. Estimate the historical impact of TOU rates on the consumption of a sample of customers drawn from participating local distribution companies (LDCs).
2. Using the results of #1, forecast the impact, all else equal, of four alternative TOU structures as specified by OEB staff.

This report is intended to address Part 1 of the goals of this study – to estimate the historical impact of TOU rates on the consumption patterns of residential and general service (GS) customers. The latter only includes RPP eligible general service customers with peak demand less than 50 kilowatts (i.e. < 50 kW).

Estimation Methods

Navigant deployed two independent econometric methods to estimate the historical impact of the transition of RPP customers from tiered to TOU rates. This approach was taken to mitigate the potential for spurious results. If two wholly independent approaches, with only the underlying data in common, deliver a similar result, we may have a very high level of confidence in the result.

The first approach deployed by Navigant has been termed the "conventional impact analysis". It is so named because of its structural similarity to the fixed effects models often used to model the impacts of conservation and demand response programs. A large number of fixed effects regressions are estimated using dummy (or indicator) variables to differentiate the period in which a given customer was subject to TOU rates from that in which a given customer was subject to tiered rates.

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[1] Source: Ontario Energy Board

The second approach deployed by Navigant, the "elasticity analysis", requires the simultaneous estimation of a system of demand equations from which own- and cross- price elasticities may be derived. An own-price elasticity quantifies the relationship between the price of a good and the quantity demanded of that good – for a "normal" good this is typically a negative number, indicating that as the price goes up the quantity demanded falls. A cross-price elasticity quantifies the relationship between the price of one good (e.g., On-Peak electricity) and the quantity demanded of another good (e.g., Mid-Peak electricity).

These elasticities are then used to estimate impacts. The elasticity estimation is based principally on the work presented in a paper by Dr. Dean Mountain and Dr. Evelyn Lawson.[2] The Rotterdam model was adapted for this project by Dr. Bill Provencher, Navigant's econometric analysis subject matter expert, and other Navignat analysts, with some advice from Dr. Mountain.[3] For Part 2 of this Study, Dr. Mountain was engaged by Navigant as a subcontractor to help forecast, from an *ex ante* perspective, the impact of alternative TOU structures based on the elasticities estimated using the adapted version of the Rotterdam model presented in this report.

Data

As part of this study the OEB has made available to Navigant the hourly consumption data of approximately 14,000 customers, 10,000 of which are residential, the rest of which are general service less than 50 kW customers ("general service" or "GS" customers). Approximately a quarter of the residential data and about 10% of the general service data is from the OEB's group of "core" LDCs[4] that have committed to providing the OEB with hourly data for a sample of their customers on an on-going basis. The rest of the data were provided directly by the LDCs at the OEB's behest.[5]

For residential customers the data is very strong; no single LDC dominates the sample[6] and there is a great deal of diversity in TOU transition times – not all customers in the sample are transferred from tiered to TOU rates in a very short time. This means that "late adopters"[7] – those transitioned

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[2] Mountain, D.C. and Lawson, E. L., *A Disaggregated Nonhomothetic Modeling of Responsiveness to Residential Time-of-Use Electricity Rates*, International Economic Review, Vol. 33, No.1, Feb 1992, pp181 - 207

[3] Dr. Mountain did not participate in the historical impact analysis of this study. His input and advice was provided as part of his involvement in Part 2 of this study – the ex ante forecasting of the impact of different TOU scenarios.

[4] The "core" LDCs include: Hydro One Networks, Inc., Hydro Ottawa, Innisfil Hydro Distribution Services Ltd., Lakeland Power Distribution Ltd., Orangeville Hydro Ltd., Orillia Power Corporation, PowerStream Inc., Rideau St. Lawrence Distribution Inc., Thunder Bay Hydro Corporation, Wasaga Distribution Inc., Welland Hydro-Electrci System Corporation, Woodstock Hydro Services Inc, Entegrus Inc. and Whitby Hydro.

[5] Note that the OEB provided data for approximately 200 Hydro One and 200 Hydro Ottawa customers as part of its "core" group, with the balance of data for these LDCs being provided directly by the LDCs.

[6] Collectively, however, Hydro One, Toronto Hydro, Hydro Ottawa and Newmarket Hydro represent about 80% of the customers in the residential data set. There are data from 16 different LDCs.

[7] Note that this term is not meant to imply that adoption of TOU rates is voluntary. TOU rates are compulsory for all Ontario RPP customers. The term is intended merely to convey the fact that due to the gradual rollout of the rate structure some customers become subject to TOU rates later than others.

to TOU later in the sample – can act as pseudo controls for the “early adopters”, adding considerable accuracy to the estimation. Unfortunately, the same cannot be said for the general service customer data set. In this case, about 80% of the customers in the data set come from Hydro Ottawa, and the vast majority of general service customers in the data set transition to TOU rates over three short months in the summer of 2011. This means that, except for the summer Navigant cannot use late adopters as pseudo controls.

Navigant has sufficient misgivings about the suitability of the general service data for the non-summer analysis that we are not reporting general service results for any season other than summer.

Throughout this report, Navigant provides results for four seasons. They are:

- Summer (June, July, August);
- Summer Shoulder (May, September, October);
- Winter (December, January, February); and
- Winter Shoulder (November, April, March).

When Navigant wishes to make reference to the TOU “summer” (May through October) or “winter” (November through April) the season is described as the “RPP summer” or “RPP winter”, in reference to the Regulated Price Plan that defines it.

Impacts are provided for four periods in each season:

- On-Peak period;
- Mid-Peak period;
- Off-Peak weekdays; and
- Off-Peak weekends

Elasticities are provided for four periods in each season:

- On-Peak period;
- Mid-Peak period;
- Off-Peak 7pm to 9pm period (weekdays only); and
- Off-Peak remainder.

The first two periods correspond to the current On-Peak and Mid-Peak periods under the RPP TOU rate. The Off-Peak 7pm to 9pm period is split out from the rest of the Off-Peak period due to the fact that prior to May 1, 2011 this period was part of either the On-Peak (in the winter) or the Mid-Peak (in the summer) periods. The Off-Peak remainder period covers from 9pm to 7am on weekdays and all day on weekends. Together the Off-Peak 7pm to 9pm and the Off-Peak remainder make up the Off-Peak period under the RPP TOU rate.

The periods provided for elasticities differ from those provided for impacts due to the manner in which elasticities are estimated.

Results

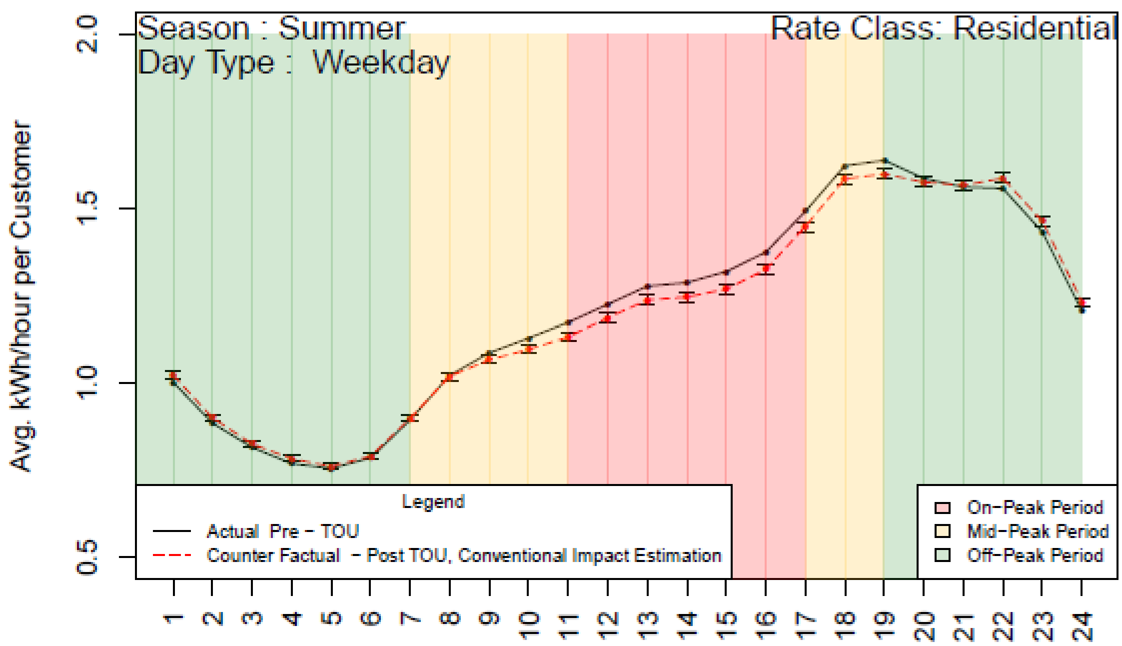
As noted above, Navigant has deployed two independent econometric methods to estimate the historical impact of the transition of RPP customers from tiered to TOU rates. The first two sub-sections below provide a summary of the results obtained using both methods, and the final sub-section provides a summary of the extrapolated provincial impact, as well as a brief discussion of the appropriateness of this extrapolation.

The most significant result of those presented below is that both the conventional impact analysis and the elasticity analysis report the same result for the estimated residential summer weekday On-Peak reduction, 3.3%. This result is estimated by two independent econometric models that take very different approaches and is therefore a very robust estimate.

Conventional Impact Analysis

A plot of the conventional impact analysis results is shown in Figure ES- 1, below, with the impact of TOU rates clearly visible. Mid-Peak consumption also fell and Off-Peak consumption, both weekday and weekend, increased. Plots of the conventional impact analysis results for GS<50 customers, as well as for residential customers on summer weekends or in other seasons, may be found in Appendix A. Error bars in this figure represent the 95% confidence interval of the impact estimates.

Figure ES- 1: Average Residential Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A summary of the estimated impacts provided by the conventional impact analysis approach are shown in Figure ES- 2, below. Impacts are provided as the average kWh impact over an entire period (e.g., for summer On-Peak the average kWh impact between 11am and 5pm EDT), the average kW impact per hour in that period and the average percentage change in demand.

These results suggest that the summer and summer shoulder response of residential customers to TOU rates is to engage in some shifting and some conservation, whereas response in the winter is predominantly a conservation response.

Figure ES- 2: Complete Results, Residential Conventional Impact Estimation

		Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.263	-0.044	-3.3%
	Mid-Peak	-0.173	-0.029	-2.2%
	Off-Peak	0.156	0.013	1.2%
	Off-Peak Weekend	0.556	0.023	1.9%
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.132	-0.022	-2.2%
	Mid-Peak	-0.103	-0.017	-1.5%
	Off-Peak	0.167	0.014	1.5%
	Off-Peak Weekend	0.362	0.015	1.4%
Winter (Dec, Jan, Feb)	On-Peak	-0.300	-0.050	-3.4%
	Mid-Peak	-0.395	-0.066	-3.9%
	Off-Peak	-0.420	-0.035	-2.5%
	Off-Peak Weekend	-0.468	-0.020	-1.2%
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-0.136	-0.023	-2.1%
	Mid-Peak	-0.177	-0.030	-2.3%
	Off-Peak	-0.144	-0.012	-1.1%
	Off-Peak Weekend	0.140	0.006	0.5%

Rows shaded in gray are not statistically significant at the 95% level.

****Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)***

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Estimates of the seasonal conservation effect in kWh and as a percent of annual consumption are shown in Figure ES- 3, below. The average annual residential consumption is approximately 10,700 kWh. As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure ES- 3: Seasonal Conservation Estimates, Residential Conventional Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-17	-3.3%	-11	-2.2%	10	1.2%	16	1.9%	-2	-0.1%
Summer Shoulder	-8	-2.2%	-6	-1.5%	10	1.5%	11	1.4%	7	0.3%
Winter	-22	-3.4%	-24	-3.9%	-23	-2.5%	-14	-1.2%	-83	-2.5%
Winter Shoulder	-11	-2.1%	-12	-2.3%	-8	-1.1%	4	0.5%	-27	-1.1%
Total	**-58**	**-2.8%**	**-53**	**-2.6%**	**-11**	**-0.3%**	**16**	**0.5%**	**-105**	**-1.0%**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average residential customer's electricity costs.[8] These are summarized in Figure ES- 4, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure ES- 4: Approximate Impact on Average Residential Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$1	$1	$1	**-$2**
Summer Shoulder	-$1	-$1	$1	$1	**$0**
Winter	-$3	-$3	-$2	-$1	**-$8**
Winter Shoulder	-$1	-$1	-$1	$0	**-$3**
Total Across Seasons	**-$7**	**-$6**	**-$1**	**$1**	**-$12**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Navigant, as noted above, has sufficient misgivings about the suitability of the general service data for the non-summer analysis that we are not reporting general service results for any season other than summer. Summer GS estimates provided by the conventional impact analysis are shown in Figure ES- 5, below.

For general service customers on summer weekdays, Navigant has estimated a barely statistically significant impact only in the Mid-Peak period..

8 These are calculated as the estimated conservation impact by period (kWh) as shown in Figure ES- 3 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

Figure ES- 5: Complete Results, GS Conventional Impact Estimation

		Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.206	-0.034	-1.2%
	Mid-Peak	-0.263	-0.044	-1.8%
	Off-Peak	-0.119	-0.010	-0.5%
	Off-Peak Weekend	-0.087	-0.004	-0.2%

Rows shaded in gray are not statistically significant at the 95% level.

****Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)***

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Estimates of the seasonal conservation effect in kWh and as a percent of annual consumption are shown in Figure ES- 6, below. The average annual GS consumption is approximately 20,000 kWh. As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure ES- 6: Seasonal Conservation Estimates, GS Conventional Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-13	-1.2%	-17	-1.8%	-8	-0.5%	-3	-0.2%	-40	-0.8%

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average GS customer's electricity costs.[9] These are summarized in Figure ES- 7, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure ES- 7: Approximate Impact on Average GS Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$2	-$1	$0	**-$4**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

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9 These are calculated as the estimated conservation impact by period (kWh) as shown in Figure ES- 5 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

Elasticity Analysis

The estimated own- and cross-price elasticities for residential customers are shown in Figure ES- 8, below. Own-price elasticities are shown in the boxes along the diagonal within each season. Cells highlighted in dark gray denote estimates that are not statistically significant at the 95% level.

Note that for all seasons except for winter shoulder the significant own-price elasticities are of the expected sign (negative) and magnitude (less than one in absolute value). The most significant result shown here is that it appears that residential customers are, in the summer, most price sensitive during the morning and afternoon Mid-Peak periods and the least price sensitive during the early evening Off-Peak period (i.e., around dinner time). A more comprehensive discussion of these estimated elasticities may be found in section 4.2.1.

Figure ES- 8: Residential Elasticity Estimates – by TOU Period

		Elasticities			
		Price Period			
Season (Commodity Period)	Commodity Period	On-Peak	Mid-Peak	Off-Peak 7pm - 9pm	Off-Peak Remainder
Summer (Jun, Jul, Aug)	On-Peak	-0.34	0.35	0.04	-0.11
	Mid-Peak	0.39	-0.71	-0.05	0.32
	Off-Peak 7pm - 9pm	0.14	-0.13	-0.06	0.00
	Off-Peak Remainder	-0.05	0.13	0.00	-0.14
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.09	-0.08	0.08	-0.02
	Mid-Peak	-0.08	-0.02	-0.08	0.07
	Off-Peak 7pm - 9pm	0.21	-0.22	-0.01	-0.09
	Off-Peak Remainder	-0.01	0.03	-0.01	-0.11
Winter (Dec, Jan, Feb)	On-Peak	-0.06	-0.08	0.02	-0.03
	Mid-Peak	-0.11	0.03	-0.01	-0.08
	Off-Peak 7pm - 9pm	0.06	-0.01	-0.12	-0.07
	Off-Peak Remainder	-0.02	-0.03	-0.01	-0.10
Winter Shoulder (Nov, Mar, Apr)	On-Peak	0.14	-0.24	0.01	0.10
	Mid-Peak	-0.33	0.50	-0.05	-0.11
	Off-Peak 7pm - 9pm	0.04	-0.10	0.03	0.04
	Off-Peak Remainder	0.05	-0.04	0.01	-0.01

Rows shaded in gray are not statistically significant at the 95% level.

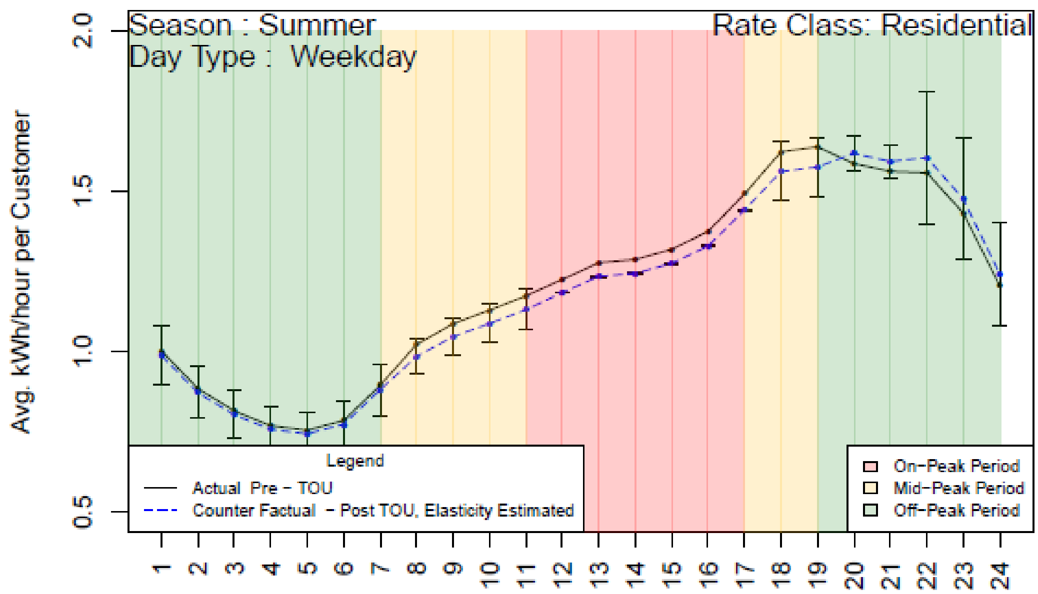
Cells in boxes represent own-price elasticities. The remainder are cross-price elasticities.

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A plot of the elasticity analysis results is shown in Figure ES- 9, below, with the impact of TOU rates clearly visible. Mid-Peak consumption also fell and Off-Peak consumption, both weekday and weekend, increased. Plots of the elasticity analysis results for GS customers, as well as for residential customers on summer weekends or in other seasons, may be found in Appendix A.

Note that the error bars in this plot do *not* correspond to the 95% confidence interval around the estimated impact, but rather the range of estimated impacts based on the 95% confidence intervals estimated for the elasticities. Due to the effect of compounding, these error bars may overstate the width of the confidence interval around the estimated impacts.

Figure ES- 9: Average Residential Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual, as estimated using the elasticities, may be found in Figure ES- 10, below.

Figure ES- 10: Estimated Impacts, Residential Elasticity Estimation

Season	Period	Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.266	-0.044	-3.3%
	Mid-Peak	-0.286	-0.048	-3.7%
	Off-Peak	0.103	0.009	0.8%
	Off-Peak Weekend	1.022	0.043	3.5%
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.253	-0.042	-4.2%
	Mid-Peak	-0.196	-0.033	-2.9%
	Off-Peak	0.081	0.007	0.7%
	Off-Peak Weekend	0.604	0.025	2.4%
Winter (Dec, Jan, Feb)	On-Peak	-0.167	-0.028	-1.9%
	Mid-Peak	-0.291	-0.049	-2.9%
	Off-Peak	0.071	0.006	0.4%
	Off-Peak Weekend	-0.102	-0.004	-0.3%
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-0.009	-0.002	-0.1%
	Mid-Peak	-0.036	-0.006	-0.5%
	Off-Peak	0.187	0.016	1.4%
	Off-Peak Weekend	-0.050	-0.002	-0.2%

**Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)*

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Estimates of the seasonal conservation effect in kWh and as a percent of annual consumption are shown in Figure ES- 11, below. The average annual residential consumption is approximately 10,700 kWh. As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure ES- 11: Seasonal Conservation Estimates, Residential Elasticity-Estimated Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-17	-3.3%	-18	-3.7%	7	0.8%	29	3.5%	0	0.0%
Summer Shoulder	-16	-4.2%	-12	-2.9%	5	0.7%	18	2.4%	-5	-0.2%
Winter	-12	-1.9%	-18	-2.9%	4	0.4%	-3	-0.3%	-29	-0.9%
Winter Shoulder	-1	-0.1%	-2	-0.5%	11	1.4%	-1	-0.2%	7	0.2%
Total	**-46**	**-2.1%**	**-51**	**-2.5%**	**27**	**0.8%**	**43**	**1.3%**	**-27**	**-0.2%**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average residential customer's electricity costs.[10] These are summarized in Figure ES- 12, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure ES- 12: Approximate Impact on Average Residential Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$2	$0	$2	**-$2**
Summer Shoulder	-$2	-$1	$0	$1	**-$2**
Winter	-$2	-$2	$0	$0	**-$3**
Winter Shoulder	$0	$0	$1	$0	**$0**
Total Across Seasons	**-$6**	**-$5**	**$2**	**$3**	**-$6**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The estimated elasticities for GS customers are shown in Figure ES- 13, below. As with the residential estimated elasticities, all own-price elasticities are of the expected signs, although none but the mid-peak is statistically significant at the 95% level.

A summary of the estimated impacts derived from these estimated elasticities may be found in 4.2.2, in the main body of the report.

Figure ES- 13: GS kW Summer Elasticity Estimates – by TOU Period

			Elasticities			
			Price Period			
			On-Peak	Mid-Peak	Off-Peak 7pm - 9pm	Off-Peak Remainder
Summer (Jun, Jul, Aug)	Commodity Period	On-Peak	-0.20	0.01	-0.21	-0.13
		Mid-Peak	0.00	-0.35	0.31	-0.53
		Off-Peak 7pm - 9pm	-0.90	1.02	-0.35	-0.34
		Off-Peak Remainder	-0.07	-0.19	-0.04	-0.26

Rows shaded in gray are not statistically significant at the 95% level.

Cells in boxes represent own-price elastiticies. The remainder are cross-price elasticities.

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

[10] These are calculated as the estimated conservation impact by period (kWh) as shown in Figure ES- 11 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual, as estimated using the elasticities, may be found in Figure ES- 14 below.

Figure ES- 14: Estimated Impacts, GS Elasticity Estimation

		Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.973	-0.162	-5.4%
	Mid-Peak	-0.897	-0.150	-6.3%
	Off-Peak	-0.878	-0.073	-4.0%
	Off-Peak Weekend	-2.908	-0.121	-6.5%

***Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Estimates of the seasonal conservation effect in kWh and as a percent of annual consumption are shown in Figure ES- 15, below. The average annual GS consumption is approximately 20,000 kWh. As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure ES- 15: Seasonal Conservation Estimates, GS Elasticity-Estimated Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-62	-5.4%	-58	-6.3%	-56	-4.0%	-81	-6.5%	-257	-5.5%

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average GS customer's electricity costs.[11] These are summarized in Figure ES- 16, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

[11] These are calculated as the estimated conservation impact by period (kWh) as shown in Figure ES- 15times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

Figure ES- 16: Approximate Impact on Average GS Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$8	-$6	-$4	-$5	**-$23**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Province-wide Impacts

All of the preceding estimated impacts are the average estimated impacts per customer for customers included in the estimation sample. To legitimately extrapolate these results to the provincial level – to estimate what the provincial impact of TOU rates has been – requires the assumption that the customers in the estimation sample are representative of the provincial population of residential and GS<50 customers currently subject to TOU rates.

Summary statistics presented in section 3, as well as the residential customer distribution that may be found in the OEB 2012 Distributor's Handbook suggest that residential customers in the estimation sample may be reasonably (if imperfectly) representative of residential customers in the province. Given the overwhelming number of GS customers in the estimation sample drawn from a single utility (Hydro Ottawa) it seems highly unlikely that the GS customers in the estimation sample are representative of the provincial population.

That said, overall, the estimation sample used in this study *is* the most representative sample used in a TOU study in Ontario to date. Extrapolations of provincial TOU period impacts may be improved upon in the future as more smart meter data become available. Analysts using the results below for planning or other purposes should still exercise caution when using these results and be sure to understand the limitations of the underlying data's representativeness.

Navigant has extrapolated the individual impacts shown above to the province by multiplying the kW impacts in each period (and for each approach and rate class) by the most recent available estimate of the number of RPP customers subject to TOU rates in Ontario.

The provincial impact estimates (in MW) are presented in Figure ES- 17, below. As before, a negative number indicates a reduction in average demand and a positive number indicates an increase in demand.

Figure ES- 17: Estimated TOU Provincial Impact (MW) by TOU period

		Residential		GS<50	
		Conventional Impact Approach	Elasticity Approach	Conventional Impact Approach	Elasticity Approach
Summer (Jun, Jul, Aug)	On-Peak	-179	-179	-14	-64
	Mid-Peak	-118	-196	-18	-60
	Off-Peak	53	37	-4	-29
	Off-Peak Weekend	94	175	-2	-48
Summer Shoulder (May, Sept, Oct)	On-Peak	-90	-171	No robust results available.	
	Mid-Peak	-69	-134		
	Off-Peak	57	29		
	Off-Peak Weekend	61	102		
Winter (Dec, Jan, Feb)	On-Peak	-204	-114	No robust results available.	
	Mid-Peak	-269	-200		
	Off-Peak	-143	24		
	Off-Peak Weekend	-82	-16		
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-94	-8	No robust results available.	
	Mid-Peak	-122	-24		
	Off-Peak	-49	65		
	Off-Peak Weekend	24	-8		

Source: OEB-provided hourly consumption data, OEB 2012 Distributor's Yearbook, OEB Settlement Factor Files, Environment Canada weather data and Navigant analysis.

Conclusions and Recommendations

Navigant's principal conclusion, based on the results of two independent approaches to estimating the impact of TOU rates, using the same data, is that **TOU rates have led to an approximately 3.3% reduction in residential summer On-Peak consumption**. This is a very robust result – it is the same point estimate of the On-Peak impact delivered by the two very different approaches undertaken by Navigant to estimate impacts. This result is also very much in line with the estimated impacts from the three other currently published evaluations of TOU rates in Ontario (see Figure ES- 18, below). Under the assumption that the residential estimation sample used by Navigant is representative of the Ontario residential population we can conclude that **TOU rates have led to an approximately 179 MW of average demand reduction during the summer On-Peak period.**[12]

[12] Note that this is an average impact in each summer On-Peak period and not an estimate of the impact on system peak demand.

The two approaches used by Navigant yield the conclusion that **there is no significant summer conservation impact**. This is in line with a prior TOU evaluation conducted by Navigant for Newmarket Hydro, but differs from the Hydro One TOU Pilot and the OEB Smart Price Pilot, both of which estimated a statistically and practically significant conservation effect.

Figure ES- 18: Other Ontario TOU Impact Estimates

Study	On-Peak Impact, Avg. Summer Day	Conservation Impact, Summer	Date of Study	Link
Current OEB Study	-3.30%	0%	December, 2013	
Newmarket Hydro TOU Evaluation*	-2.80%	0.66% (n/s)	April, 2010	http://www.nmhydro.ca/pdf/NMH_TOU_FINAL.PDF
OEB Smart Price Pilot	-2.4% (n/s)	-6%	May, 2008	http://www.centerpointenergy.com/staticfiles/CNP/Common/SiteAssets/doc/OSPP%20Final%20Report%20-%20Final070726.pdf
Hydro One Networks Time-of-Use Pilot Project	-3.70%	-3.30%	May, 2008	http://www.oeb.gov.on.ca/documents/cases/EB-2004-0205/smartpricepilot/TOU_Pilot_Report_HydroOne_20080513.pdf
OPA Year One TOU Evaluation:			December, 2013	http://powerauthority.on.ca/sites/default/files/conservation/Preliminary-Report-First-Year-Impact-Evaluation-of-Ontario-TOU-Rates.pdf
LDC #2	-2.83%	-0.16%		
LDC #1	-4.26%	-0.01%		
LDC #3	-2.59%	0.00%		
LDC #4	-5.71%	0.00%		

**Newmarket impacts are for the entire year, not just summer.*

Navigant estimated that TOU rates resulted in an increase in summer Off-Peak period consumption of approximately 1.2% or 0.8% (for Off-Peak weekdays) and of approximately 1.9% or 3.5% (for Off-Peak weekends) depending on the approach used. Under the assumption that the residential estimation sample used by Navigant is representative of the Ontario residential population we can conclude that the average demand on summer Off-Peak weekdays has increased by either 53 or 37 MW (depending on the approach used) and that the average demand on summer Off-peak weekends has increased by either 94 or 175 MW (again, depending on the approach used).

Given the challenges associated with the general service customer data, Navigant is unable to draw a robust conclusion about the impact of TOU rates. **Based on the data available and analysed, the impact of the transition from tiered to TOU rates on general service customer consumption is ambiguous.**

Based on Navigant's findings in its study of the historical impact of TOU rates the evaluation team has the following five recommendations if the board wishes to pursue an on-going evaluation of the impact of TOU rates.

1. **Continue to collect residential smart meter data (post TOU).** The OEB should continue to collect smart meter data from Ontario LDCs. If possible, it should expand the group of "core" LDCs to include as many Ontario LDCs as possible.
2. **Collect more customers' data from each LDC.** Currently, the OEB collects the data from approximately 200 randomly chosen customers within each LDC. This number should be increased considerably for some LDCs so that it is possible to develop a sample that is more representative of the population of Ontario RPP customers.

3. **Collect more GS customers' data from different LDCs.** Navigant's attempts to estimate non-summer TOU impacts for GS customers were confounded by the lack of diversity in TOU transitions. More data should be collected from other LDCs to ensure greater transition diversity.
4. **On-going impact evaluation will need to rely on elasticity estimation.** The conventional impact approach can only provide an estimate of the average impact of the transition of customers transferring from tiered to TOU rates. Obtaining incremental, year-by-year impacts, requires relying entirely on an elasticity approach. As more and more price changes are observed (i.e., when rates are set every May 1 and November 1), this approach should increase in accuracy.
5. **Undertake an on-going survey of customer behaviours and attitudes.** Econometric estimation is a valuable tool, but the interpretation of the results it provides can be immeasurably improved when analysts also have access to qualitative survey data regarding exactly how well participants understand prices and TOU periods, and what (if any) strategies they undertake to respond to them. Navigant would recommend a semi-annual survey of customers to allow the OEB to monitor and track the on-going evolution of customer attitudes in Ontario.

Next Steps

Part 2 of this study – an analysis of a number of alternative TOU scenarios chosen by OEB staff – appears in a separate report. The principal purpose of Part 1 of this study (this report) was to deliver estimates of customer price-responsiveness (i.e., elasticities) that drive Part 2. Part 2 of this study is expected to be published in early 2014.

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1 Introduction

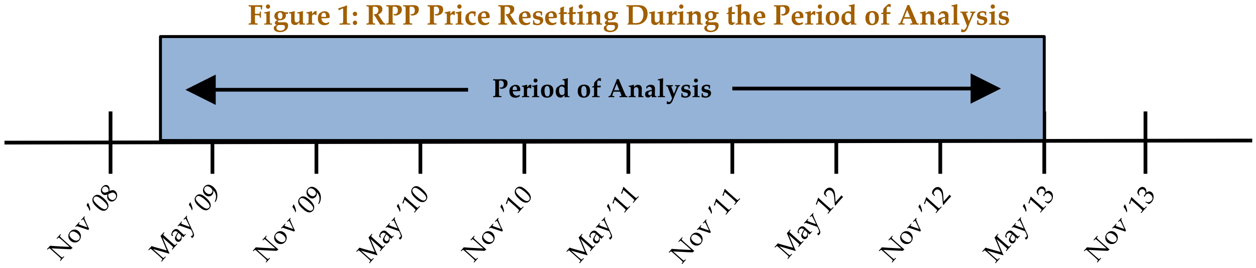
1.1 Time of Use Rates in Ontario

Under amendments to the Ontario Energy Board Act, 1998 (the Act) contained in the Electricity Restructuring Act, 2004, the Ontario Energy Board (OEB or the "Board") was mandated to develop a Regulated Price Plan (RPP) for electricity prices to be charged to consumers that have been designated by regulation. The first prices were implemented under the RPP effective on April 1, 2005, as set out in regulation.

The principles that guided the Ontario Energy Board in developing the RPP were established by government. In accordance with legislation, the prices paid for electricity by RPP consumers are based on forecasts of the cost of supplying them and must be set to recover those forecast costs. RPP prices are currently reviewed and adjusted if necessary by the OEB every six months. Any variance between the forecast and actual supply cost is recovered over a 12-month period.

During the period of analysis for this study (January 1, 2009 through May 31, 2013), customers in the sample were exposed to as many as nine different RPP prices. The OEB set prices on November 1st, 2008 and then reset prices on November 1st, 2009, 2010, 2011, 2012 and May 1st, 2009, 2010, 2011, and 2012. Figure 1 illustrates the different RPP periods experienced by customers in the sample during the period of analysis.

Figure 1: RPP Price Resetting During the Period of Analysis



Source: OEB website

1.1.1 Standard Regulated Price Plan Prices

The conventional meter RPP has a two-tiered pricing structure, one price for monthly consumption under a tier threshold and a higher price for consumption over the tier threshold. From November 1, 2005, the tier threshold for residential consumers has changed twice a year on a seasonal basis: to 600 kWh per month during the summer season (May 1 to October 31) and to 1000 kWh per month during the winter season (November 1 to April 30).

Subsequent to April 2006, the RPP prices were reviewed by the Board every six months and adjusted, if necessary. The RPP prices in effect during this study reflect this resetting frequency and are shown in Figure 2.

Figure 2: Conventional RPP Prices during the Period of Analysis

Cents/kWh	Nov '08 - April '09	May '09 - Oct '09	Nov '09 - April '10	May '10 - Oct '10	Nov '10 - April '11	May '11 - Oct '11	Nov '11 - April '12	May '12 - Oct '12	Nov '12 - April '13
Tier 1	5.6	5.7	5.8	6.5	6.4	6.8	7.1	7.5	7.4
Tier 2	6.5	6.6	6.7	7.5	7.4	7.9	8.3	8.8	8.7

Source: OEB website

1.1.2 TOU Regulated Price Plan Prices

Consumers with eligible time-of-use (or "smart") meters that can measure and record electricity consumption for hourly (or shorter) intervals will pay under a time-of-use (TOU) price structure. The prices under this plan are based on three TOU periods. These periods are referred to as Off-Peak, Mid-Peak and On-Peak. The lowest (Off-Peak) price is below the tier prices, while the other two are above them.

The RPP TOU prices are also reviewed and adjusted every six months. Figure 3 below outlines the TOU prices in effect during the period of analysis.

Figure 3: RPP TOU Prices during the Period of Analysis

Cents/kWh	Nov '08 - April '09	May '09 - Oct '09	Nov '09 - April '10	May '10 - Oct '10	Nov '10 - April '11	May '11 - Oct '11	Nov '11 - April '12	May '12 - Oct '12	Nov '12 - April '13
Off-Peak	4	4.2	4.4	5.3	5.1	5.9	6.2	6.5	6.3
Mid-Peak	7.2	7.6	8	8	8.1	8.9	9.2	10	9.9
On-Peak	8.8	9.1	9.3	9.9	9.9	10.7	10.8	11.7	11.8

Source: OEB website

The hours of these three TOU periods are set out in Figure 4 below.

Figure 4: RPP TOU Hours in the Summer and Winter

	Off-Peak	Mid-Peak	On-Peak
Prior to May 1, 2011	9pm - 7am Weekdays, 24 hours on Weekends/Holidays	7am - 11am and 5pm - 9pm Summer Weekdays 11am - 5pm Winter Weekdays	7am - 11am and 5pm - 9pm Winter Weekdays 11am - 5pm Summer Weekdays
As of May 1, 2011	7pm - 7am Weekdays, 24 hours on Weekends/Holidays	7am - 11am and 5pm - 7pm Summer Weekdays 11am - 5pm Winter Weekdays	7am - 11am and 5pm - 7pm Winter Weekdays 11am - 5pm Summer Weekdays

Note: The RPP hours are all prevailing time.
Source: OEB website

1.2 Study Objectives

Navigant was engaged by the OEB in the spring of 2013 to undertake a study of TOU rates with two principal goals

1. Estimate the historical impact of TOU rates on the consumption a sample of customers drawn from participating local distribution companies (LDCs).
2. Using the results of #1, forecast the impact, all else equal, of three alternative TOU structures as specified by OEB staff.

This report is intended to address Part 1 of the goals of this study – to estimate the historical impact of TOU rates on the consumption patterns of residential and general service customers. Part 2 of the goals of this study are addressed in a second, complementary report.

1.3 Structure of this Report

In addition to this introduction, this report is divided into four main sections, each of which itself is divided into a number of sub-sections. The four main sections of this report, and their sub-sections, are:

1. **Estimation Methods.** A description of the econometric approaches undertaken by Navigant to estimate the historical impact of TOU prices.

    a. ***Conventional Impact Analysis***. A description of the "dummy variable" econometric approach to estimating impacts.
    b. ***Elasticity Analysis***. A description of the approach using the Rotterdam model adapted from Mountain and Lawson to estimate own- and cross-price elasticities that are then used to calculate impacts.
    c. ***Comparing the Conventional Impact Analysis and Elasticity Analysis***. A discussion of the relative strengths and weaknesses of the two approaches.

2. **Data.** A description of the data underlying the analysis and a discussion of the limitations of the data in hand.

    a. ***Descriptive Statistics***. A series of plots and tables of customer counts, levels of consumption, marginal prices, etc.
    b. ***Suitability of Data.*** A discussion of the degree to which the data in the sample is sufficient to produce robust estimates of impacts.

3. **Results**. A summary of the historical impact estimation. This section includes estimated impacts and elasticities, as well as some summary plots of results.

    a. ***Conventional Impact Analysis***. Presentation of the results using the conventional impact method.
    b. ***Elasticity Analysis***. Presentation of the results using the Rotterdam model approach.

4. **Conclusions, Recommendations and Next Steps.** Navigant's conclusions from the analysis, a comparison of the impact and elasticity analysis results, and a description of the additional work coming out of this analysis..

2 Estimation Methods

This section of the report describes the methods employed by Navigant to estimate the impact of the transition from tiered to TOU rates on residential and small general service customers' electricity consumption in Ontario.

This section is divided into the following three sub-sections:

1. **Conventional Impact Analysis.** This section of the report provides a description of the model(s) and the associated input data used for the conventional impact analysis. This method is based on controlling for the impact of TOU pricing through the use of a "dummy" or indicator variable flagging whether a given customer is subject to TOU rates in the given period.
2. **Elasticity Analysis.** This section of the report provides a description of the model(s) and the associated input data used for the elasticity analysis. This method is based on estimating own- and cross-price relationships between consumption in a given period of the day, week or season and electricity prices in all periods and applying these elasticities to historical prices and levels of consumption to estimate the impact of the introduction of TOU pricing.
3. **Comparing the Conventional Impact and Elasticity Analysis.** This section of the report discusses the relative merits of the two approaches, as related to the accuracy of impact estimation.

The two methods used by Navigant are almost completely independent of one another – the only point that they have in common is that they both use the same underlying data. This was a deliberate decision taken in order to provide the OEB with comfort that the estimated impacts were robust to model specification and choice of approach – estimated impacts that are consistent across two independent well-designed approaches to estimation may safely be regarded as quite robust.

2.1 Conventional Impact Analysis

This sub-section of the methods section outlines the approach undertaken for the conventional impact analysis.

The conventional impact analysis is so named because the approach is in line with what is typically used to estimate impacts using interval or billing data for conservation and demand response programs.

To improve the accuracy of estimation, the sample data are divided up into a large number of sub-samples, each of which will be subject to its own regression equation. The data are subdivided by:

1. **Rate class** – residential customers are separated from GS<50 customers
2. **Season** – each rate class sub-sample is divided into four seasons, summer (June, July, August), Winter (December, January, February), Summer Shoulder (May, September, October) and Winter Shoulder (November, March, April).
3. **Day type** – each rate class/season combination sub-sample is divided into weekdays and weekends.

4. **Hour of the day** – each rate class/season/day type combination is divided up by each of the 24 hours in the day.

For each sub-sample defined by each discrete rate class (2), season (4), day type (2) and hour of day (24) combination a separate regression is estimated. Altogether, therefore, Navigant estimated $2\times4\times2\times24=384$ individual regressions for the conventional impact analysis.

Each regression includes a number of independent variables that are included to attempt to control non-TOU related effects that drive electricity consumption. The independent variables include:

- **Fixed effects:** Fixed effects are employed to control for time-invariant unobserved heterogeneity across customers For example: size of home, presence or absence of certain types of appliances, etc. Fixed effects are intended to control for all individual characteristics that do not vary within the time-span considered by the equation.
- **Monthly Dummy Variables:** These control for seasonal effects – effectively they act as a coarse control for weather variation.
- **Weather Variables:** These account for temperature effects that drive space heating and cooling. Navigant's weather variables are analogous to cooling and heating degree hours, and differ only that they also take into account humidity. These variables act as a fine control for weather variation.
- **LDC-specific Trend:** A separate trend is assigned to each LDC in the sample, to account for gradual structural changes in the various jurisdictions.
- **TOU Dummy:** A binary variable that takes a value of 1 when a given customer is subject to TOU rates, and zero when he is not. This variable is also interacted with weather effects to capture the effect on the impact of TOU rates of weather variability.

Equation 1, below shows a set of 24 generalized regression equations that apply to each day type, season and rate class.

Algebraically the model used for the conventional impact analysis is represented by:

$$
\begin{aligned}
y_{i,s,t} &= \alpha_{i,s} + \sum_{j=1}^{16}\phi_{j,s}\left(trend_t \times LDC_j\right) + \sum_{r=1}^{2}\varphi_r Month_{r,t} + \beta_{1,s} Cooling\_THI_{i,s,t} \\
&\quad + \beta_{2,s} Heating\_THI_{i,s,t} + \gamma_{1,s} TOU_{i,t} + \gamma_{2,s}\left(TOU_{i,t} \times Cooling\_THI_{i,s,t}\right) \\
&\quad + \gamma_{3,s}\left(TOU_{i,t} \times Heating\_THI_{i,s,t}\right) + e_{i,s,t}
\end{aligned}
$$

Equation 1: Conventional Impact Analysis Model

Source: Navigant analysis.

Where:

$y_{i,s,t}$	=	Electricity consumption (kWh) of customer i, during hour of the day s (i.e., 1 through 24), on day t
$\alpha_{i,s}$	=	The fixed effect for customer i, during hour of the day s

$trend_t$ = The value of annual linear trend on day t

LDC_j = A set of 16 dummy variables, each one corresponding to a given LDC in the sample

$\phi_{j,s}$ = The parameter measuring the average effect of the annual trend on consumption in LDC_j in hour s

$Month_{r,t}$ = Two dummy variables flagging the first and second months of the given season (e.g., for the summer season, $Month_{1,t}$ would be equal to one where hour t fell in the first month of the season and zero otherwise.

φ_r = The parameter measuring the average seasonal effect of month r on consumption during hour of the day s

$Cooling\_THI_{i,s,t}$ = A temperature-humidity index when temperatures are high. This is a combined measure of humidity and temperature (analogous to cooling degree hours) observed for customer i (varies by location), during hour of day s on day t

$\beta_{1,s}$ = The parameter measuring the average effect of the cooling THI on the consumption of electricity during hour s of day t.

$Heating\_THI_{i,s,t}$ = A temperature-humidity index when temperatures are low; this is a combined measure of humidity and temperature (analogous to heating degree hours) observed for customer i (varies by location), during hour of day s on day t.

$\beta_{2,s}$ = The parameter measuring the average effect of the heating THI on the consumption of electricity during hour s of day t.

$TOU_{i,t}$ = A dummy variable flagging the post-TOU period; equal to one if customer i is subject to TOU rates on day t and zero otherwise.

$\gamma_{1,s}$ = The parameter measuring the average effect of the TOU rates on the consumption of electricity during hour s of day t.

$\gamma_{2,s}$	=	The parameter measuring the average effect of the TOU rates interacted with cooling THI on the consumption of electricity during hour s of day t.
$\gamma_{3,s}$	=	The parameter measuring the average effect of the TOU rates interacted with heating THI on the consumption of electricity during hour s of day t.

And where:

$$Cooling\_THI_{i,s,t} = \max\left\{THI_{i,s,t} - 30, 0\right\}$$

$$Heating\_THI_{i,s,t} = \max\left\{25 - THI_{i,s,t}, 0\right\}$$

$$THI_{i,s,t} = 17.5 + 0.55 \times DryBulb_{i,s,t} + 0.2 \times DewPnt_{i,s,t}$$

Where Drybulb and DewPnt are the Environment Canada-reported hourly dry bulb and dew point temperatures reported in Celsius. Navigant used weather from five different weather stations:

- Ottawa;
- London;
- North Bay;
- Thunder Bay; and
- Toronto.

Navigant assigned weather, by city, to individuals in the data set based on the location of the LDC that serves them. For those Hydro One customers for which forward sortation area codes (FSAs) were provided, the weather station most proximate to that FSA was assigned. For Hydro One customers where no FSA was provided (approximately 200 customers, about 1.4% of all customers in the set), Navigant assigned the North Bay weather station.[13]

Impacts were calculated by subtracting actual average levels of hourly consumption from a calculated counterfactual. That is, the impacts presented are the difference between actual pre-TOU levels of consumption, and what the model predicts *would have been* consumed (on average) in those periods had customers been subject to TOU rather than tiered rates.

[13] The choice to assign the North Bay weather station was based on Navigant's understanding of the distribution of Hydro One customers, and the fact that, being a relatively central weather station, it is likely that the weather actually experienced by this small number of customers would be correlated with that of North Bay.

Regressions were estimated using SAS and the PROC SURVEYREG procedure applied to de-meaned data.[14] Clustered standard errors were estimated, clustered across individual customers.

2.2 Elasticity Analysis

This sub-section of the methods section will outline the approach undertaken for the elasticity analysis.

An elasticity is a quantitative measure of price responsiveness. An elasticity captures the relationship between a given good's price and the quantity of that good demand (own-price elasticity) or the relationship between a given good's price and the quantity demanded of *another* good (cross-price elasticity). Own-price elasticities are, for "normal" goods[15] expected to be less than zero, indicating that an increase in price results in a decrease in quantity demand. Demand is typically described as "inelastic" when the own-price elasticity is less than one in absolute value. Demand for essential goods (such as energy, food and housing) is typically considered to be inelastic. Cross-price elasticities may be either negative (where the two goods are substitutes for one another) or positive (where the two goods are complementary). For some examples of different kinds of cross-price elasticity, please see the inset box below.

The approach for the elasticity analysis differs from the conventional impact analysis both in that it is less direct and considerably more complex. Rather than simply applying estimated parameters directly to the data to obtain counterfactual levels of consumption and estimated impacts, the estimated parameters must first be transformed, using other inputs from the data into a set of own- and cross-price elasticities (see inset box, below for definitions and examples of these terms).

These elasticities are in turn applied to the applicable price and consumption data to obtain estimates of the impact that the transition from tiered to TOU rates have had. Elasticities are particularly useful in that they can allow analysts to estimate the impact of different changes in price as opposed to the conventional impact analysis that is agnostic to the effects of price as a signal and only identifies the overall impact of a treatment.

This section is divided into the following sub-sections:

1. **Commodity Periods and Price Periods.** This sub-section describes the way in which Navigant has split up the hours within a day and week for estimating own- and cross-price effects.
2. **Composite Variable Definitions.** Impacts are estimated based on a series of somewhat complicated variables that are themselves functions of other variables in the data. This sub-section describes how these composite variables are calculated.

---

14 SAS' PROC SURVEYREG is a procedure originally designed to perform analysis for sample survey data. It uses elementwise regression to compute the regression coefficient estimators by generalized least squares estimation. The principal reason it is used, rather than, for example, PROC GLM, is its ability to easily output clustered standard errors.

15 As opposed to "Veblen" goods where quantity demanded increases as the price rises.

Own- and Cross-Price Elasticities

Most readers will be familiar with the concept of an own-price elasticity of demand. This describes the relationship between the quantity of a good demanded and the price at which it is sold. For most economically "normal" goods this is negative – as the price for something rises, the quantity demanded falls. In these cases the own-price elasticity will be negative.

Own-price effects drive ***conservation****.*

Cross-price elasticity is the quantification of the relationship between the quantity demanded of one good and the price of another good.

If two goods are complements, *the cross-price elasticity will be positive. As hot dogs rise in price, fewer hot dog buns will be sold, even though the price of buns has not changed.*

If two goods are substitutes *the cross-price elasticity will be negative. As butter increases in price, more margarine will be sold, even though the price of margarine has not changed.*

Cross-price effects drive ***substitution*****.**

3. **The Rotterdam Model.** This sub-section describes the system of demand equations used to estimate the parameters that are used to calculate TOU impacts.
4. **Aggregate Elasticity Estimation.** This sub-section describes the model used to estimate the aggregate own-price elasticity of monthly electricity consumption.
5. **Elasticity and Impact Calculation.** This sub-section describes how Navigant has used the estimated parameters from the Rotterdam model and the aggregate elasticity estimation to calculate estimated own-and cross-price elasticities and in turn how these elasticities were applied to calculate estimated impacts.

The elasticity estimation is based principally on the work presented in a paper by Dr. Dean Mountain and Dr. Evelyn Lawson.[16] The Rotterdam model was adapted for this project by Dr. Bill Provencher, Navigant's econometric analysis subject matter expert, and other Navigant analysts, with some advice from Dr. Mountain.[17] For Part 2 of this Study, Dr. Mountain was engaged by Navigant as a subcontractor to help forecast, from an *ex ante* perspective, the impact of alternative TOU structures based on the elasticities estimated using the adapted version of the Rotterdam model presented in this report.

2.2.1 Commodity Periods and Price Periods

Navigant's version of the Rotterdam model uses monthly observations of average weekly consumption values. These are split into seven of what Navigant refers to as "commodity periods".

[16] Mountain, D.C. and Lawson, E. L., *A Disaggregated Nonhomothetic Modeling of Responsiveness to Residential Time-of-Use Electricity Rates*, International Economic Review, Vol. 33, No.1, Feb 1992, pp181 - 207

[17] Dr. Mountain did not participate in the historical impact analysis of this study. His input and advice was provided as part of his involvement in part 2 of this study – the ex ante forecasting of the impact of different TOU scenarios.

The seven commodity periods correspond to (all times in prevailing time[18]):

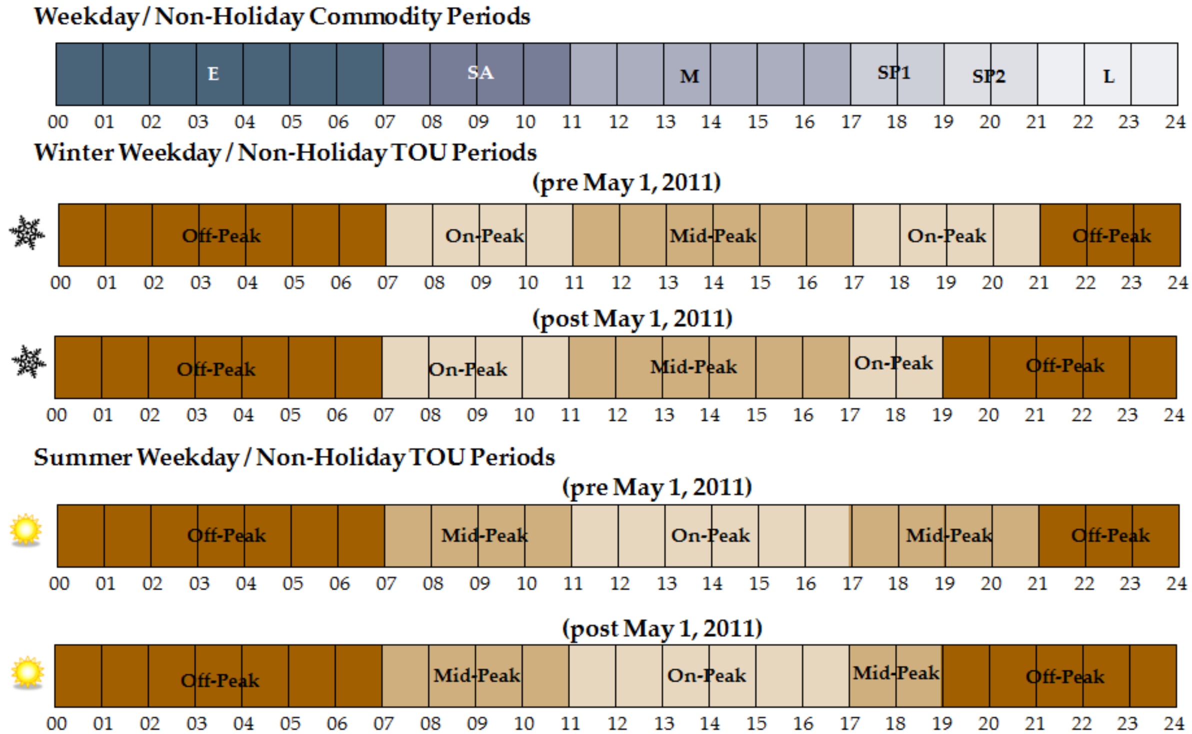
1. **Early (E)**: Midnight to 7am, weekdays.
2. **Shoulder AM (SA)**: 7am to 11am, weekdays
3. **Middle (M)**: 11am to 5pm, weekdays
4. **Shoulder PM 1 (SP 1)**: 5pm to 7pm, weekdays
5. **Shoulder PM 2 (SP 2)**: 7pm to 9pm, weekdays
6. **Late (L):** 9pm to midnight, weekdays
7. **Weekend (W)**: all day weekends and holidays.

These periods were chosen because they reasonably capture periods of the day that may be thought of (from the perspective of consumers) as different commodities. For example, customers will, on average, likely be indifferent between the consuming a given quantity of electricity at noon or at one p.m. On average, however, they are very likely *not* to be indifferent between consuming electricity at noon or at eight p.m. – one will, all else equal, likely be preferred to the other.

As may clearly be seen in Figure 5, each weekday commodity period is, in effect a subdivision of the weekday TOU periods. Weekends under the TOU are entirely off-peak. Similarly, all weekend hours are treated as a single commodity period.

[18] Eastern prevailing time (EPT) simply means eastern standard time in the winter months and eastern daylight time in the summer months

Figure 5: Elasticity Model Commodity Periods Compared to TOU Periods.

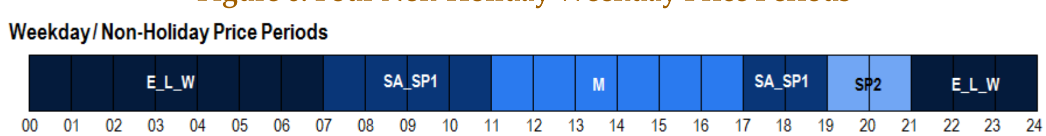


Note: The hours are Eastern Prevailing Time (EPT), so Eastern Standard Time (EST) in the winter and Eastern Daylight Time (EDT) in the summer.
Source: OEB website and Navigant analysis.

Unlike the number of commodity periods, the number of price periods is strictly limited to the number of periods where a unique TOU price exists. There are four periods instead of three due to the fact that the TOU pricing periods in Ontario changed in May of 2011. This makes it possible to create four price periods. These are listed immediately below and shown in Figure 6.

1. **Early, Late and Weekend (E_L_W)** – covering all the hours of the Early, Late and Weekend commodity periods. This corresponds to the Off-Peak TOU period.
2. **Shoulder AM and Shoulder PM1 (SA_SP1)** – covering the weekday period from 7am to 11am and from 5pm to 7pm (all times EPT). This corresponds to the RPP summer (May through October) Mid-Peak period and the RPP winter On-Peak period as of May 1, 2011.
3. **Middle (M)** – covering the weekday period from 11am to 5pm. This corresponds to the RPP summer On-Peak period and the RPP winter Mid-Peak period.
4. **Shoulder PM2 (SP2)** – covering the weekday period from 7pm to 9pm. This corresponds to the Off-Peak period as of May 1, 2011 and the RPP summer (May through October) Mid-Peak period and the RPP winter On-Peak period in the period prior to May 1, 2011.

Figure 6: Four Non-Holiday Weekday Price Periods



Source: OEB website and Navigant analysis.

2.2.2 Composite Variable Definitions

The Rotterdam model makes use of two somewhat complicated composite variables. The first is the dependent variable used in the system of equations, which tracks the change in the expenditure share and consumption from one year to the next. The second is the principal independent variable of interest, which tracks changes in price, in particular the ratio of the price in a given price period to the Early, Late and Weekend price from one year to the next.

The dependent variable used in the Rotterdam equations may be described algebraically as:

$$Y_{k,i,t} = \frac{\left(\dfrac{Exp_{k,i,t}}{\sum_{k=1}^{K} Exp_{i,t}} + \dfrac{Exp_{k,i,t-12}}{\sum_{k=1}^{K} Exp_{i,t-12}} \right)}{2} \times \left(\ln kWh_{k,i,t} - \ln kWh_{k,i,t-12} \right)$$

Equation 2: Rotterdam Model Dependent Variable

Source: Mountain and Lawson, adapted by Navigant.

Where:

$Exp_{k,i,t}$ = Customer i's average weekly expenditure on electricity in commodity period k, during month t.

$kWh_{k,i,t}$ = Customer i's average weekly electricity consumption (kWh) in commodity period k, during month t.

Note that this composite variable is in essence a differenced variable, this means that it is unnecessary to control for customer-specific time-invariant characteristics explicitly (i.e., fixed effects) since they are removed by the differencing.

The price index independent variable used in the Rotterdam equations may be described algebraically as:

$$P_{r,i,t} = \ln\left(\frac{mp_{r,i,t}}{mp_{E\_L\_W,i,t}} \right) - \ln\left(\frac{mp_{r,i,t-12}}{mp_{E\_L\_W,i,t-12}} \right)$$

Equation 3: Rotterdam Model Price Index Variable

Source: Mountain and Lawson, adapted by Navigant.

Where:

$mp_{r,i,t}$ = The marginal price of electricity ($/kWh) faced by customer in price period r, during month t. Note that this price includes both commodity and LDC-specific non-commodity variable costs.

$mp_{E\_L\_W,i,t}$ = The marginal price of electricity ($/kWh) faced by customer in the Early/Late/Weekend (i.e., Off-Peak) price period, during month t.

2.2.3 The Rotterdam Model

The Rotterdam model that Dr. Provencher adapted from Mountain and Lawson requires the simultaneous estimation of a system of seven equations, one for each commodity period k. This system may be described algebraically in the following manner:

$$y_{k,i,t} = \beta_{k,1} Heating\_\mathrm{THI}_{k,i,t} + \beta_{k,2} Cooling\_\mathrm{THI}_{k,i,t} + \sum_{j=1}^{16} \alpha_{k,s} LDC_{\mathrm{j},i} + \sum_{r=1}^{4} \gamma_{k,r} P_{r,i,t} + \theta_k V_{i,t} + e_{k,i,t}$$

Equation 4: Rotterdam System of Equations

Source: Mountain and Lawson, adapted by Navigant.

Where:

$y_{k,i,t}$		As defined in 4, above.
$Heating\_\mathrm{THI}_{k,i,t}$	=	The difference between the average weekly heating THI observed during commodity period k, for customer i, in month t and the same value twelve months prior.
$Cooling\_\mathrm{THI}_{k,i,t}$	=	The difference between the average weekly cooling THI observed during commodity period k, for customer i, in month t and the same value twelve months prior.
$LDC_{s,i}$	=	A dummy variable equal to one if customer i is a customer for LDC j, and zero otherwise. Note that due to the differencing in the equation, inclusion of this set of dummy variables is equivalent to including the LDC specific trend in the conventional impact approach.
$\beta_{k,1}, \beta_{k,2}, \alpha_{k,\mathrm{j}}$	=	Parameters that quantify the estimated relationship between the dependent variable, the heating THI, the cooling THI and the LDC dummy variables.
$P_{r,i,t}$	=	As defined in Equation 3, above.
$\gamma_{k,r}$	=	The parameter capturing the relationship between the commodity period k and price period r.
$V_{i,t}$	=	Note that this variable's value will be the same in all equations (although it does vary by individual and across time). It is calculated in the following manner:

$$V_{i,t} = \sum_{k=1}^{7} y_{k,i,t}$$

The equations above must be estimated simultaneously and the parameters are subject to the following restrictions:

1. Adding-Up (*Across* Equations) Restriction:

$$\sum_{k=1}^{7}\beta_{k,1}=0\,,\quad \sum_{k=1}^{7}\beta_{k,2}=0\,,\quad \sum_{k=1}^{7}\alpha_{k,s}=0\,,\quad \sum_{k=1}^{7}\gamma_{k,r}=0\,,\quad \sum_{k=1}^{7}\theta_{k}=0$$

2. Homogeneity (Within Each Equation) Restriction:

$$\sum_{r=1}^{4}\gamma_{k,r}=0$$

3. Symmetry Restrictions[19]

$$\gamma_{M,SA\_SP1}=\gamma_{SA,M}+\gamma_{SP1,M}$$
$$\gamma_{SP2,SA\_SP1}=\gamma_{SA,SP1}+\gamma_{SP1,SP2}$$
$$\gamma_{M,SP2}=\gamma_{SP2,M}$$

Navigant has taken advantage of the restrictions to simplify the system. Rather than estimating seven equations, each with four price variables, we have estimated six equations each with three price variables. The symmetry restriction is then applied to calculate the estimated coefficients for the seventh equation. The "missing" parameters that are required for calculating the elasticities may simply be derived from a combination of the estimated parameters and the adding-up and homogeneity restrictions outlined above. When Navigant implemented this approach, the equation for the weekend commodity period was omitted and the early/late/weekend (i.e., Off-Peak) price period was omitted.

2.2.4 Aggregate Elasticity Estimation

An additional input required for calculating elasticities is obtained from an auxiliary regression used to estimate the aggregate own-price elasticity of electricity. This is required since, by construction, the Rotterdam model does not allow for a net reduction in consumption based on a change in price, only a shifting of consumption from one period to another.

The aggregate own-price elasticity of electricity is estimated using the following equation:

[19] The specific, rather than generic, restrictions are shown here because the manner in which different commodity periods have been splintered from the four basic price periods. In a case where the price periods are identical to the commodity periods the symmetry restriction is simply: $\gamma_{k,r}=\gamma_{r,k}$.

$$\ln kWh_{i,t} = \sum_{j=1}^{16} \alpha_j LDC_{i,j} \times \ln Trend_t + \sum_{w=1}^{4} \rho_w Month_w + \beta_1 \ln Heating\_THI_{i,t}$$
$$+ \beta_2 Cooling\_\mathrm{THI}_{i,t} + \phi Cost_{i,t} + e_{i,t}$$

Equation 5: Equation for Aggregate Own-Price Elasticity of Demand

Source: Mountain and Lawson, adapted by Navigant.

Where:

$kWh_{i,t}$	=	Total consumption by customer i in month t.
$LDC_{i,j}$	=	A dummy variable equal to one if customer i is a customer for LDC j, and zero otherwise.
$Trend_t$	=	The value of an annual linear trend in month t
α_j	=	The parameter capturing the effect of the LDC-specific trend on customer i's monthly electricity consumption.
$Month_w$	=	A dummy variable equal to one if month t is month of the year w, and zero otherwise.
ρ_w	=	The parameter capturing the effect of monthly seasonality on customer i's monthly electricity consumption.
$Heating\_THI_{i,t}$	=	The average heating THI experienced by customer i in month t.
β_1	=	The parameter capturing the effect of heating THI on customer i's monthly consumption.
$Cooling\_\mathrm{THI}_{i,t}$	=	The average cooling THI experienced by customer i in month t.
β_2	=	The parameter capturing the effect of cooling THI on customer I's monthly consumption.
$Cost_{i,t}$	=	The average cost of electricity for customer i in month t. This simply calculated as total monthly expenditure divided by total monthly consumption.
ϕ	=	The parameter capturing the effect of total monthly average cost on customer i's monthly consumption.

After estimating this equation we obtain the average aggregate own-price elasticity of demand using the estimated ϕ and the average value of $Cost_{i,t}$:

$$\Phi = \phi \times \overline{Cost}$$

2.2.5 Calculating Elasticities and Impacts

An elasticity is calculated for each γ estimated as part of the Rotterdam model. The Rotterdam system delivers four elasticities for seven commodity periods. We have this four-by-seven matrix to estimate the historical impacts. For simplicity of exposition, and to make interpretation more intuitive, we have aggregated the elasticities so that they are a closer match to the three TOU periods. This aggregation results in four commodity periods that match the four price periods and approximately match the RPP TOU periods: an Off-Peak period (the early, weekend and late price period), an On-Peak (summer) or Mid-Peak period (winter) (the middle price period), a Mid-Peak (summer) or On-Peak period (winter) (the morning shoulder and first afternoon shoulder price period) and a Mid-Peak/Off-Peak (summer) or On-Peak/Off-Peak (winter) period[20] (the second shoulder price period). This is aggregation done simply by summing the appropriate gammas.

More simply put, the commodity periods (as shown in Figure 5 above) now align precisely with the price periods (as shown in Figure 6 above).

Whether calculating elasticities using the original 28 γ[21] or using the 16 TOU-aligned γ[22], the process is identical and follows three steps.

1. Calculate the compensated elasticities. Algebraically:

$$\varepsilon_{k,r}^{c} = \frac{\gamma_{k,r}}{W_k}$$

Where:

$\varepsilon_{k,r}^{c}$	=	Is the compensated elasticity between commodity period k and price period r. When k=r this is an own-price elasticity, otherwise it is a cross-price elasticity.
W_k	=	Is the average customer's share expenditure on electricity in commodity period k. Note that $0 < W_k < 1$.

And the remaining variable is drawn from the Rotterdam estimates.

2. Calculate the Marshallian elasticities.[23] Algebraically:

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[20] Recall that this period was part of the On-Peak/Mid-Peak (summer/winter) period prior to May 1, 2011, but as of that date has been part of the Off-Peak period.

[21] Seven commodity periods times four price periods.

[22] Four commodity periods times four price periods.

$$\varepsilon_{k,r}^{M} = \varepsilon_{k,r}^{c} - \theta_k \frac{W_r}{W_k}$$
$$= \frac{\gamma_{k,r}}{W_k} - \theta_k \frac{W_r}{W_k}$$

Where:

W_r	=	Is the average customer's expenditure on electricity in price period r. Note that $0 < W_r < 1$

And all other variables are as defined above or drawn from the Rotterdam estimates.

3. Finally, modify the Marshallian elasticities to take into account the aggregate elasticity of demand for electricity:

$$\varepsilon_{k,r}^{Magg} = \frac{\gamma_{k,r}}{W_k} - \theta_k \frac{W_r}{W_k} + \frac{\theta_k}{W_k}(1+\Phi)W_r$$

The impact of a change in price is calculated as:

$$\%\Delta kWh_h = \exp\left(\sum_{r=4}^{4}\left(\Delta \ln\left(\mathrm{mp}_r\right) \times \varepsilon_{k,r}^{Magg}\right)\right)$$

Where:

$\%\Delta kWh_h$	=	Is the estimated impact in hour h. This expresses the new level of consumption (at the new prices) as a percentage of the level of consumption at the old prices.
mp_r	=	Is the marginal price of electricity in price period r

And the elasticities used should be those where hour h falls within commodity period k.

2.3 Comparing the Conventional Impact Analysis and Elasticity Analysis

The two methods used by Navigant are almost completely independent of one another – the only point that they have in common is that they both use the same underlying data. This was a

[23] Compensated (sometimes called Hicksian) and Marshallian elasticities are so called because of the demand functions from which they are derived. As per Varian (1978): "[The terminology of compensated demand function] comes from viewing the demand function as being constructed by varying prices and income so as to keep the consumer at a fixed level of utility. Thus the income changes are arranged to 'compensate' for the price changes… Hicksian demand functions are not observable since they depend on utility, which is not directly observable. Demand functions expressed as a function of prices and income are observable… we will refer to the latter as the **Marshallian demand function**..." (emphasis in original).

deliberate decision to provide the OEB with some comfort that the estimated impacts are robust to model specification and choice of approach – estimated impacts that are consistent across two independent well-designed approaches to estimation may safely be regarded as quite robust.

Both approaches have their relative strengths and their weaknesses. Neither is categorically "better" for estimating the historical impact of the transition from tiered to TOU prices. Although, there may be some specific instances in which a case could be made that one approach delivers an estimated impact that is more accurate.

The strength and weaknesses of both approaches may be characterised as follows.

Conventional Impact Estimation

Strength: As this approach is much more granular, it is better at controlling for exogenous effects, that may be correlated with the TOU impact (such as provincial conservation programs, the increasing efficiency of appliances, etc.). Altogether, there are 384 regressions estimated for all rate classes, seasons, hours and day types. As a result, the model controls for unobserved heterogeneity at a very precise level, reducing the chance that cross-sectional bias may accrue to the estimated impact. That is to say that the fixed effects are very fine-grained – we are able to control for the individual customer effects for (for example) the hour between midnight and 1am on winter weekdays. This control (the fixed effect) will be different for the hour between 1am and 2am on winter weekdays. There is a very fine-grained control in place for individual-specific hourly electricity consumption behaviours.

Weakness: Delivers a static impact estimate – does not make use of all the information in the data. The conventional impact model greatly oversimplifies the reality of the underlying process. The use of a dummy variable (even interactive dummies) effectively means that we are modeling a single change in regime, or state – from a world of tiered pricing to one of TOU pricing. The likely reality is that transition from tiered to TOU pricing provokes an initial reaction, but that incremental price changes thereafter provoke further reactions. The conventional impact approach cannot fully take advantage of this additional information to improve its accuracy – the conventional impact approach does not account fully for the changing relative prices through the duration of the analysis.

Elasticity Estimation

Strength: This model is a truer reflection of reality –the impact of TOU rates is not a result of a one-time change in consumer behaviour, but an on-going incremental one. It is thus better able to extract useful information from additional price-quantity pairs that can improve the accuracy of its estimates. Note that additional price quantity pairs will only provide significant additional useful information when the prices vary. Additional data with identical prices will add little.

Weakness: The Rotterdam approach specification used for this study is much coarser than the conventional impact analysis. Where there are 24 regressions (one for each hour of a summer weekday) in the conventional impact model, there are only six in the elasticity model. Where there are another 24 regressions for weekends for the conventional impact model, there is only a single one in the elasticity model. The aggregate own-price elasticity (that is a component of the Rotterdam-derived elasticities) is coarser still, using a single equation for each season and rate-class combination. This means that exogenous differences between individuals and across time are *much* more difficult to control for. Where cross-sectional differences between early and late adopters (i.e. those that transitioned to TOU rates earlier and those that transitioned to TOU rates later) are significant, for example, these differences are more likely to bias impacts using the elasticity rather than the conventional impact approach.

3 Data

This section of the report describes the data used for estimating the impact of the transition from tiered to TOU rates, and discusses its suitability for the estimation of those impacts.

This section is divided into the following two sub-sections:

1. **Descriptive Statistics.** This section provides some summary statistics to help the reader understand the scope of the data made available to Navigant for this analysis.
2. **Suitability of Data**. This section will outline the reasons why Navigant is concerned that the available general service customer data is insufficient to estimate impacts without significant possible bias.

Throughout this report, Navigant reports statistics about the data, and results, on a seasonal level. Navigant has defined four seasons for each year. They are defined as follows:

- **Summer**: June, July, August
- **Summer Shoulder**: May, September, October
- **Winter**: December, January, February
- **Winter Shoulder**: November, March, April

3.1 Descriptive Statistics

This section will highlight some summary statistics to provide context for the analysis that follows. This section includes:

- the **count of unique customers** included in the analysis, by local distribution company (LDC) and rate class;
- a **summary of the time** span covered by each LDC's sample, and when customers in that LDC's sample were transitioned to TOU rates;
- the **average daily consumption** (kWh) per customer by LDC, season and rate class;
- the **average marginal price**[24] ($/kWh) faced by customers in the each of the TOU time periods;

[24] The marginal price is the price that a given customer pays for each incremental unit of electricity. The marginal price faced by customers subject to TOU rates is simply the commodity price for the given TOU period, plus volumetric non-commodity costs. Volumetric non-commodity costs are all the per-kWh costs paid by customers that are not part of the commodity charge, e.g. distribution charges, the Debt-Retirement Charge, etc..

The marginal price faced by a customer subject to tiered rates will be the volumetric non-commodity costs, plus either the commodity price for Tier 1 (if, after that customer's next kWh of consumption, his cumulative monthly consumption is below the Tier 1 threshold), or the commodity price for Tier 2 (if, after that customer's next kWh of consumption, his cumulative monthly consumption is above the Tier 1 threshold).

The average marginal price therefore is an average that includes both TOU and tiered electricity prices, as well as the non-volumetric commodity costs across a number of LDCs. This is a weighted average across all customers

- the **geographic distribution** of customers included in the analysis; and
- a high level summary of the **representativeness of the sample** of LDCs included in the analysis.

3.1.1 Number of Unique Customers

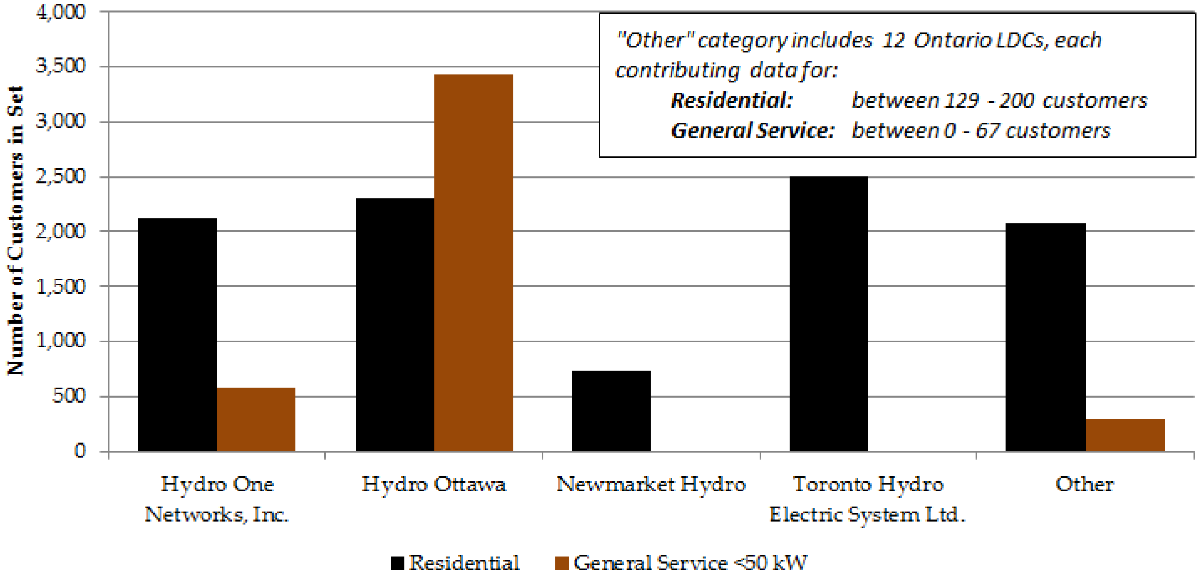
Altogether, Navigant's data set contains the hourly energy consumption of over 14,000 customers, nearly 10,000 of which are residential. A summary of the split of these customers by rate class and LDC is shown below in Figure 7.

The "Other" category of LDCs includes the following LDCs:

- Entegrus, Inc.
- Innisfil Hydro Distribution Services Ltd.
- Lakeland Power Distribution Ltd.
- Orangeville Hydro Limited
- Orillia Power Corporation
- Powerstream Inc.
- Rideau St. Lawrence Distribution Inc.
- Thunder Bay Hydro Corporation
- Wasaga Distribution Inc.
- Welland Hydro-Electric System Corporation
- Whitby Hydro
- Woodstock Hydro Services Inc.

(tiered and TOU) at each point in time. These weights will vary as customers move from tiered pricing to TOU pricing .

Figure 7: Customer Counts by LDC and Rate Class



Source: OEB-provided hourly consumption data.

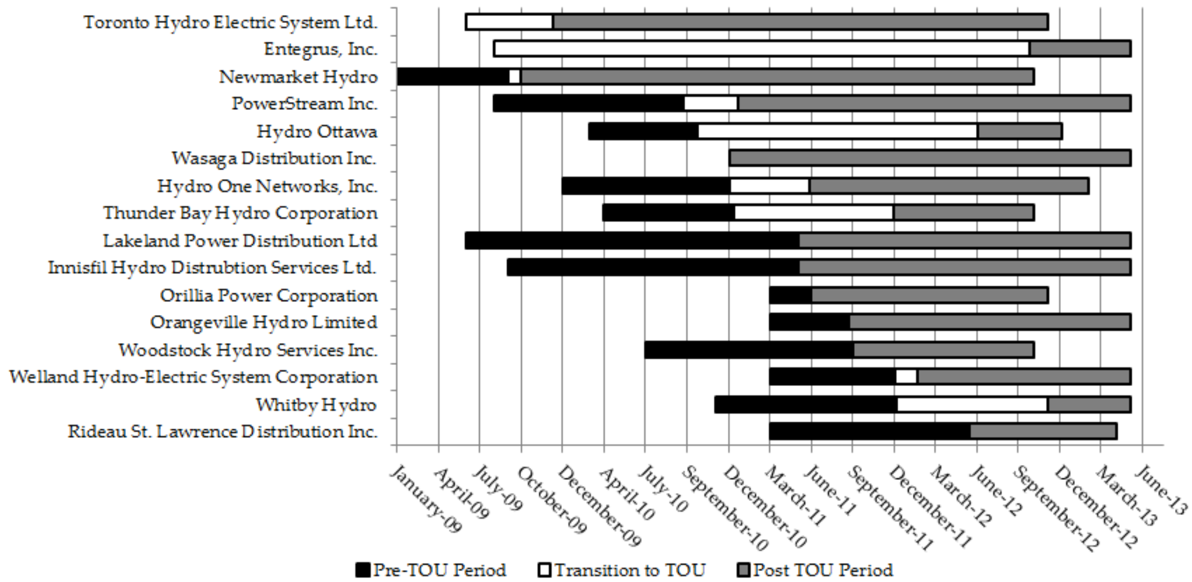
As may clearly be seen, although residential data are reasonably well distributed amongst Ontario's population centres (with perhaps insufficient representation from the south west of the province), the general service customer data set is clearly dominated by Hydro Ottawa. Hydro Ottawa customers represent approximately 80% of all general service customers in Navigant's data set.

3.1.2 Time Span Covered by Sample

Altogether, Navigant's data sample included data from 16 different LDCs. Figure 8, below shows graphically the start and end times of each LDC data set included in this analysis. The tri-coloured bars in this graph are defined in the following way:

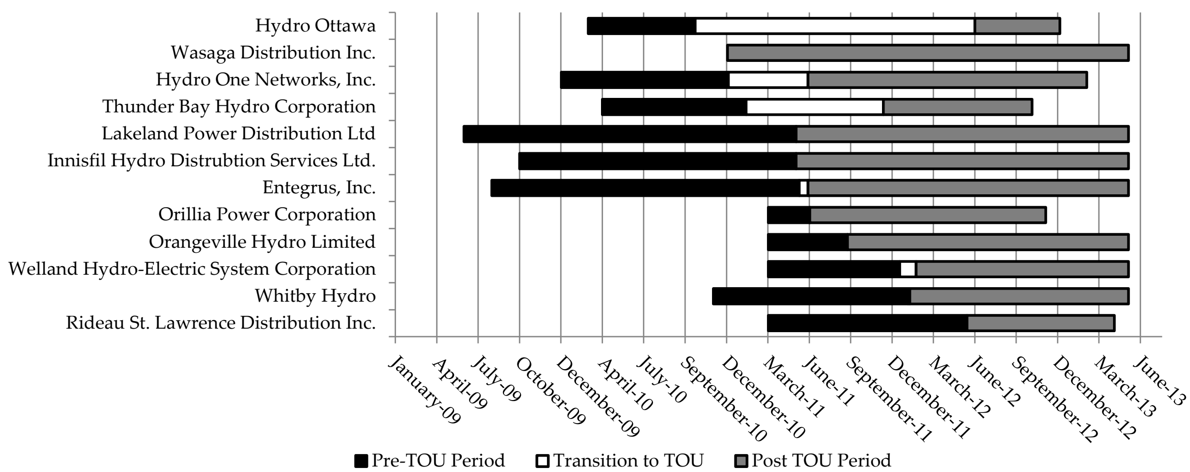
- A **black** bar covers a time span in which *no* customer in that LDC's data set was subject to TOU rates.
- A **white** bar covers a time span in which *at least one* customer in that LDC's data set was subject to TOU rates and *at least one* was not.
- A **gray** bar covers a time span in which *all* customers in that LDC's data set were subject to TOU rates.

Figure 8: Start and End of Data Series by LDC - Residential



Source: OEB-provided hourly consumption data.

Figure 9: Start and End of Data Series by LDC – GS



Source: OEB-provided hourly consumption data.

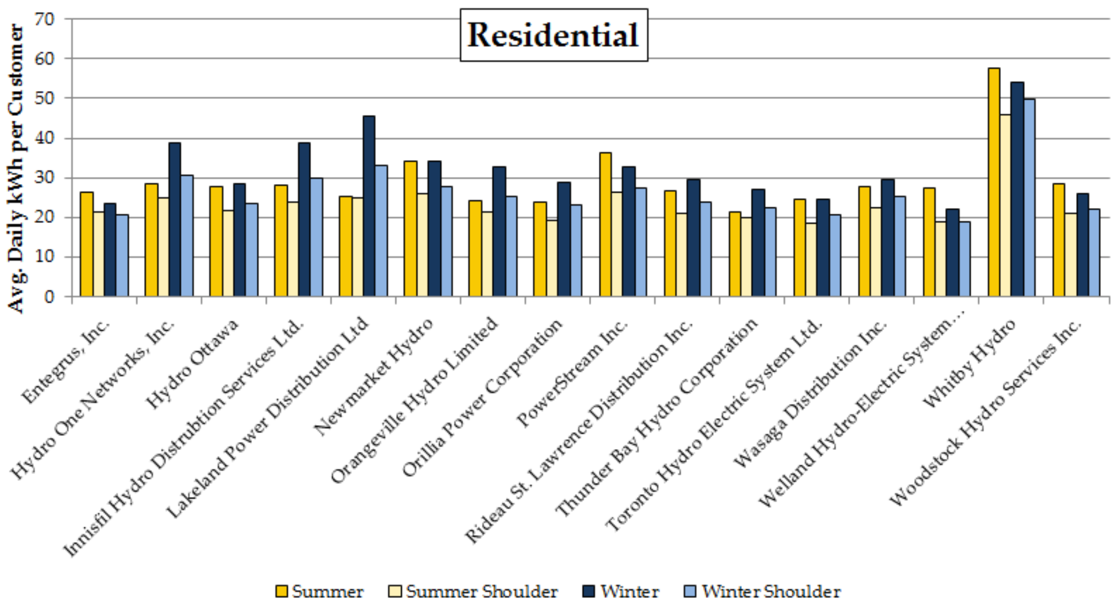
As may be seen, across the residential data set there is considerable diversity in when all customers became subject to TOU rates, with some LDCs being early adopters (Toronto Hydro, Entegrus and Newmarket), and others being later adopters (Welland, Whitby and Rideau). This diversity is very important for this analysis since it means that late adopters can act as pseudo controls for the early adopters, and thus make it possible to estimate the TOU impacts more accurately.

When considering the above graphics it is important to note that the white bars define an area where at least one customer is on tiered rates and at least one customer is on TOU rates. This does not necessarily mean a long gradual transition. In the case of Hydro Ottawa for example, although there are some customers that were subject to TOU rates as early as Autumn of 2010, and others that only became subject to TOU rates as late as June of 2012, the vast majority actually transitioned during the summer of 2011.

3.1.3 Average Daily Consumption per Customer

Seasonal consumption patterns varied across LDCs, as expected. LDCs with customers that tend to be more remote from the major population centres tend to have a customer base that consumes more electricity during the winter than the summer. The average weekday consumption of electricity (kWh) per customer is shown by LDC and by season in Figure 10, below. Interestingly, residential customers in the three of the four largest contributors to the overall data set (Hydro Ottawa, Toronto Hydro and Newmarket Hydro) appear to have very similar levels of consumption in winter and summer.

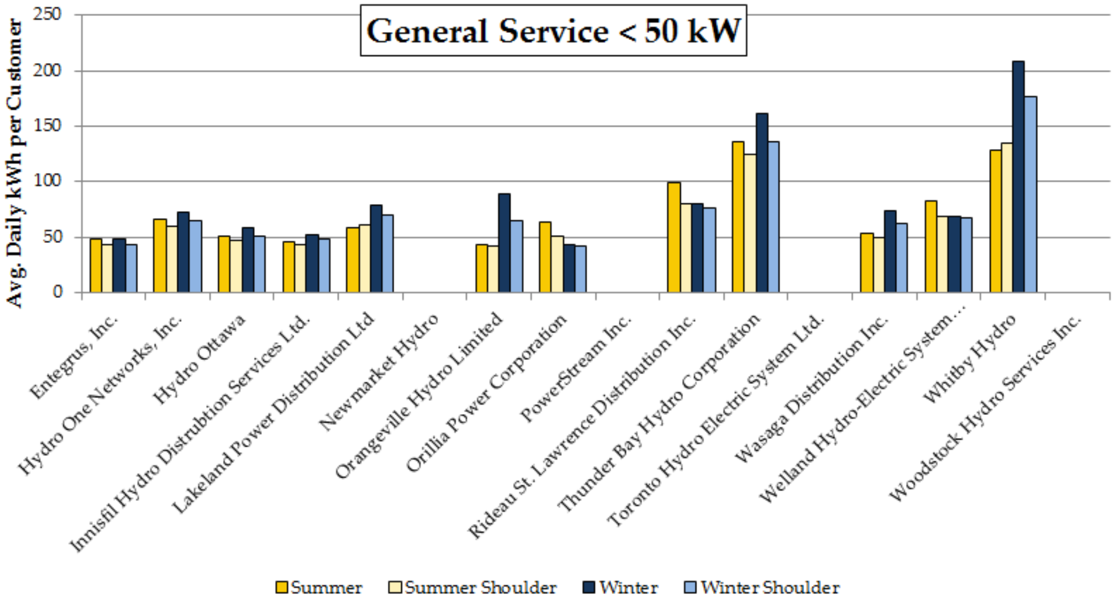
Figure 10: Average Residential Weekday kWh per Customer by LDC and Season



Source: OEB-provided hourly consumption data.

It is interesting to note how much more customers in the Whitby data set consume, on average. It should be noted that Whitby Hydro customers comprise less than 1.5% of the total number of residential customers in the data set. Whitby Hydro general service customers in the data set also have a very high level of consumption relative to the customers contributed by other LDCs, as may be seen in Figure 11, below. Note that nearly 95% of the general service data contributed to the overall sample comes from Hydro One and Hydro Ottawa, with the average number of general service customers per LDC (where any exist) for all others representing less than 1% of the general service data used.

Figure 11: Average GS<50 Weekday kWh per Customer by LDC and Season



Source: OEB-provided hourly consumption data.

3.1.4 Average Marginal Prices Faced by Customers

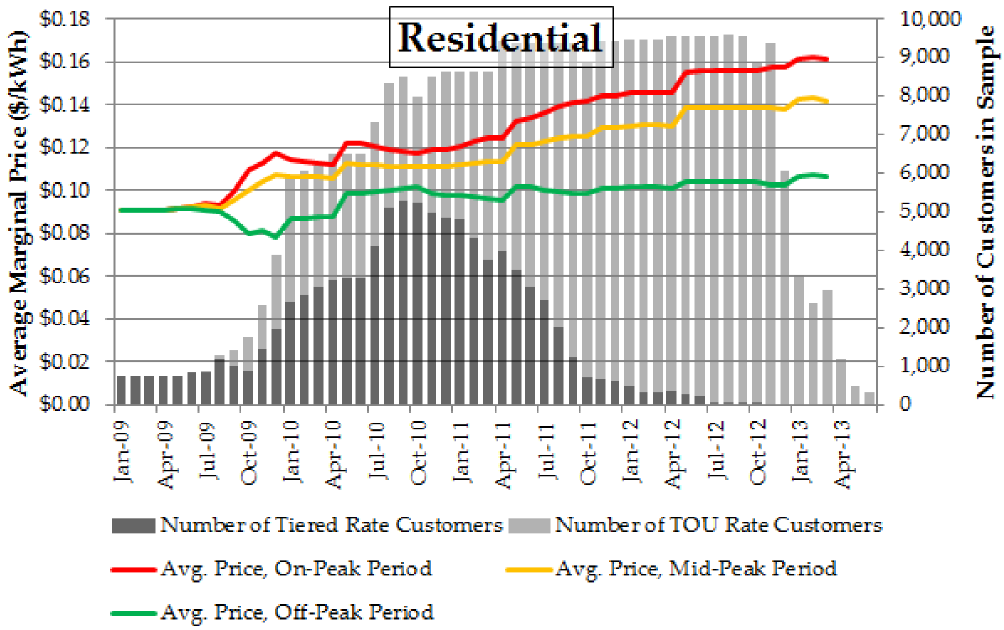
The central independent variable of interest used in Navigant's elasticity analysis is the marginal price of electricity faced by a consumer. This marginal price is the sum of the commodity costs (i.e., the explicit tiered or TOU prices) and of the non-commodity variable charges (distribution charges, etc.). Figure 12 shows the average marginal price faced by residential customers in each of the three TOU periods. Note that this average for each TOU period includes the marginal price faced by customers still subject to tiered rates in the sample. The average marginal prices are shown on the left axis. The number of customers in the sample subject to TOU or tiered rates is represented by the stacked columns that may be read from the right hand axis.

There are three important features to note in this figure:

1. The red, orange and green lines in Figure 12 *do not* indicate the On-Peak, Mid-Peak and Off-Peak prices. They indicate the average marginal price *across all customers in the sample during the time period covered by On-Peak, Mid-Peak or Off-Peak prices*, regardless of the rate structure to which they are subject. This means that these average marginal prices are a blend of tiered prices, TOU prices and volumetric non-commodity costs (e.g., distribution charges, Debt-retirement charge, etc.).
2. This in turn means that at the beginning of the period of analysis, when all customers in the sample were subject to tiered rates, all three lines overlap.
3. Except for the initial period when customers first begin switching to TOU rates, price changes are correlated across periods – when the average price of electricity in the On-Peak period increases, so too does the marginal price of electricity in the Mid-Peak and Off-Peak periods. Close examination of the price series will also reveal discrete breaks in the series at each new RPP setting period – November and May of each year.

The sharp drop in the number of customers in the sample as of December 2012 is due to the fact that the samples provided by THESL, Hydro Ottawa, THESL and Newmarket Hydro do not extend past that date.

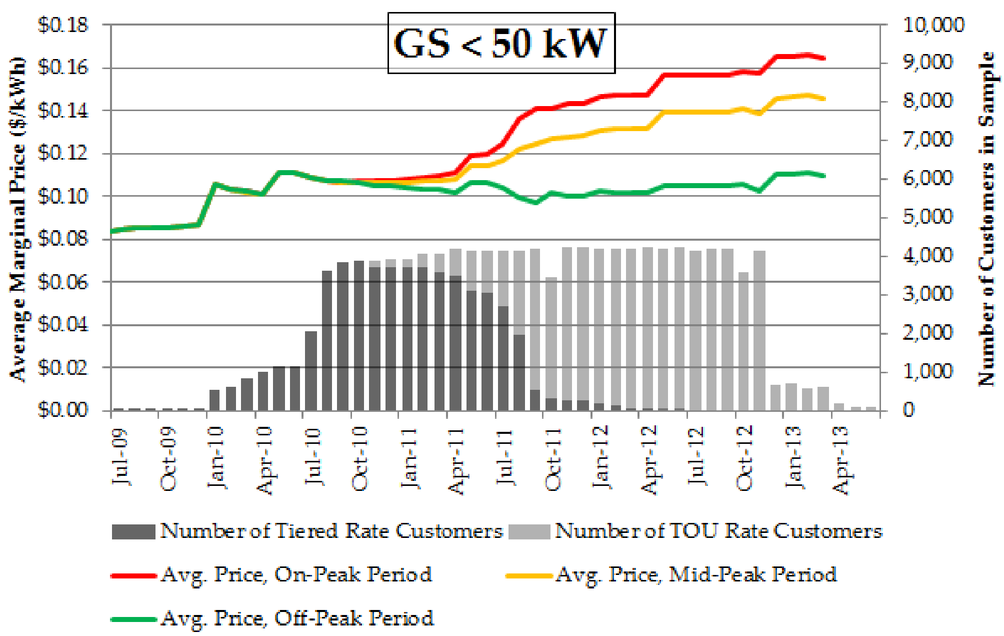
Figure 12: Average Marginal Prices Faced by Customers in the Sample - Residential



Source: OEB-provided hourly consumption data and OEB website.

Figure 13 shows the same data as Figure 12, except for the general service customers in the sample.

Figure 13: Average Marginal Prices Faced by Customers in the Sample – GS

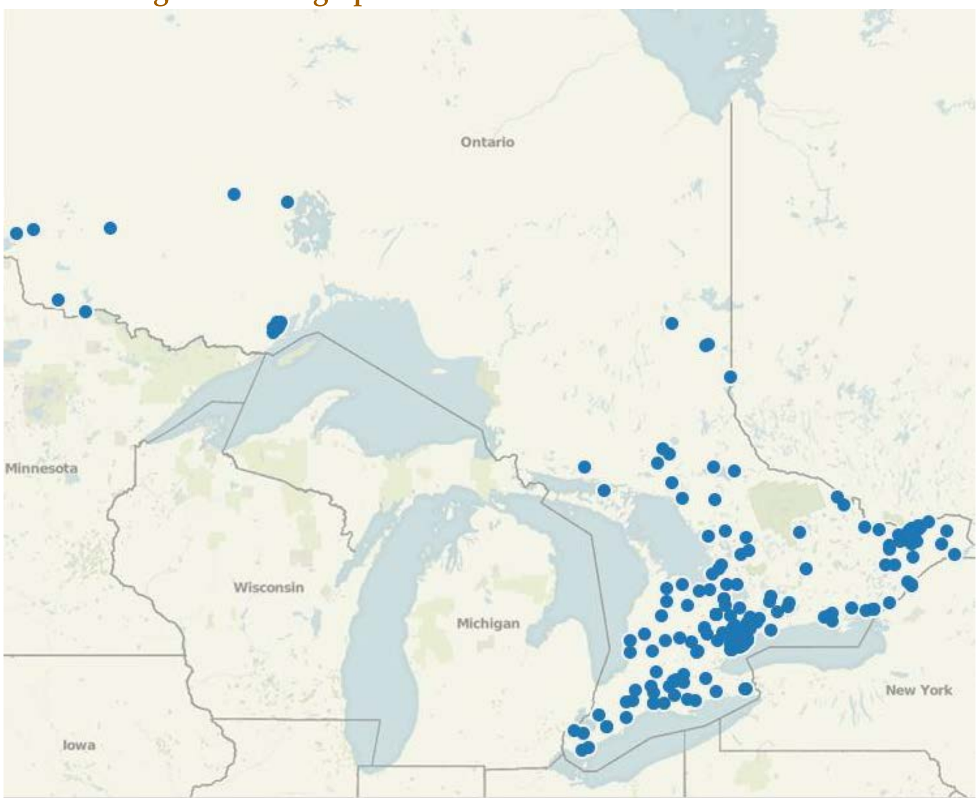


Source: OEB-provided hourly consumption data and OEB website.

3.1.5 Geographic Distribution of Participating Customers

Navigant's data sample is geographically diverse, with customers representing a high proportion of the province included in the data set. Figure 14 shows a blue dot for all the forward sortation areas (FSAs) in which customers that have data in the Navigant data set are located. Note that dot size is not representative of the number of customers at that location.

Figure 14: Geographic Location of Customers in Data Set



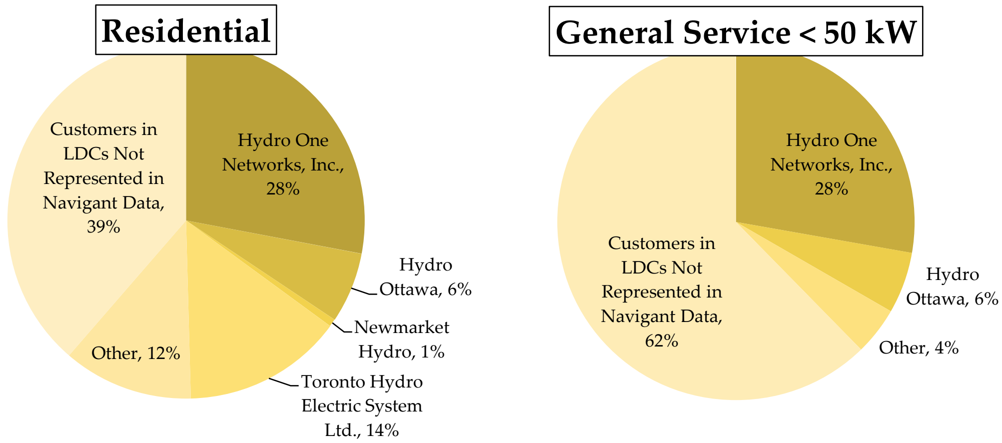
Source: OEB-provided hourly consumption data, Canada Post FSA data.

FSAs were only provided by Hydro One. For all other utilities, all FSAs within the municipal boundaries of the LDC were included. As noted before, although there is representation from a large geographic area of the province, the vast majority of customers in the data set come from Hydro Ottawa, Toronto Hydro, Hydro One and Newmarket Hydro.

3.1.6 Representativeness of LDC Distribution in Sample

LDCs represented in Navigant's residential sample together account for 61% of all residential electricity customers in Ontario. Those represented in Navigant's general service sample account for 48% of all general service less than 50 kW customers in Ontario. The degree to which the LDCs in Navigant's sample include a very high proportion of the population of the province is illustrated in Figure 15. Note that, as in Figure 7, the "Other" category is, for the most part, comprised of the "core" LDCs that are part of the OEB's ongoing data collection efforts.

Figure 15: Percent of Customers Represented by LDCs Included in Sample



Source: OEB 2012 Electricity Distributors Handbook

3.2 Suitability of Data

This section discusses the suitability of the data provided to Navigant for the principal goal of this study – the estimation of the impact of the transition from tiered to TOU rates on electricity consumption.

Residential and general service consumption of electricity is a function of many different factors, some of which are observed by the analyst (weather, seasonality, the transition from tiered to TOU rates) and others that are not observed (building size, heating fuel, number of inhabitants, etc.). Obtaining accurate estimates of the impact of TOU rates requires effectively controlling for all of these factors. Failing to accurately control for a given factor will tend to bias the estimate of the parameter we are interested in (in this case the impact of a change in price) because we will ascribe some or all of the effects of the uncontrolled-for factor, as well as the effects of TOU rates, to the parameter(s) estimating the effects of TOU rates.

Controlling for observable factors is straightforward - these are simply included as explicit variables in a regression equation (for example, heating degree days or monthly dummy variables). Even some unobservable variables may be controlled for using a proxy. For example, it is possible to control for the size of a building, the number of windows it has and in fact any other unobservable factor *that does not change over time* by applying what econometricians refer to as "fixed effects".

To control for unobservable factors that, for whatever reason, change over time requires an experimental design that includes both individuals subject to the treatment (in this case TOU rates) and "control" individuals that are not subject to the treatment.

The transition of Ontario electricity consumers to TOU rates is not an experiment and thus all customers in Ontario will eventually transition to TOU rates. In Navigant's data, by the end of the sample period, all customers in the data set have transitioned to TOU rates – there are no controls. That said, the diversity of the transition to TOU rates across LDCs is taken advantage of to create pseudo control customers. As noted above, some customers are "early adopters"[25] – they became subject to TOU rates quite early on in the sample. Others are "late adopters" – they only became subject to TOU rates later on in the sample. If the sample is pooled, and there is sufficient diversity in the transition to TOU rates, then "late adopters" can act as pseudo controls for the "early adopters" and thus allow Navigant to control for unobservable effects that change across individuals and time.

If early and late adopters are sufficiently similar to one another (in terms of electricity consumption) prior to becoming subject to TOU rates that the differences between them can be accurately controlled for using fixed effects, weather data, etc. then estimates of the impact of TOU rates should be reasonably accurate.

The two sub-sections that follow will discuss:

1. **TOU transition diversity.** Is there some period of time sufficiently long, with a sufficiently even proportion of customers subject to tiered rates or TOU rates that temporally correlated effects can be controlled for?
2. **Similarity of early and late adopters.** Are the late adopters really suitable controls for the early adopters – are the differences between the pre-TOU consumption of both group sufficiently small that it is reasonable to expect that the regression variables can effectively control for them?

3.2.1 TOU Transition Diversity

This sub-section discusses the transition diversity for residential and general service customers.

As may clearly be seen in Figure 16, there is considerable transition diversity amongst residential customers. For approximately half of the months in each of the four seasons, there are a roughly similar number of customers that are subject to TOU rates as are subject to tiered rates. As a result, the residential data has a considerable number of pseudo control customers that may be used to control for time-varying unobservable effects.

[25] Note that this term is not meant to imply that adoption of TOU rates is voluntary. TOU rates are compulsory for all Ontario RPP customers. The term is intended merely to convey the fact that due to the gradual rollout of the rate structure some customers become subject to TOU rates earlier than others.

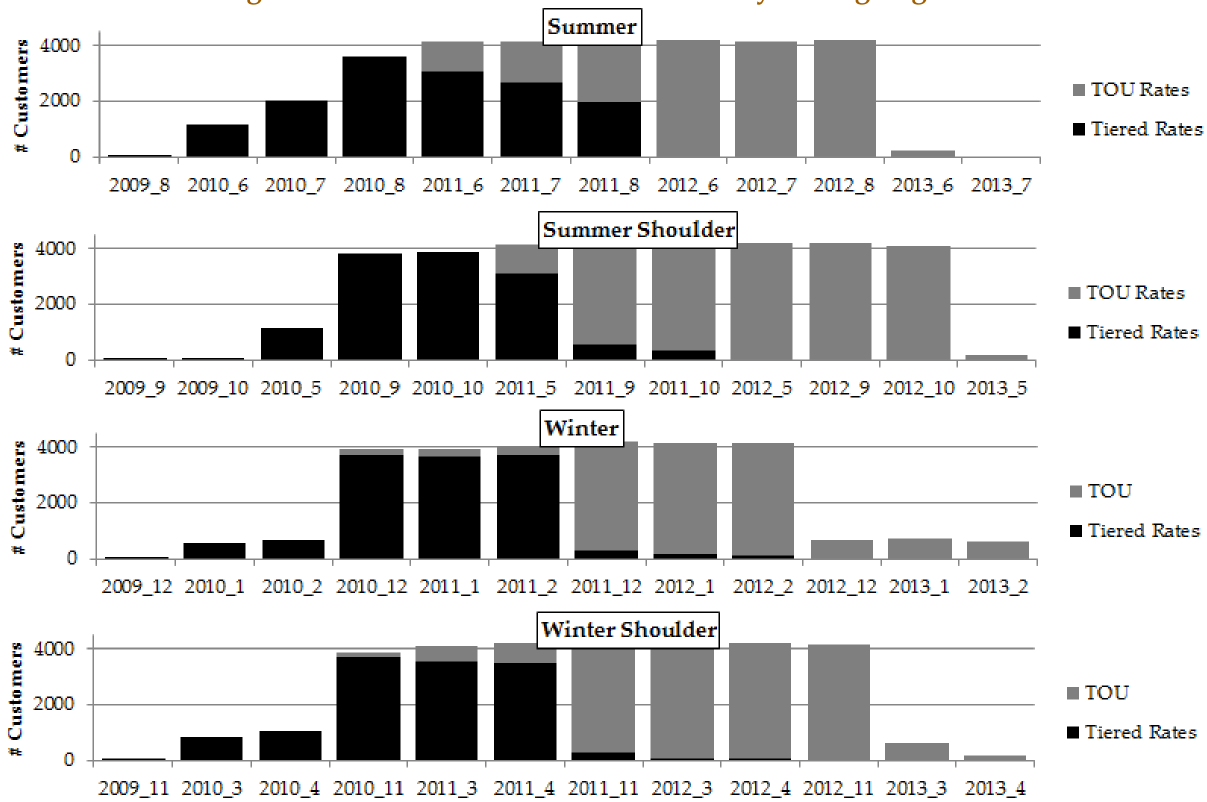
Figure 16: Residential Customer Counts by Pricing Regime

Source: OEB-provided hourly consumption data.

This is not the case for all but one of the general service seasons. Note, in Figure 17 below, how sharp the transition is in the non-summer months from tiered rates to TOU rates; in one month nearly all the customers in the sample are subject to tiered rates, in the next month (within that season), nearly all the customers are subject to TOU rates.

The exception to this pattern is the summer season, although even in this case there appear to be only two or three months – roughly a quarter of those in the sample – where late adopters can act as pseudo controls for early adopters.

Figure 17: GS < 50 kW Customer Counts by Pricing Regime



Source: OEB-provided hourly consumption data.

The very sharp transition from tiered to TOU rates may result in bias in estimates of the impact of TOU rates on general service customers. Any estimate of the effect of the introduction of TOU rates may potentially be biased by other unobservable effects that are temporally correlated with the transition to TOU rates. Note that this effect will be present regardless of whether impacts are estimated using a dummy variable to represent the switch to TOU rates or using electricity prices. Since by far the sharpest change in price will occur when the transition from tiered to TOU rates occurs, it is probable that the uncontrolled for temporally correlated non-price effects will be collected by the price impact estimates, biasing them.

For these reasons, Navigant believes that the data for the general service customers in non-summer months is unsuitable to use for the estimation of TOU impacts.

3.2.2 Similarity of Late and Early Adopters

As was shown in the section above, there is only a single season for general service customers in which it is possible for the late adopters to act as pseudo controls for the early adopters – the summer.

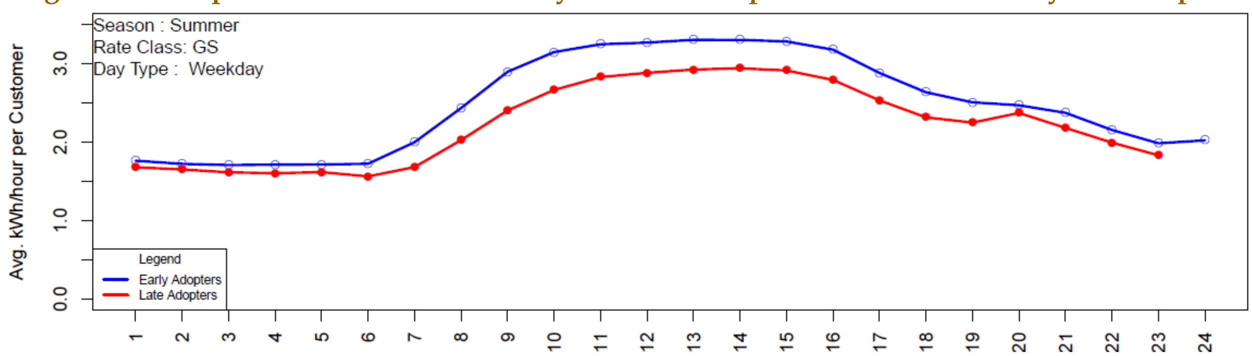
For impact estimates for general service customers in the summer to be reasonably accurate, the late adopter general service customers must have pre-TOU consumption that is sufficiently similar to that of the early adopters, such that the difference between them can be reasonably controlled for through fixed effects and other available data.

To judge to what degree general service late adopters make good controls for early adopters, Navigant has compared the average weekday load profile of a late adopter with an early adopter in Figure 18, below.

- **Early adopters** are considered any customer that were subject to TOU rates prior to June 30, 2011
- **Late adopters** are considered any customer that became subject to TOU rates after June 30th, 2011.

In Figure 18, the pre-TOU consumption of general service early adopters in the summer of 2010 is compared with the pre-TOU consumption of late adopters in the same summer.

Figure 18: Comparison of GS < 50 kW Early and Late Adopters' Summer Weekday Consumption

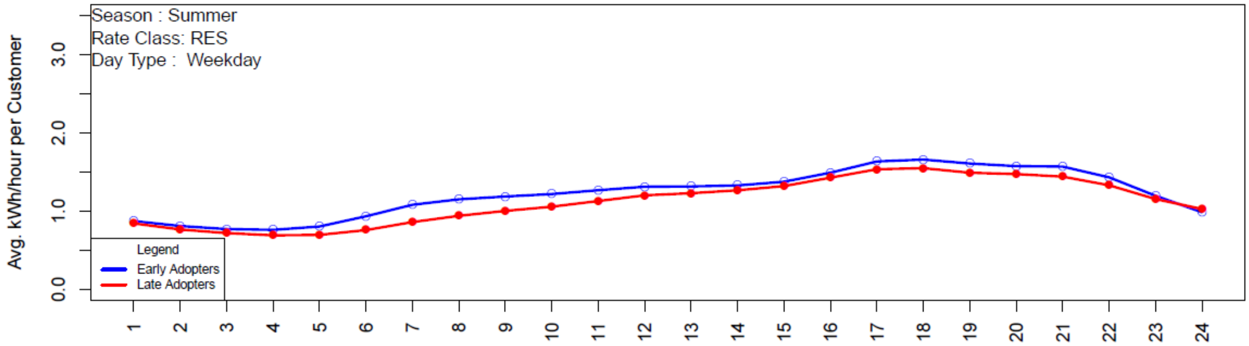


Source: OEB-provided hourly consumption data, and Navigant analysis.

Clearly, the early adopters tend to consume more electricity in the middle of the day than the late adopters. As a result, the late adopters are not perfect controls for the early adopters. The contrast is striking when comparing residential early and late adopters, as shown in Figure 19, below. This graph was generated using identical parameters to that used for the general service customers (e.g., late and early adopter definitions, etc.). Note how much closer the two residential profiles are to one another, compared to the general service profiles.[26]

[26] Testing the hypothesis of equality of means between the mean consumption of early and late GS adopters from the 6am to 7pm (hours ending 7 through 19) we find that we can reject this hypothesis at the 95% level of confidence. Applying the same test to the residential profiles, we cannot reject the hypothesis that the means are the same.

Figure 19: Comparison of Residential Early and Late Adopters' Summer Weekday Consumption



Source: OEB-provided hourly consumption data, and Navigant analysis.

While it is clear that the general service late adopters aren't nearly as good controls for the general service early adopters as the residential late adopters are for the residential early adopters, it is not clear whether the general service late adopters are *good enough* as controls. Recall that fixed effects and other variables can be deployed to correct (to some degree) for the spread between the blue and the red lines in Figure 18. The width of the spread, however, means that estimates of the impact of TOU on general service consumption will tend to be much more sensitive to the model specification than the estimated impact on residential consumption. Since the general service analysis relies more on independent variables (as opposed to the control individuals in the data) to control for non-TOU effects, it will inevitably be more sensitive to what variables are included in the model.

The results above suggest that estimated impacts for general service customers in the summer season will almost certainly be less robust than the estimated residential impacts.

4 RESULTS

This section of the report provides the estimated impact of the introduction of TOU rates on consumption and average levels of demand by season, rate class and TOU period.

This section is divided into the following three sub-sections:

1. **Conventional Impact Analysis.** This section provides the conventionally estimated impacts of the transition from tiered to TOU rates for:

    a. residential customers in all seasons; and,
    b. general service customers in the summer.

2. **Elasticity Analysis.** This section provides the impacts estimated, based on the estimated own- and cross-price elasticities, of the transition from tiered to TOU rates for:

    a. residential customers in all seasons; and,
    b. general service customers in the summer

3. **Provincial Impacts.** This section provides a discussion regarding the suitability of extrapolating these results out to the provincial level and an estimate of the MW impact at the provincial level of TOU rates.

General service impact estimates for non-summer seasons are not provided, due to the data concerns outlined in section 3.2.1 and 3.2.2, above. Likewise, comparative discussion of the two sets of estimated general service results has been omitted due to concerns regarding the robustness of the general service summer results.

4.1 Conventional Impact Analysis

This section provides the conventionally estimated impacts of the transition from tiered to TOU rates for:

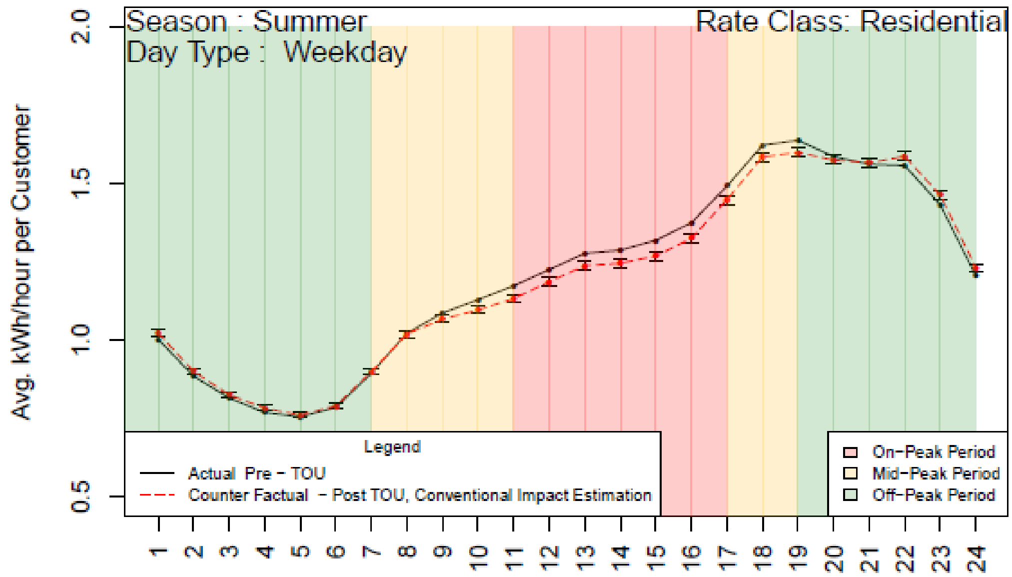
a. residential customers in all seasons; and,
b. general service customers in the summer.

Plots of average actual and fitted values and the 95% confidence intervals around the fitted values for each season, rate class and day type may be found in Appendix B, below.

4.1.1 Residential Customers

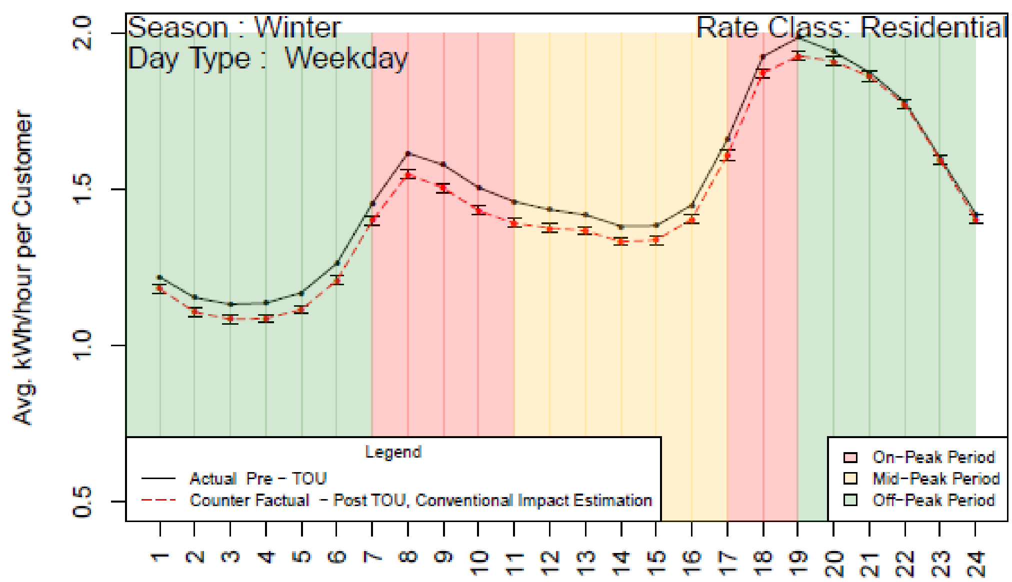
A plot of the actual average load profile of customers subject to tiered rates (black line) compared with the estimated counterfactual load profile of the same customers, had they been subject to TOU rates in the same period, is presented in Figure 20 (summer) and Figure 21 (winter), below. Ninety-five percent confidence intervals are indicated by the black error bars. The TOU periods[27] are indicated by colour shading.

Figure 20: Average Residential Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Figure 21: Average Residential Pre- and Post-TOU Load Profile, Winter Weekday



Note: The x-axis is Eastern Standard Time (EST).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

[27] The TOU periods shown correspond to the TOU periods as of May 1, 2011, i.e., with a two hour rather than a four hour afternoon Mid-Peak.

Similar plots for the other seasons and for weekend days in all seasons may be found in Appendix A, at the end of this report.

Using the conventional fixed effects model, controlling for the introduction of TOU rates with a dummy variable and weather-interactive dummy variables, as outlined in section 2.1, Navigant has estimated that the transition from tiered to TOU rates resulted in a reduction of summer residential On-Peak consumption of approximately 3.3%. This is equivalent to an average hourly kW reduction per customer of approximately 0.044 kW during the summer months (June, July and August).

In the winter months, using the conventional impact analysis, Navigant has estimated that TOU rates resulted in a reduction of residential On-Peak consumption of approximately 3.4%. This is equivalent to an average hourly kW reduction, per customer, of between 0.05 kW during the winter months (December, January and February).

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual may be found in Figure 22, below. Where an estimate is not statistically significant, the row is coloured dark gray.

The estimated impacts shown in Figure 22, below are, for the most part as expected. The conventional impact analysis estimates suggest that residential customers have shifted consumption away from the more expensive periods (On- and Mid-Peak) and into the less expensive Off-Peak period.

It is important to note that although the estimated impacts suggest that TOU prices have shifted demand, this does not necessarily mean that customers have shifted specific end-uses. That is, a demand shift from On-Peak and Mid-Peak periods to Off-Peak does not necessarily mean that customers have postponed running a given piece of equipment until the Off-Peak period. It could just as easily mean that customers are conserving in the more expensive periods, and being less careful than they might otherwise have been in the cheaper periods. For example, an estimated shift in demand could be the result of reduced air conditioning use during the day, but increased lighting consumption in the evening due to customers being less mindful of turning off lights in empty rooms.

In contrast to the summer and summer shoulder response, the conventional impact estimates suggest that the principal residential customer response to the transition from tiered toTOU rates in the winter has been one of conservation – there are reductions in consumption in all periods. There are two possible explanations for this effect.

The first is that in an effort to respond to higher On-Peak and Mid-Peak prices customers have adopted general conservation behaviours rather than On-Peak or Mid-Peak specific measures. For example, increased awareness and curtailment of phantom load (e.g., unplugging chargers or other appliances when not in use), improved hot water heater insulation (for homes with electric water heat), increased vigilance with respect to turning off unused lighting, etc.

The other possible explanation is that the results may be slightly biased due an omitted control variable. If, for example, customers with electric water and space heating were over-represented amongst the "early" adopters, this could skew the results somewhat and result in an over-estimation of the impact of TOU rates in winter months. Navigant did not have household heating fuel specific data to control for these effects.

The fixed effects employed as part of the conventional impact approach and the fact that separate regressions were estimated for each hour should have corrected, to a large degree, for the presence of electric space heat in some homes. It is noteworthy that although there is an apparent reduction in consumption in the early morning Off-Peak hours, there is no such corresponding reduction in the evening Off-Peak hours (see plot, Figure 21). Were the estimates being significantly biased due to the over-representation of electrically heated homes amongst the early adopters we would expect to see a very similar impact in both the early morning and the late evening hours.

Overall, Navigant believes that, given the reasons above, and despite the similar magnitude of the confidence intervals, the summer impacts based on the conventional impact analysis are more robust than the winter impacts.

Figure 22: Complete Results, Residential Conventional Impact Estimation

		Avg kWh Impact* (Entire Period)	95% Conf. Interval	Avg. kW Impact (Per Hour)	95% Conf. Interval	Average % Impact	95% Conf. Interval
Summer (Jun, Jul, Aug)	On-Peak	-0.263	+/- 0.083	-0.044	+/- 0.014	-3.3%	+/- 1%
	Mid-Peak	-0.173	+/- 0.077	-0.029	+/- 0.013	-2.2%	+/- 1%
	Off-Peak	0.156	+/- 0.137	0.013	+/- 0.011	1.2%	+/- 1%
	Off-Peak Weekend	0.556	+/- 0.326	0.023	+/- 0.014	1.9%	+/- 1.1%
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.132	+/- 0.063	-0.022	+/- 0.01	-2.2%	+/- 1%
	Mid-Peak	-0.103	+/- 0.067	-0.017	+/- 0.011	-1.5%	+/- 1%
	Off-Peak	0.167	+/- 0.117	0.014	+/- 0.01	1.5%	+/- 1%
	Off-Peak Weekend	0.362	+/- 0.312	0.015	+/- 0.013	1.4%	+/- 1.2%
Winter (Dec, Jan, Feb)	On-Peak	-0.300	+/- 0.081	-0.050	+/- 0.014	-3.4%	+/- 0.9%
	Mid-Peak	-0.395	+/- 0.09	-0.066	+/- 0.015	-3.9%	+/- 0.9%
	Off-Peak	-0.420	+/- 0.168	-0.035	+/- 0.014	-2.5%	+/- 1%
	Off-Peak Weekend	-0.468	+/- 0.352	-0.020	+/- 0.015	-1.2%	+/- 0.9%
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-0.136	+/- 0.062	-0.023	+/- 0.01	-2.1%	+/- 0.9%
	Mid-Peak	-0.177	+/- 0.07	-0.030	+/- 0.012	-2.3%	+/- 0.9%
	Off-Peak	-0.144	+/- 0.128	-0.012	+/- 0.011	-1.1%	+/- 1%
	Off-Peak Weekend	0.140	+/- 0.5	0.006	+/- 0.021	0.5%	+/- 1.7%

Rows shaded in gray are not statistically significant at the 95% level.

**Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)*

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A discussion comparing the results above with those estimated using the elasticity analysis is found in section 5, below.

Estimates of the seasonal conservation effect, in kWh and as a percent of consumption, are shown in Figure 23. These estimates are calculated simply by summing the average kW impacts cited above across all the hours of a given season. That is, each hour of the year was assigned an average kW impact, as per the estimates shown in Figure 26. The conservation impact is then estimated simply by summing across the desired hours. The sum across all the summer On-Peak hours, for example deliver an estimated 17 kWh of conservation. Overall, customers reduced annual energy consumption by approximately 1% (bottom right cell of Figure 26). The average annual residential consumption is approximately 10,700 kWh.

In this case, the conservation effect was estimated using the TOU periods in 2011.[28] As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure 23: Seasonal Conservation Estimates, Residential Conventional Impact kWh

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-17	-3.3%	-11	-2.2%	10	1.2%	16	1.9%	-2	-0.1%
Summer Shoulder	-8	-2.2%	-6	-1.5%	10	1.5%	11	1.4%	7	0.3%
Winter	-22	-3.4%	-24	-3.9%	-23	-2.5%	-14	-1.2%	-83	-2.5%
Winter Shoulder	-11	-2.1%	-12	-2.3%	-8	-1.1%	4	0.5%	-27	-1.1%
Total	**-58**	**-2.8%**	**-53**	**-2.6%**	**-11**	**-0.3%**	**16**	**0.5%**	**-105**	**-1.0%**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average residential customer's electricity costs.[29] These are summarized in Figure 24, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

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[28] The exact number of On-Peak, Mid-Peak and Off-Peak hours will vary slightly from year to year. For example, in 2011 and 2010 there were 105 weekend days, whereas in 2006 through 2009 there were only 104.

[29] These are calculated as the estimated conservation impact by period (kWh) as shown in Figure 23 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

Figure 24: Approximate Impact on Average Residential Commodity Costs

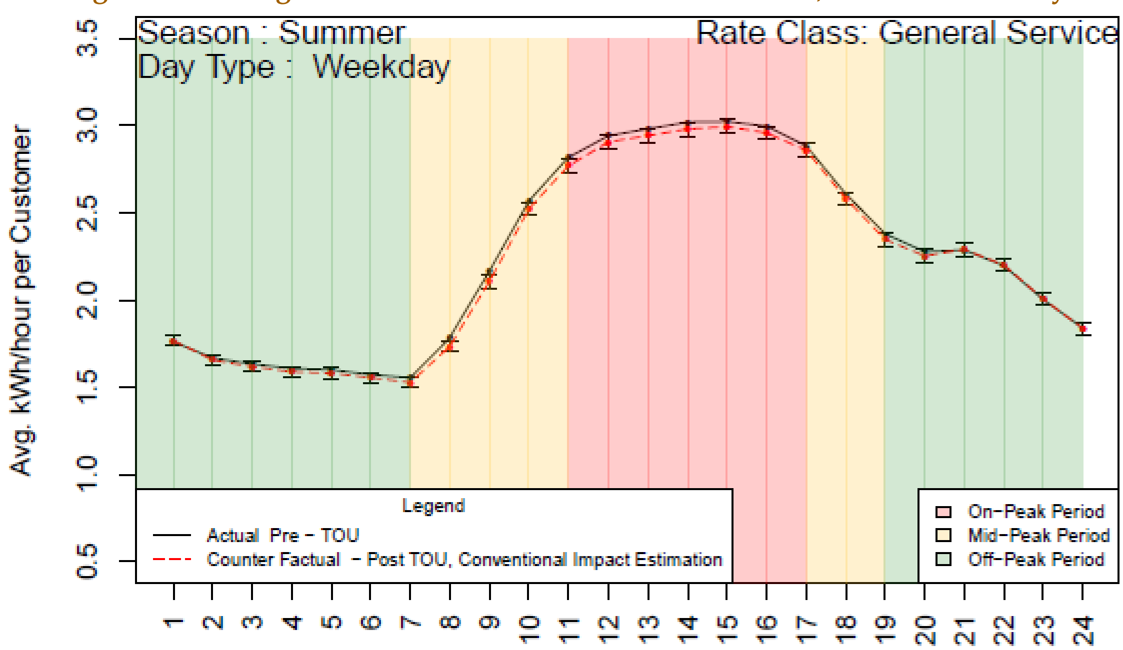
Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$1	$1	$1	**-$2**
Summer Shoulder	-$1	-$1	$1	$1	**$0**
Winter	-$3	-$3	-$2	-$1	**-$8**
Winter Shoulder	-$1	-$1	-$1	$0	**-$3**
Total Across Seasons	**-$7**	**-$6**	**-$1**	**$1**	**-$12**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

4.1.2 General Service (<50 kW) Customers

A plot of the actual average load profile of customers subject to tiered rates (black line) compared with the estimated counterfactual load profile of the same customers, had they been subject to TOU rates in the same period, is presented in Figure 25, below. Ninety-five percent confidence intervals are indicated by the black error bars. The TOU periods[30] are indicated by colour shading.

Figure 25: Average GS kW Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The corresponding weekend day plot may be found in Appendix A, at the end of this report.

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30 The TOU periods shown correspond to the TOU periods as of May 1, 2011, i.e., with a two hour rather than a four hour afternoon Mid-Peak.

As noted above, due to data concerns, Navigant only included general service impact estimates for the summer, the sole season where there exists sufficient diversity in TOU transition dates to allow Navigant to use late adopters as pseudo controls for early adopters.

Using the conventional fixed effects model, controlling for the introduction of TOU rates using a dummy variable and weather-interactive dummy variables, as outlined in section 2.1, Navigant has estimated that TOU rates have resulted in no statistically significant impact on general service summer On-Peak consumption. In fact, the only TOU period in which the impact of the introduction of TOU rates appears to have been statistically significant is the Mid-Peak period.

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual for the summer season only may be found in Figure 26, below. Where an estimate is not statistically significant, the row is coloured dark gray.

Figure 26: Complete Results, GS Conventional Impact Estimation

		Avg kWh Impact* (Entire Period)	95% Conf. Interval	Avg. kW Impact (Per Hour)	95% Conf. Interval	Average % Impact	95% Conf. Interval
Summer (Jun, Jul, Aug)	On-Peak	-0.206	+/- 0.234	-0.034	+/- 0.039	-1.2%	+/- 1.3%
	Mid-Peak	-0.263	+/- 0.223	-0.044	+/- 0.037	-1.8%	+/- 1.6%
	Off-Peak	-0.119	+/- 0.386	-0.010	+/- 0.032	-0.5%	+/- 1.8%
	Off-Peak Weekend	-0.087	+/- 0.825	-0.004	+/- 0.034	-0.2%	+/- 1.9%

Rows shaded in gray are not statistically significant at the 95% level.

**Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)*

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A discussion comparing the results above with those estimated using the elasticity analysis is found in section 5, below.

Estimates of the seasonal conservation effect, in kWh and as a percent of consumption, are shown in Figure 27. These estimates are calculated simply by summing the average kW impacts cited in Figure 26 above across all the hours of a given season. That is, each hour of the year was assigned an average kW impact, as per the estimates shown in Figure 26. The conservation impact is then estimated simply by summing across the desired hours. The sum across all the summer On-Peak hours, for example deliver an estimated 13 kWh of conservation. The average annual GS consumption is approximately 20,000 kWh.

In this case, the conservation effect was estimated using the TOU periods in 2011.[31] As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

[31] The exact number of On-Peak, Mid-Peak and Off-Peak hours will vary slightly from year to year. For example, in 2011 and 2010 there were 105 weekend days, whereas in 2006 through 2009 there were only 104.

Figure 27: Seasonal Conservation Estimates, GS Conventional Impact kWh

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-13	-1.2%	-17	-1.8%	-8	-0.5%	-3	-0.2%	-40	-0.8%

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average GS customer's electricity costs.[32] These are summarized in Figure 28, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure 28: Approximate Impact on Average GS Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$2	-$1	$0	**-$4**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

4.2 Elasticity Analysis

This section provides the estimated own- and cross-price Marshallian elasticities (taking into account the aggregate elasticity of demand, i.e., $\varepsilon_{k,r}^{Magg}$, as described in 2.2.5) , as well as the impact of the transition to TOU rates on consumption that are implied by those elasticities for:

a. residential customers in all seasons; and,
b. general service customers in the summer.

In the two sub-sections that follow, Navigant provides its elasticity estimates, by TOU period. Navigant warns readers to proceed with caution when interpreting these elasticities. When considering how a price change might affect consumption it is insufficient to look at simply the own-price effect – the cross-price effects must also be considered. Caution must also be exercised in using these elasticities for projections of consumption changes: TOU prices have, in the sample, uniformly increased in price, and always at the same time as one another. Likewise, fluctuations in the price have been relatively modest. Projecting the effects of price changes larger than those observed in the sample or of price changes where not all prices move in the same direction is outside all observed historical data and such projections should acknowledge the uncertainty inherent in such out of sample projection.

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[32] These are calculated as the estimated conservation impact by period (kWh) as shown in Figure 27 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

Elasticities are provided for four periods in each season:

- On-Peak period;
- Mid-Peak period;
- Off-Peak 7pm to 9pm period (weekdays only); and
- Off-Peak remainder.

The first two periods correspond to the current RPP On-Peak and Mid-Peak periods. The Off-Peak 7pm to 9pm period is split out from the rest of the Off-Peak period due to the fact that prior to May 1, 2011 this period was part of either the On-Peak (in the winter) or the Mid-Peak (in the summer) periods. The Off-Peak remainder period covers from 9pm to 7am on weekdays and all day on weekends.

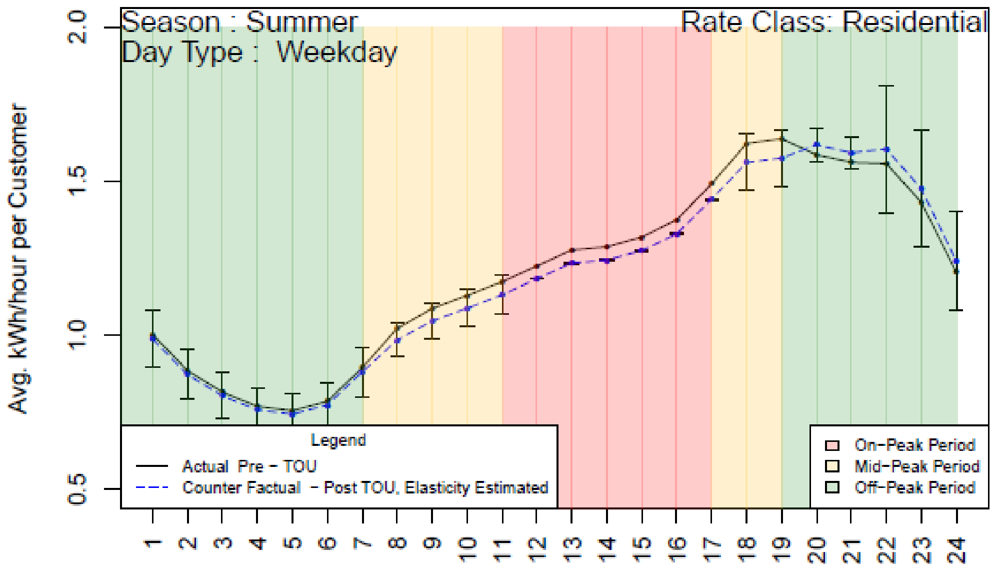
Plots of average actual and fitted values of the Rotterdam model dependent variable and the 95% confidence intervals around the fitted values for each season and rate class may be found in Appendix B, below.

4.2.1 Residential Customers

A plot of the actual average load profile of customers subject to tiered rates (black line) compared with the elasticity-estimated counterfactual load profile of the same customers, had they been subject to TOU rates in the same period, is presented in Figure 29, for the summer and Figure 30, for the winter, below.

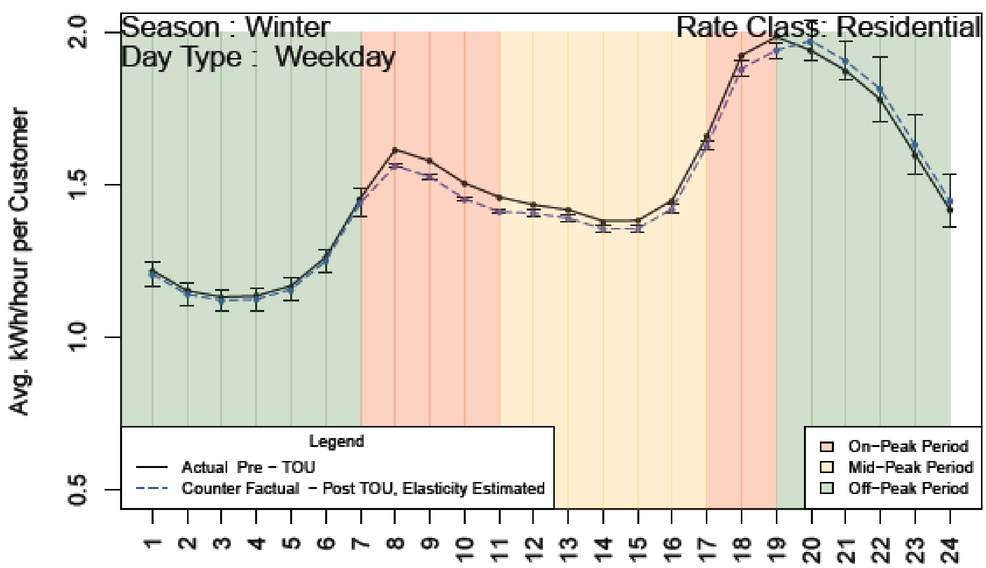
Note that the error bars in this plot do *not* correspond to the 95% confidence interval around the estimated impact, but rather the range of estimated impacts based on the 95% confidence intervals estimated for the elasticities. Due to the effect of compounding, these error bars may overstate the width of the confidence interval around the estimated impacts. That said, they do provide a good indication of the relative precision of each impact – note, for example, that the bars are tightest around the estimates during the summer On-Peak period and the winter On-Peak and Mid-Peak periods, indicating that we may be much more confident in the accuracy of the elasticity-based impact estimates in these periods than in the others.

Figure 29: Average Residential Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Figure 30: Average Residential Pre- and Post-TOU Load Profile, Winter Weekday



Note: The x-axis is Eastern Standard Time (EST).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Similar plots for the other three seasons and for weekend days in all seasons may be found in Appendix A, at the end of this report.

For residential customers in the summer season, Navigant estimated that customers are generally price sensitive in the On-Peak and Mid-Peak TOU periods, slightly price sensitive in the early evening Off-Peak TOU period, but not very price sensitive (at the prices observed historically) in the late evening, early morning, or the weekend of the Off-Peak TOU period. The discussion of estimated elasticities that follows draws heavily from the estimated elasticities shown in Figure 31, below.

All the own- and cross-price elasticities estimated for residential customers, in all seasons, along with the 95% confidence interval, are shown in Figure 31, below. Note that cells that are in boxes (along the diagonal) are own-price elasticities. Cells shaded gray are estimated elasticities that are not statistically significant.

Note that the elasticities reported in Figure 31 are a slightly aggregated version of those estimated by Navigant. Navigant obtained elasticities for the four periods shown by summing up the underlying regression parameters by commodity period and re-calculating the elasticity. This aggregation allows the reader to interpret the results more intuitively.

The columns in Figure 31 refer to the price periods and the rows to the commodity periods. Thus the first column provides an estimate of the effect on consumption in each of the periods (rows) when On-Peak price changes, the second column provides an estimate of the effect on consumption in each of the periods (rows) when the Mid-Peak price changes. For residential customers in the summer season, Navigant estimated an own-price elasticity for On-Peak and Mid-Peak consumption of -0.34 and -0.71, respectively.[33] These are of the expected sign – negative – indicating that electricity in these periods is a "normal" good – as its price increases, the quantity consumed falls.

The summer own-price elasticities for the Off-Peak 7pm to 9pm period (-0.06) and Off-Peak remainder period (-0.14) are both also significant and negative, although smaller in absolute value than those estimated for the Mid-Peak and On-Peak periods. These estimates suggest that residential customers are less sensitive to Off-Peak price fluctuations than they are to those in the Mid-Peak and On-Peak periods. Of the two Off-Peak periods, the own-price elasticity is lowest for the Off-Peak 7pm to 9pm period indicating that the summer period in which customers are least sensitive to price changes is the period between 7pm and 9pm on weekdays – dinnertime and just after.

The cross-price elasticities in the summer suggest that, for the most part, electricity is substitutable from one period to another; that, for example, as the price of On-Peak electricity increases (and On-Peak consumption falls) there will be an increase in consumption in the Mid-Peak and Off-Peak 7pm to 9pm periods (cross-price elasticities of +0.39 and +0.14, respectively). Interestingly, the cross-price elasticity estimated for the effect of a change in the On-Peak price and the consumption of energy in the Off-Peak remainder period[34] is negative (-0.05). It is also, however, quite small in absolute value and not significant, suggesting that overnight and weekend consumption is relatively unaffected by On-Peak prices.

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33 An elasticity is a quantification of the relationship between the price of a good and the quantity demand of that good (own-price elasticity) or the quantity demanded of another good (cross-price elasticity). The elasticity represents a factor which, when multiplied by the difference of the logged prices delivers the incremental change in the quantity demanded. A more intuitive explanation is that when an own price elasticity is -0.1 then a 10% increase in price will lead to approximately a 1% decrease in quantity demanded.

34 Consisting of the weekday period from 9pm to 7am and weekends and holidays.

The estimated elasticities in the summer shoulder and winter seasons also all have the expected sign, except for the winter mid-peak own-price elasticity (+0.03), which is positive but not statistically significant.

For the winter shoulder period, all of the own-price elasticities are positive, an unexpected result. This would suggest that as the price of electricity increases, so too does consumption – clearly a spurious result. It is important, when considering these results, however, to also look at the cross-price elasticities. Note, for example that the cross-price elasticities for the winter shoulder between the Mid-Peak and On-Peak periods (-0.33 and -0.24) are both negative and quite large in absolute terms. In fact, these are, in absolute terms, the second and third-largest estimated elasticities outside of the summer period.

What these elasticities imply is that as the price of On-Peak electricity increases, the consumption of Mid-Peak electricity falls (due to the -0.33 cross-price elasticity) by a higher proportion than On-Peak consumption increases (due to the +0.14 own-price elasticity). Likewise, if the price of Mid-Peak electricity increases, the consumption of On-Peak electricity falls (due to the -0.24 elasticity) although by a lower proportion than Mid-Peak consumption increases (due to the +0.5 elasticity).

What this suggests is that when the prices increase in all periods (as they have historically) there will be a net shifting of consumption from the On-Peak period to the Mid-Peak period. This may be clearly seen in the plot of this season's impacts calculated using the elasticity estimates shown in Appendix A. Navigant believes it is likely that the apparently spurious estimate of positive own-price elasticities for this season is driven by the relatively small change in consumption observed, combined with the confounding correlation in the movements of TOU prices, i.e., they always increase together.

Figure 31: Residential Elasticity Estimates – by TOU Period

Season	Commodity Period	Elasticities: On-Peak	Elasticities: Mid-Peak	Elasticities: Off-Peak 7pm - 9pm	Elasticities: Off-Peak Remainder	95% Conf. Intervals: On-Peak	95% Conf. Intervals: Mid-Peak	95% Conf. Intervals: Off-Peak 7pm - 9pm	95% Conf. Intervals: Off-Peak Remainder
Summer (Jun, Jul, Aug)	On-Peak	-0.34	0.35	0.04	-0.11	+/- 0.06	+/- 0.1	+/- 0.01	+/- 0.04
	Mid-Peak	0.39	-0.71	-0.05	0.32	+/- 0.08	+/- 0.13	+/- 0.01	+/- 0.05
	Off-Peak 7pm - 9pm	0.14	-0.13	-0.06	0.00	+/- 0.03	+/- 0.04	+/- 0.02	+/- 0.03
	Off-Peak Remainder	-0.05	0.13	0.00	-0.14	+/- 0.05	+/- 0.08	+/- 0.01	+/- 0.05
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.09	-0.08	0.08	-0.02	+/- 0.06	+/- 0.08	+/- 0.01	+/- 0.03
	Mid-Peak	-0.08	-0.02	-0.08	0.07	+/- 0.06	+/- 0.1	+/- 0.01	+/- 0.04
	Off-Peak 7pm - 9pm	0.21	-0.22	-0.01	-0.09	+/- 0.03	+/- 0.04	+/- 0.03	+/- 0.03
	Off-Peak Remainder	-0.01	0.03	-0.01	-0.11	+/- 0.04	+/- 0.06	+/- 0.01	+/- 0.04
Winter (Dec, Jan, Feb)	On-Peak	-0.06	-0.08	0.02	-0.03	+/- 0.03	+/- 0.04	+/- 0.01	+/- 0.01
	Mid-Peak	-0.11	0.03	-0.01	-0.08	+/- 0.06	+/- 0.07	+/- 0.02	+/- 0.03
	Off-Peak 7pm - 9pm	0.06	-0.01	-0.12	-0.07	+/- 0.04	+/- 0.04	+/- 0.02	+/- 0.02
	Off-Peak Remainder	-0.02	-0.03	-0.01	-0.10	+/- 0.03	+/- 0.03	+/- 0.01	+/- 0.02
Winter Shoulder (Nov, Mar, Apr)	On-Peak	0.14	-0.24	0.01	0.10	+/- 0.04	+/- 0.05	+/- 0.01	+/- 0.01
	Mid-Peak	-0.33	0.50	-0.05	-0.11	+/- 0.06	+/- 0.09	+/- 0.01	+/- 0.03
	Off-Peak 7pm - 9pm	0.04	-0.10	0.03	0.04	+/- 0.03	+/- 0.03	+/- 0.02	+/- 0.02
	Off-Peak Remainder	0.05	-0.04	0.01	-0.01	+/- 0.03	+/- 0.03	+/- 0.01	+/- 0.02

Rows shaded in gray are not statistically significant at the 95% level.

Cells in boxes represent own-price elastiticies. The remainder are cross-price elasticities.

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

It is important to note that although the estimated own- and cross-price elasticities indicate that TOU prices have shifted demand this does not necessarily mean that customers have shifted specific end-uses. That is, a demand shift from On-Peak to Off-Peak does not necessarily mean that customers have postponed running a given piece of equipment to the Off-Peak period. It could just as easily mean that customers are conserving in the more expensive periods, and being less careful than they might otherwise have been in the cheaper periods. For example, an estimated shift in demand could be the result of reduced A/C use during the day, but increased lighting consumption in the evening due to customers being less mindful of turning off lights in empty rooms.

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual, as estimated using the elasticities, may be found in Figure 32, below.

Figure 32: Estimated Impacts, Residential Elasticity Estimation

		Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.266	-0.044	-3.3%
	Mid-Peak	-0.286	-0.048	-3.7%
	Off-Peak	0.103	0.009	0.8%
	Off-Peak Weekend	1.022	0.043	3.5%
Summer Shoulder (May, Sept, Oct)	On-Peak	-0.253	-0.042	-4.2%
	Mid-Peak	-0.196	-0.033	-2.9%
	Off-Peak	0.081	0.007	0.7%
	Off-Peak Weekend	0.604	0.025	2.4%
Winter (Dec, Jan, Feb)	On-Peak	-0.167	-0.028	-1.9%
	Mid-Peak	-0.291	-0.049	-2.9%
	Off-Peak	0.071	0.006	0.4%
	Off-Peak Weekend	-0.102	-0.004	-0.3%
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-0.009	-0.002	-0.1%
	Mid-Peak	-0.036	-0.006	-0.5%
	Off-Peak	0.187	0.016	1.4%
	Off-Peak Weekend	-0.050	-0.002	-0.2%

Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A discussion comparing the results above with those estimated using the elasticity analysis is found in section 5, below.

Estimates of the seasonal conservation effect, in kWh and as a percent of consumption, are shown in Figure 33. These estimates are calculated simply by summing the average kW impacts cited above across all the hours of a given season. That is, each hour of the year was assigned an average kW impact, as per the estimates shown in Figure 26. The conservation impact is then estimated simply by summing across the desired hours. The sum across all the summer On-Peak hours, for example deliver an estimated 17 kWh of conservation. Overall, customers reduced annual energy consumption by approximately 0.2% (bottom right cell of Figure 33). The average annual residential consumption is approximately 10,700 kWh.

In this case, the conservation effect was estimated using the TOU periods in 2011.[35] As above, a negative number indicates conservation, and a positive number indicates an increase in consumption.

Figure 33: Seasonal Conservation Estimates, Residential Elasticity-Estimated Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-17	-3.3%	-18	-3.7%	7	0.8%	29	3.5%	0	0.0%
Summer Shoulder	-16	-4.2%	-12	-2.9%	5	0.7%	18	2.4%	-5	-0.2%
Winter	-12	-1.9%	-18	-2.9%	4	0.4%	-3	-0.3%	-29	-0.9%
Winter Shoulder	-1	-0.1%	-2	-0.5%	11	1.4%	-1	-0.2%	7	0.2%
Total	**-46**	**-2.1%**	**-51**	**-2.5%**	**27**	**0.8%**	**43**	**1.3%**	**-27**	**-0.2%**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average residential customer's electricity costs.[36] These are summarized in Figure 36, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure 34: Approximate Impact on Average Residential Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$2	-$2	$0	$2	**-$2**
Summer Shoulder	-$2	-$1	$0	$1	**-$2**
Winter	-$2	-$2	$0	$0	**-$3**
Winter Shoulder	$0	$0	$1	$0	**$0**
Total Across Seasons	**-$6**	**-$5**	**$2**	**$3**	**-$6**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis

35 The exact number of On-Peak, Mid-Peak and Off-Peak hours will vary slightly from year to year. For example, in 2011 and 2010 there were 105 weekend days, whereas in 2006 through 2009 there were only 104.

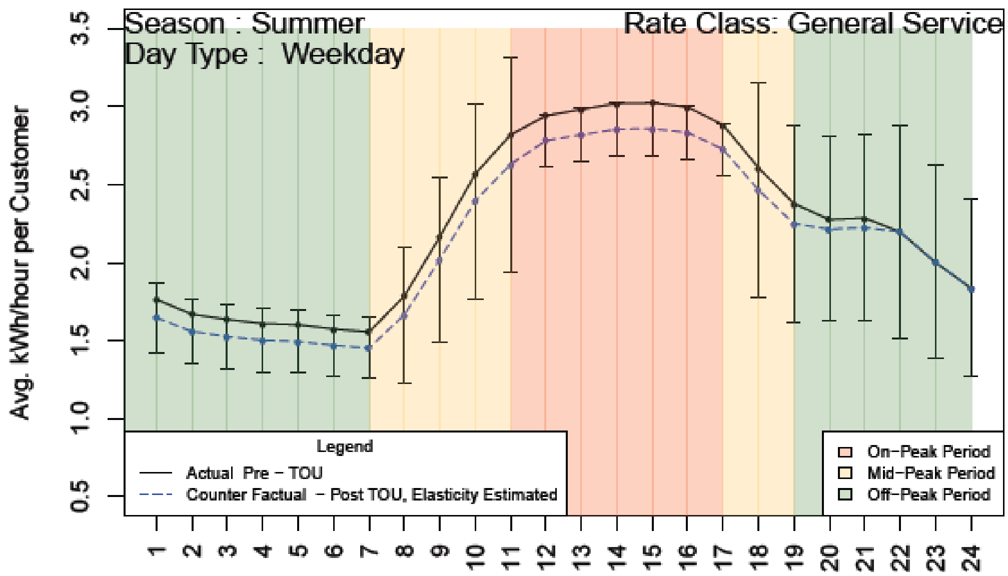
36 These are calculated as the estimated conservation impact by period (kWh) as shown in Figure 33times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

4.2.2 General Service (<50 kW) Customers

As noted above, due to data concerns, Navigant is publishing general service impact estimates only for the summer, the sole season where there exists sufficient diversity in TOU transition dates to allow Navigant to use later adopters as pseudo controls for earlier adopters.

A plot of the actual average load profile of general service customers subject to tiered rates (black line) compared with the elasticity-estimated counterfactual load profile of the same customers, had they been subject to TOU rates in the same period, is presented in Figure 29, below. Note that the error bars in this plot do *not* correspond to the 95% confidence interval around the estimated impact, but rather express the range of estimated impacts based on the 95% confidence intervals estimated for the elasticities. These error bars thus may overstate the width of the confidence interval around the estimated impacts.

Figure 35: Average GS Pre- and Post-TOU Load Profile, Summer Weekday



Note: The x-axis is Eastern Daylight Time (EDT).
Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

Note that the elasticity-estimated counter-factual consumption is consistently below the actual in all except the late evening hours. This suggests one of two possibilities:

1. general service customers respond to TOU rates by investing in technologies that result in a level change in consumption (typically a more long-term elasticity response); or,
2. the elasticity-estimated general service impacts are capturing some effect correlated with changes in electricity prices that is causing a spurious impact estimate.

For general service customers, very few of the estimated elasticities are statistically significant at the 95% level. The statistically significant relationships are of a magnitude that suggests these may be spurious results. All of the elasticities estimated for the summer period for general service customers, and the 95% confidence interval, are presented in Figure 36, below.

Note that the elasticities reported in Figure 36 are a slightly aggregated version of those estimated by Navigant. Navigant obtained elasticities by TOU period by taking averages of the commodity period elasticities, weighted by customers' expenditure share in each commodity period. This aggregation allows the reader to interpret the results more intuitively.

Figure 36: GS < 50 kW Summer Elasticity Estimates – by TOU Period

			Elasticities				95% Conf. Intervals For Elasticities			
			Price Period							
			On-Peak	Mid-Peak	Off-Peak 7pm - 9pm	Off-Peak Remainder	On-Peak	Mid-Peak	Off-Peak 7pm - 9pm	Off-Peak Remainder
Summer (Jun, Jul, Aug)	Commodity Period	On-Peak	-0.20	0.01	-0.21	-0.13	+/- 0.18	+/- 0.28	+/- 0.12	+/- 0.15
		Mid-Peak	0.00	-0.35	0.31	-0.53	+/- 0.29	+/- 0.44	+/- 0.39	+/- 0.39
		Off-Peak 7pm - 9pm	-0.90	1.02	-0.35	-0.34	+/- 0.52	+/- 0.8	+/- 1.33	+/- 1.3
		Off-Peak Remainder	-0.07	-0.19	-0.04	-0.26	+/- 0.15	+/- 0.23	+/- 0.36	+/- 0.3

Rows shaded in gray are not statistically significant at the 95% level.

Cells in boxes represent own-price elasticities. The remainder are cross-price elasticities.

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The estimated average daily impact by TOU period (in kWh), the estimated average hourly kW impact within each period and the estimated average percentage change between the actual and the counterfactual, as estimated using the elasticities, may be found in Figure 37 below.

Figure 37: Estimated Impacts, GS <50 kW Elasticity Estimation

		Avg kWh Impact* (Entire Period)	Avg. kW Impact (Per Hour)	Average % Impact
Summer (Jun, Jul, Aug)	On-Peak	-0.973	-0.162	-5.4%
	Mid-Peak	-0.897	-0.150	-6.3%
	Off-Peak	-0.878	-0.073	-4.0%
	Off-Peak Weekend	-2.908	-0.121	-6.5%

Impact on average energy consumption per customer, per period, per day (On-Peak, Mid-Peak, Off-Peak) or per week (Off-Peak Weekend)

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

A discussion comparing the results above with those estimated using the elasticity analysis is found in section 5, below.

Estimates of the seasonal conservation effect, in kWh and as a percent of consumption, are shown in Figure 33. These estimates are calculated simply by summing the average kW impacts cited above across all the hours of a given season. That is, each hour of the year was assigned an average kW impact, as per the estimates shown in Figure 26. The conservation impact is then estimated simply by summing across the desired hours. The sum across all the summer On-Peak hours, for example deliver an estimated 62 kWh of conservation. The average annual GS consumption is approximately 20,000 kWh.

In this case, the conservation effect was estimated using the TOU periods in 2011.[37] As above, a negative number indicates conservation, and a positive number indicates an increase in consumption..

Figure 38: Seasonal Conservation Estimates, GS<50 Elasticity-Estimated Impact

Season	On-Peak		Mid-Peak		Off-Peak Weekdays		Off-Peak Weekends		Total Seasonal	
	kWh	%	kWh	%	kWh	%	kWh	%	kWh	%
Summer	-62	-5.4%	-58	-6.3%	-56	-4.0%	-81	-6.5%	-257	-5.5%

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

The conservation impacts presented above are only those attributable to the transition from tiered to TOU rates. Navigant has attempted to control for other trends in changing energy consumption through the inclusion of LDC-specific trend variables in its regressions.

Navigant has also estimated the approximate impact that customer behaviour changes due to the introduction of TOU rates may have had on the commodity component of the average GS customer's electricity costs.[38] These are summarized in Figure 41, below. As previous, a positive number indicates an increase in cost and a negative number indicates a cost saving.

Figure 39: Approximate Impact on Average GS Commodity Costs

Season	On-Peak	Mid-Peak	Off-Peak Weekdays	Weekend	Total Within Season
Summer	-$8	-$6	-$4	-$5	**-$23**

Source: OEB-provided hourly consumption data, Environment Canada weather data and Navigant analysis.

4.3 Provincial Impacts

All of the preceding estimated impacts are the average estimated impacts per customer for customers included in the estimation sample. To legitimately extrapolate these results to the provincial level – to estimate what the provincial impact of TOU rates has been – requires the assumption that the customers in the estimation sample are representative of the provincial population of residential and GS<50 customers currently subject to TOU rates.

Of the two rate classes subject to RPP rates (both tiered and TOU), those in the residential estimation sample are certainly more representative of the province than those in the GS estimation sample. As

37 The exact number of On-Peak, Mid-Peak and Off-Peak hours will vary slightly from year to year. For example, in 2011 and 2010 there were 105 weekend days, whereas in 2006 through 2009 there were only 104.

38 These are calculated as the estimated conservation impact by period (kWh) as shown in Figure 38 times the TOU commodity prices in effect from May 1, 2013 through October 31, 2013.

may clearly be seen in in Figure 7 (in chapter 3) the vast majority of GS<50 customers in the estimation sample are drawn from Hydro Ottawa. Thus, to extrapolate the GS impacts out to the provinicial level one must make the assumption that Hydro Ottawa GS customers are representative of all GS customers in the province. This is clearly a very restrictive assumption, and so the extrapolated provincial impacts for this group of customers should be used with some caution, and regarded more as illustrative rather than definitive.

The residential data is considerably more representative of the diversity of the province. As may be seen in Figure 40, below, approximately 22% of the residential customers in the estimation sample are drawn from Hydro One, very close to the 25% of provincial customers. Toronto Hydro is over-represented, with nearly twice the proportion of Toronto Hydro customers in the estimation sample as in the province as a whole. Hydro Ottawa and Newmarket Hydro are even more over-represented.

Figure 40: Distribution of Residential Customers in Ontario and in Sample

	Toronto Hydro-Electric System Limited	Hydro One Networks Inc.	Hydro Ottawa Limited	Newmarket-Tay Power Distribution Ltd.
% of Ontario Customers	14%	25%	6%	1%
% of Estimation Sample	26%	22%	24%	8%

Source: OEB-provided hourly consumption data, OEB 2012 Distributor's Yearbook.

This suggests that while assuming that the residential customers are representative of the provincial population is a much less restrictive assumption than assuming the same thing for GS customers, it is still not a wholly accurate assumption.

That said, the estimation sample used in this study *is* the most representative sample used in a TOU study in Ontario to date. Although extrapolations of provincial TOU period impacts may be improved upon in the future as more smart meter data become available for future studies, it is currently the best available information. Analysts using the results below for planning or other purposes, should still exercise caution when using these results and be sure to understand the limitations of the underlying data's representativeness.

Navigant has extrapolated the individual impacts shown in Figure 22, Figure 26, Figure 32, and Figure 37, to the province by multiplying the kW impacts in each period (and for each approach and rate class) by the most recent available estimate of the number of RPP customers subject to TOU rates in Ontario. As of June, 2013, there were nearly 4.5 million RPP eligible customers subject to TOU rates in Ontario. This is approximately 93% of RPP eligible customers in Ontario.[39] This number includes both GS and residential customers. Navigant has split the 4.5 million TOU

[39] OEB correspondence.

customers by rate class using the proportions found in the 2012 Distributor's yearbook, which indicates that approximately 91% of RPP customers are residential customers.

The provincial impact estimates (in MW) are presented in Figure 41, below. As before, a negative number indicates a reduction in average demand and a positive number indicates an increase in demand.

Figure 41: Estimated TOU Provincial Impact (MW) by TOU period

		Residential		GS<50	
		Conventional Impact Approach	Elasticity Approach	Conventional Impact Approach	Elasticity Approach
Summer (Jun, Jul, Aug)	On-Peak	-179	-179	-14	-64
	Mid-Peak	-118	-196	-18	-60
	Off-Peak	53	37	-4	-29
	Off-Peak Weekend	94	175	-2	-48
Summer Shoulder (May, Sept, Oct)	On-Peak	-90	-171	No robust results available.	
	Mid-Peak	-69	-134		
	Off-Peak	57	29		
	Off-Peak Weekend	61	102		
Winter (Dec, Jan, Feb)	On-Peak	-204	-114	No robust results available.	
	Mid-Peak	-269	-200		
	Off-Peak	-143	24		
	Off-Peak Weekend	-82	-16		
Winter Shoulder (Nov, Mar, Apr)	On-Peak	-94	-8	No robust results available.	
	Mid-Peak	-122	-24		
	Off-Peak	-49	65		
	Off-Peak Weekend	24	-8		

Source: OEB-provided hourly consumption data, OEB 2012 Distributor's Yearbook, OEB Settlement Factor Files, Environment Canada weather data and Navigant analysis.

5 Conclusions, Recommendations and Next Steps

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

1. **Conclusions:** This section presents the most important of Navigant's conclusions from its study of the impact of the introduction of TOU rates on RPP electricity consumption and summarizes the strengths and weakness of the two analytic approaches employed.
2. **Recommendations:** This section presents five recommendations Navigant has for the on-going evaluation of the impact of TOU rates on RPP electricity consumption.
3. **Next Steps:** This section briefly indicates how the results from Part 1 of this study will be used for Part 2 – modeling the impact of alternative TOU structures.

5.1 Conclusions

Navigant's principal conclusion, based on the results of two independent approaches to estimating the impact of TOU rates, using the same data, is that **TOU rates have led to an approximately 3.3% reduction in residential summer On-Peak consumption**. This is a very robust result – it is the same point estimate of the On-Peak impact delivered by the two very different approaches undertaken by Navigant to estimate impacts. This result is also very much in line with the estimated impacts from the three other currently published evaluations of TOU rates in Ontario (see Figure 42 below). Under the assumption that the residential estimation sample used by Navigant is representative of the Ontario residential population, we can conclude that **TOU rates have led to an approximately 179 MW of average demand reduction during the summer On-Peak period.** [40]

The two approaches used by Navigant yield the conclusion that **there is no significant summer conservation impact**. This is in line with a prior TOU evaluation conducted for Newmarket Hydro, but differs from the Hydro One TOU Pilot and the OEB Smart Price Pilot, both of which estimated a statistically and practically significant conservation effect.

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[40] Note that this is an average impact in each summer On-Peak period and not an estimate of the impact on system peak demand.

Figure 42: Other Ontario TOU Impact Estimates

Study	On-Peak Impact, Avg. Summer Day	Conservation Impact, Summer	Date of Study	Link
Current OEB Study	-3.30%	0%	December, 2013	
Newmarket Hydro TOU Evaluation*	-2.80%	0.66% (n/s)	April, 2010	http://www.nmhydro.ca/pdf/NMH_TOU_FINAL.PDF
OEB Smart Price Pilot	-2.4% (n/s)	-6%	May, 2008	http://www.centerpointenergy.com/staticfiles/CNP/Common/SiteAssets/doc/OSPP%20Final%20Report%20-%20Final070726.pdf
Hydro One Networks Time-of-Use Pilot Project	-3.70%	-3.30%	May, 2008	http://www.oeb.gov.on.ca/documents/cases/EB-2004-0205/smartpricepilot/TOU_Pilot_Report_HydroOne_20080513.pdf
OPA Year One TOU Evaluation:			December, 2013	http://powerauthority.on.ca/sites/default/files/conservation/Preliminary-Report-First-Year-Impact-Evaluation-of-Ontario-TOU-Rates.pdf
LDC #2	-2.83%	-0.16%		
LDC #1	-4.26%	-0.01%		
LDC #3	-2.59%	0.00%		
LDC #4	-5.71%	0.00%		

**Newmarket impacts are for the entire year, not just summer.*

Navigant estimated that TOU rates resulted in an increase in summer Off-Peak period consumption of approximately 1.2% or 0.8% (for Off-Peak weekdays) and of approximately 1.9% or 3.5% (for Off-Peak weekends) depending on the approach used. Under the assumption that the residential estimation sample used by Navigant is representative of the Ontario residential population we can conclude that the average demand on summer Off-Peak weekdays has increased by either 53 or 37 MW (depending on the approach used) and that the average demand on summer Off-peak weekends has increased by either 94 or 175 MW (again, depending on the approach used).

Given the challenges associated with the general service customer data, Navigant is unable to draw a robust conclusion about the impact of TOU rates. **Based on the data available and analysed, the impact of the transition from tiered to TOU rates on general service customer consumption is ambiguous.**

Despite having data from multiple LDCs, Navigant has not estimated LDC-specific impacts. This is due to the fact that often within each LDC the transition from tiered to TOU rates was fairly abrupt, meaning that there is often insufficient diversity to allow for using late adopters to control for early adopters. Essentially, individual LDC impact estimates would have suffered from the same problems described for the GS customers (the data set of which was dominated by customers from a single LDC, Hydro Ottawa).

The residential impacts estimated using the conventional impact approach differs slightly from those estimated using the elasticity approach. In the case of general service summer impacts, the difference is substantial.

For example: for residential customers the average difference between the percentage impacts estimated using the conventional impact approach and those estimated using the elasticity approach was only 0.08 percentage points. In contrast, for GS customers, the average difference between the percentage impacts estimated using the conventional impact approach and those estimated using the elasticity approach was 4.6 percentage points.[41]

To understand some of the factors that are driving the different estimates, it is worthwhile revisiting the relative benefits of each approach, first discussed in section 2.

The great advantage that the conventional impact approach has is its granularity; because the sample is split into so many different periods and groups, each getting its own regression (384 in total) we are able to control more precisely for other exogenous effects (such as provincial conservation programs, the increasing efficiency of appliances, etc.) that may be correlated with the TOU effect. Without controlling for these exogenous effects we risk biasing our estimate of the impact of TOU rates. **The conventional impact approach is very good at controlling for non-TOU effects.**

The Rotterdam model approach, however, is much coarser. Instead of 24 equations for each hour for each combination of day type, season and type of customer, there are six weekday equations and one weekend equation for each combination of season and type of customer. The aggregate own-price elasticity (that is a component of the Rotterdam-derived elasticities) is coarser still, using a single equation for each season and rate-class combination. This means there is *much* less precise control for unobservable exogenous effects (such as provincial conservation programs, the increasing efficiency of appliances, etc.) that may be correlated with the TOU price effect. **The elasticity approach is not as good at controlling for non-TOU effects as the conventional impact effect.**

The principal strength of the Rotterdam elasticity approach is that it models the response to TOU rates in a manner that more accurately reflects reality. TOU prices change every six months at the RPP setting, and with those changes come concomitant changes in consumption, however subtle. The elasticity approach allows for the accuracy of the estimates to improve continuously as new information (i.e., new price and consumption combinations) becomes available. This is especially true when there is a reasonable amount of cross-sectional price variation within the sample as a result of differing non-commodity costs across LDCs. **The elasticity approach improves the accuracy of its estimates as, time-wise, more data becomes available and as cross-sectional price variation increases.** It should be noted that since the general service data is so heavily dominated by Hydro Ottawa customers, there is very little cross-sectional variation in price (all customers are subject to the same non-commodity costs).

The weakness of the conventional impact approach is that it models TOU rates not as an on-going dynamic system to which customers respond, but a one-time change in state, or regime. Ignoring the effects of weather, this model's estimate implicitly assumes that TOU rates have a single level effect for each hour/season/day type/customer type combination. As more data accrues, the model will adjust its estimate of the average – one-time – effect, but this will not substantially improve the accuracy of the estimate of the effect of TOU at any individual point in time. **The conventional**

[41] These figures calculated based on the percentage impacts shown in Figure 22, Figure 26, Figure 32 and Figure 37.

impact approach will improve the accuracy of its estimate only of the average impact, not of the relationship, as more time-wise data accrues.

The points above should be borne in mind when examining and comparing the results above. There is no clear way to weigh the pros and cons of one model against the other and categorically state that one provides more accurate estimates than the other.

5.2 Recommendations

Based on Navigant's findings in its study of the historical impact of TOU rates the evaluation team has the following five recommendations if the board wishes to pursue an on-going evaluation of the impact of TOU rates.

1. **Continue to collect residential smart meter data.** The OEB should continue to collect smart meter data from Ontario LDCs. If possible it should expand the group of "core" LDCs to include as many Ontario LDCs as possible.
2. **Collect more customers' data from each LDC.** Currently, the OEB collects the data from approximately 200 randomly chosen customers within each LDC. This number should be increased considerably for some LDCs so that it is possible to develop a sample that is more representative of the population of Ontario RPP customers.
3. **Collect more GS customers' data from different LDCs.** Navigant's attempts to estimate non-summer TOU impacts for GS customers were confounded by the lack of diversity in TOU transitions. More data should be collected from other LDCs to ensure a greater transition diversity.
4. **On-going impact evaluation will need to rely on elasticity estimation.** The conventional impact approach can only provide an estimate of the average impact of the transition of customers transferring from tiered to TOU rates. To obtain incremental, year-by-year impacts, will require relying entirely on an elasticity approach. As more and more price changes are observed (i.e., when rates are set every May 1 and November 1), this approach should increase in accuracy.
5. **Undertake an on-going survey of customer behaviours and attitudes.** Econometric estimation is a valuable tool, but the interpretation of the results it provides can be immeasurably improved when analysts also have access to qualitative survey data regarding exactly how well participants understand prices and TOU periods, and what (if any) strategies they undertake to respond to them. Navigant would recommend a semi-annual survey of customers to allow the OEB to monitor and track the on-going evolution of customer attitudes in Ontario.

5.3 Next Steps

Part 2 of this study – an analysis of a number of alternative TOU scenarios chosen by OEB staff – appears in a separate report. The principal purpose of Part 1 of this study (this report) was to deliver estimates of customer price-responsiveness (i.e., elasticities) that drive Part 2. Part 2 of this study is expected to be published in early 2014.

Appendix A – Plotted Impact Estimates

This appendix contains plots showing the actual and counterfactual average hourly consumption by approach used (conventional impact vs. elasticity analysis), rate class, season and day type.

Each plot shows the three TOU periods as colours: red for On-Peak, orange for Mid-Peak and green for Off-Peak. The TOU periods shown are those applicable as of May 1, 2011. Note that the horizontal time scale varies depending on the season.

This appendix is divided into the following sections:

1. Residential Plots (all seasons)
    a. Conventional Impact Analysis Plots
    b. Elasticity Analysis Plots
2. General Service Plots (summer only)
    a. Conventional Impact Analysis Plots
    b. Elasticity Analysis Plots

In each case, the actuals presented are the average across the relevant class of customers in the relevant time period, drawn from those customers *not subject to TOU rates*.

The counter-factual is calculated by applying the estimated change in behaviour due to TOU rates to the pre-TOU actuals. This delivers an estimate of what consumption might have been, had those customers been subject to TOU instead of tiered rates.

Specifically, the counterfactual for the conventional impact analysis approach is calculated in the following way for each season (summer, summer shoulder, winter, winter shoulder) and day type (weekday and weekends):

$$\widehat{\overline{y_s^{CF}}} = \overline{y_s^A} + \widehat{\gamma_{1,s}} + \widehat{\gamma_{2,s}}\left(\overline{Cooling\_THI_s}\right) + \widehat{\gamma_{3,s}}\left(\overline{Heating\_THI_s}\right)$$

Where:

$\widehat{\overline{y_s^{CF}}}$	=	Estimated average counterfactual electricity consumption (kWh, during hour of the day s (i.e., 1 through 24
$\overline{y_s^A}$	=	Actual average electricity consumption (kWh), during hour of the day s (i.e., 1 through 24
$\widehat{\gamma_{1,s}}, \widehat{\gamma_{2,s}}, \widehat{\gamma_{3,s}}$	=	Estimates of the variables $\gamma_{1,s}, \gamma_{2,s}, \gamma_{3,s}$ as defined above.
$\overline{Cooling\_THI_s}$	=	Average cooling THI during hour of the day s.

$\overline{Cooling\_THI_s}$ = Average heating THI during hour of the day s.

These are then averaged in the appropriate way for the plots below.

The counterfactual for the elasticity-based impacts is calculated in the following manner:

$$\widehat{\overline{y_s^{CF}}} = exp\left[ln\left(\overline{y_s^A}\right) + \sum_{r=1}^{R=4} \varepsilon_{k,r}^{Magg} \cdot \left(ln\left(\overline{mp_r^{TOU}}\right) - ln\left(\overline{mp_r^{tier}}\right)\right)\right]$$

Where:

$\widehat{\overline{y_s^{CF}}}$ = Estimated average counterfactual electricity consumption (kWh, during hour of the day s (i.e., 1 through 24).

$\overline{y_s^A}$ = Actual average electricity consumption (kWh), during hour of the day s (i.e., 1 through 24).

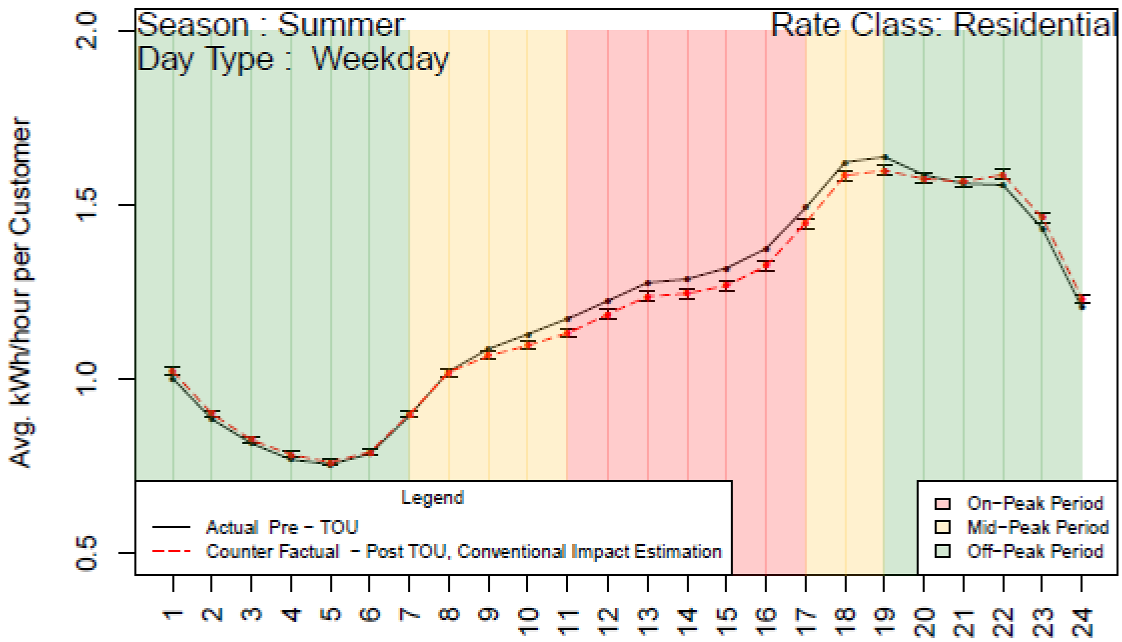
$\varepsilon_{k,r}^{Magg}$ = The marshallian elasticity for commodity period k and price period r. The commodity period k is determined by the hour of the day s, the season and whether or not the day is a weekend. For example, when s = 13, the season is summer and the day type is a weekday, k would be the "Middle" or On-Peak commodity period.

$\overline{mp_r^{TOU}}$ = The average marginal price in price period r faced by customers subject to TOU rates.

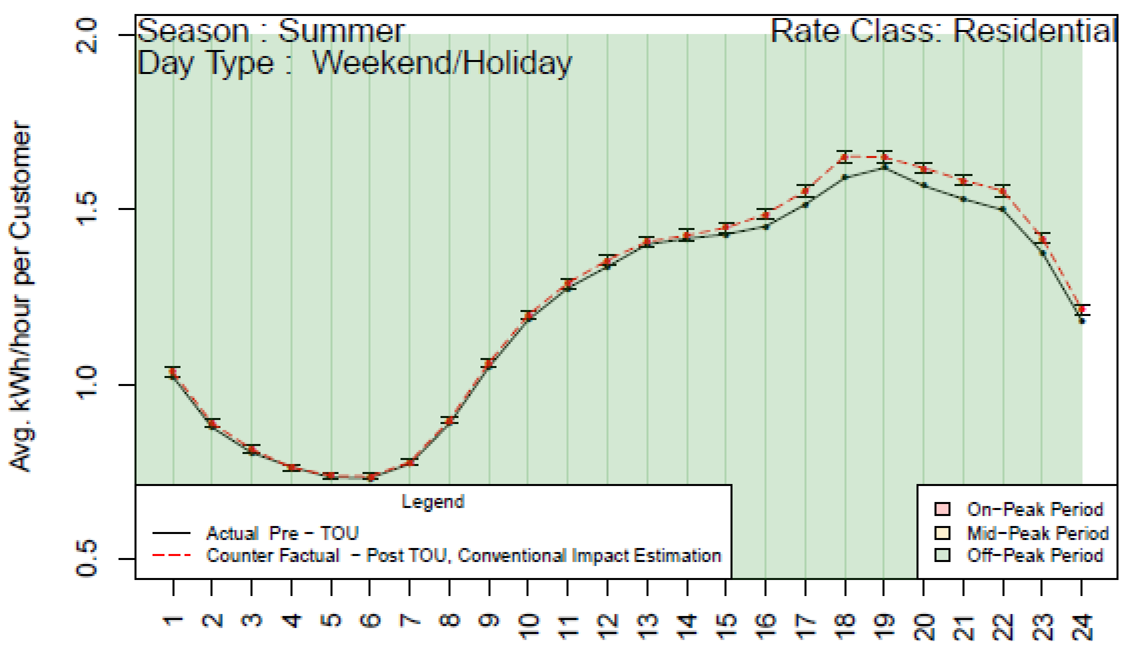
$\overline{mp_r^{TOU}}$ = The average marginal price in price period r faced by customers subject to tiered rates.

1. Residential Plots

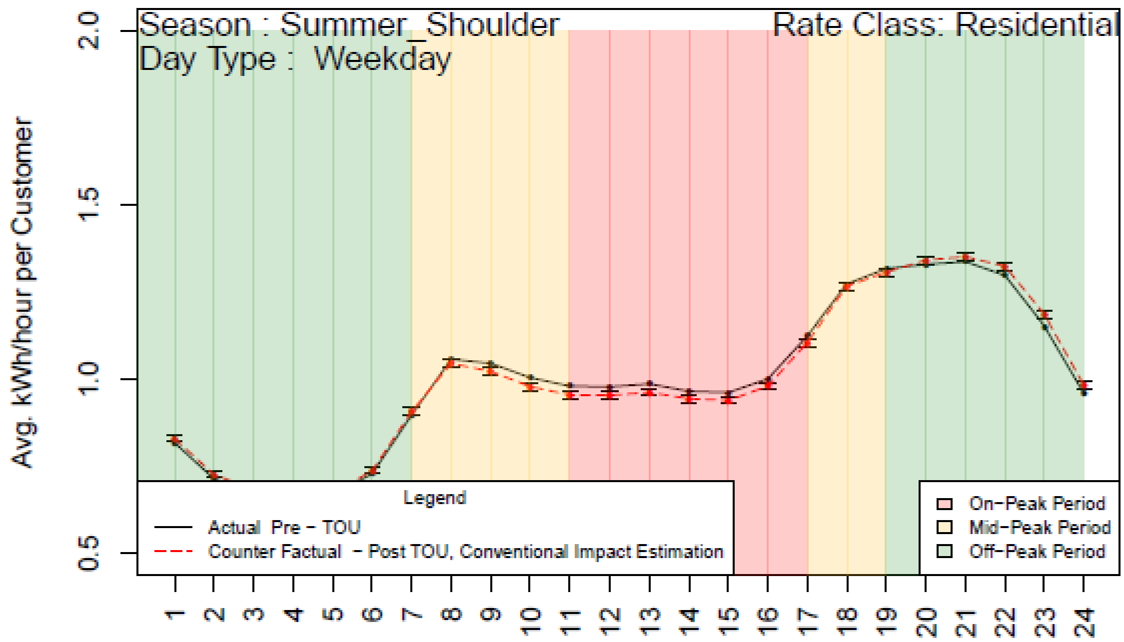
1.a. Conventional Impact Analysis Plots



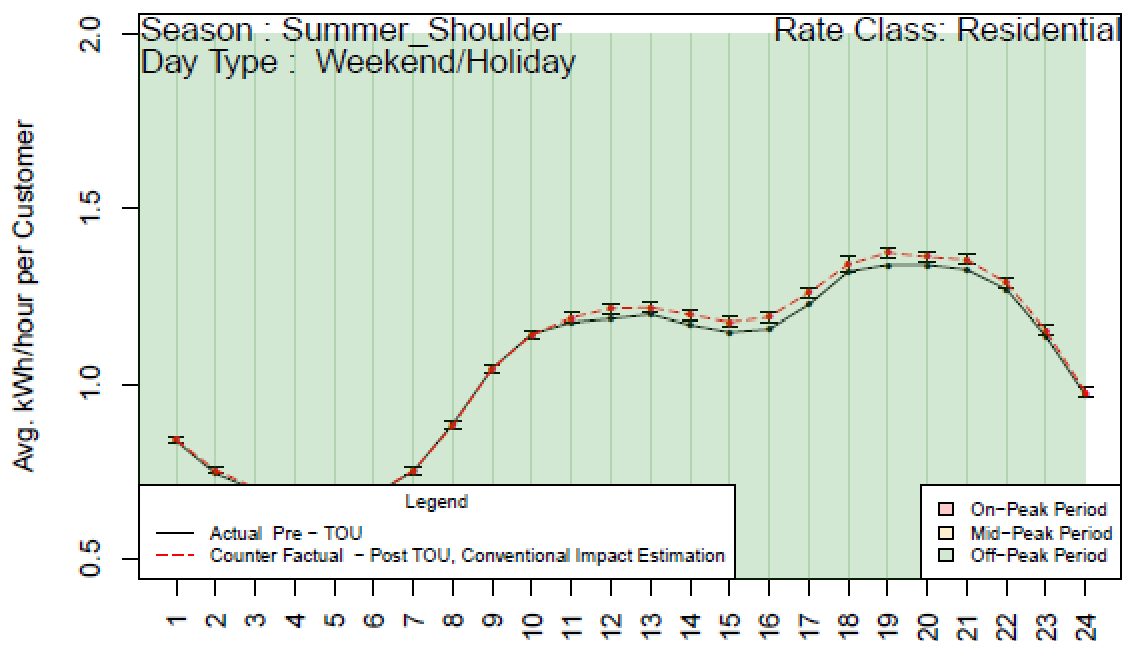
Note: The x-axis is Eastern Daylight Time (EDT).



Note: The x-axis is Eastern Daylight Time (EDT).



Note: The x-axis is Eastern Daylight Time (EDT).



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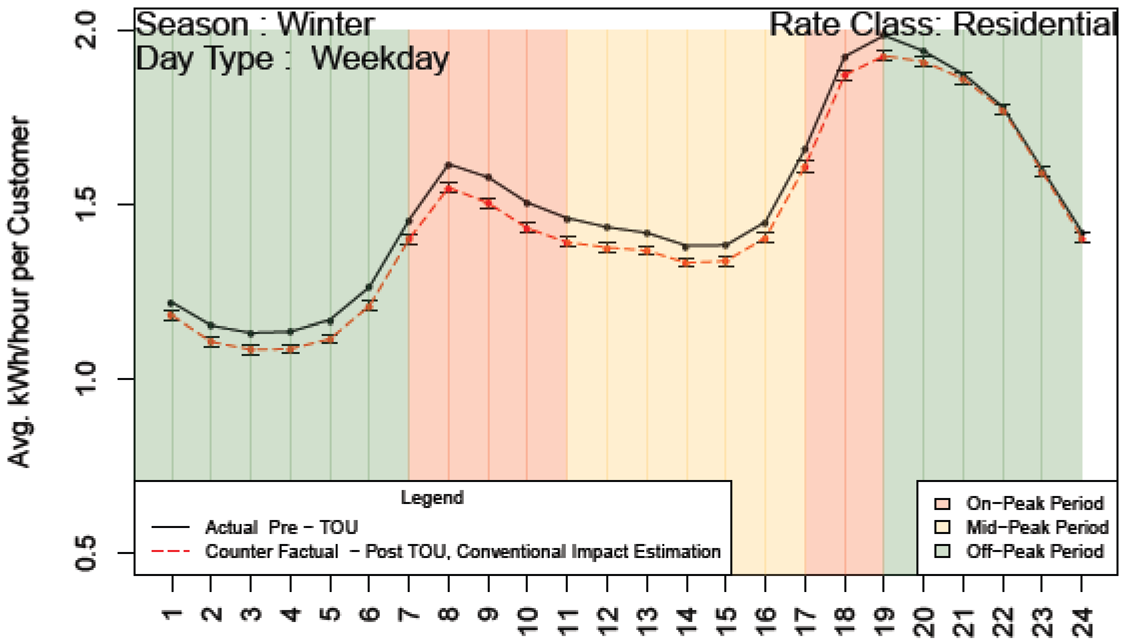

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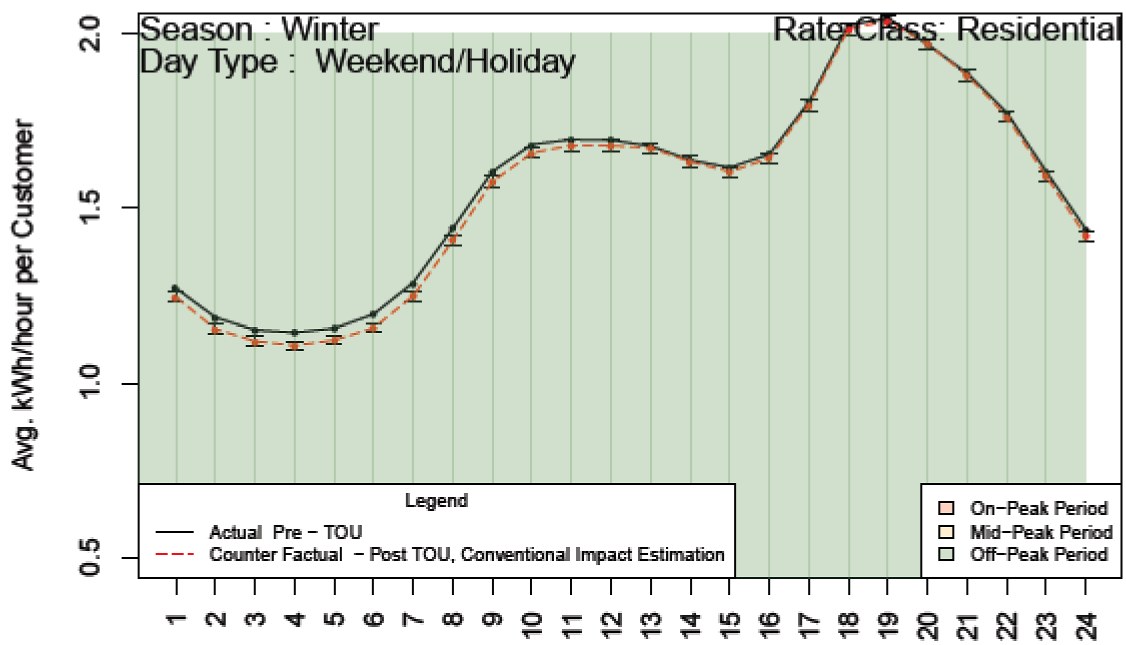
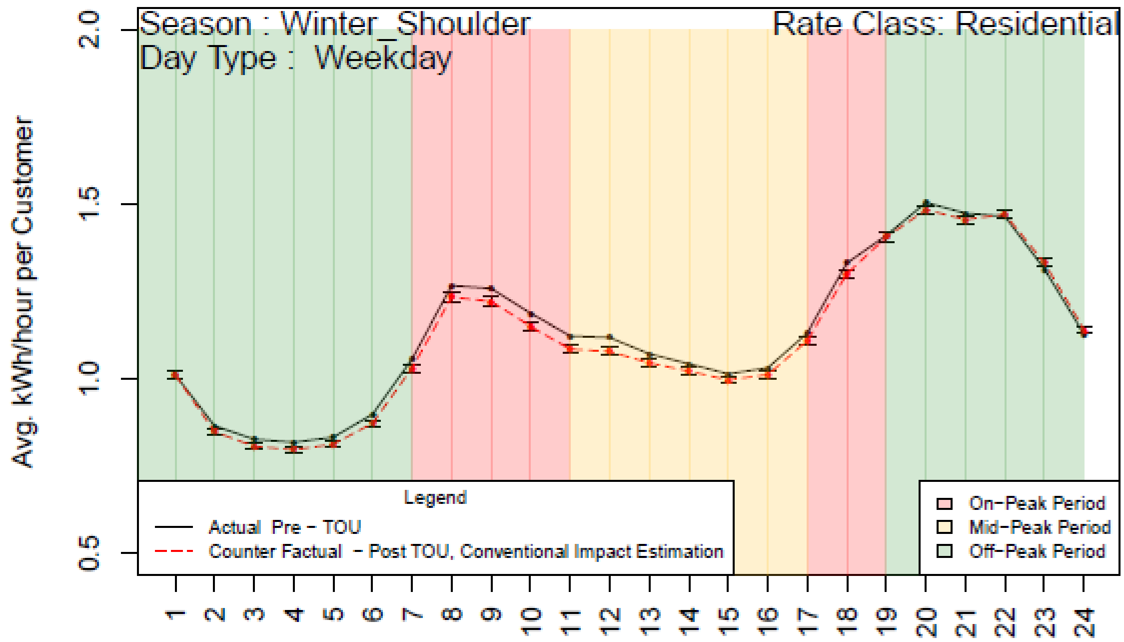


Note: The x-axis is Eastern Standard Time (EST).



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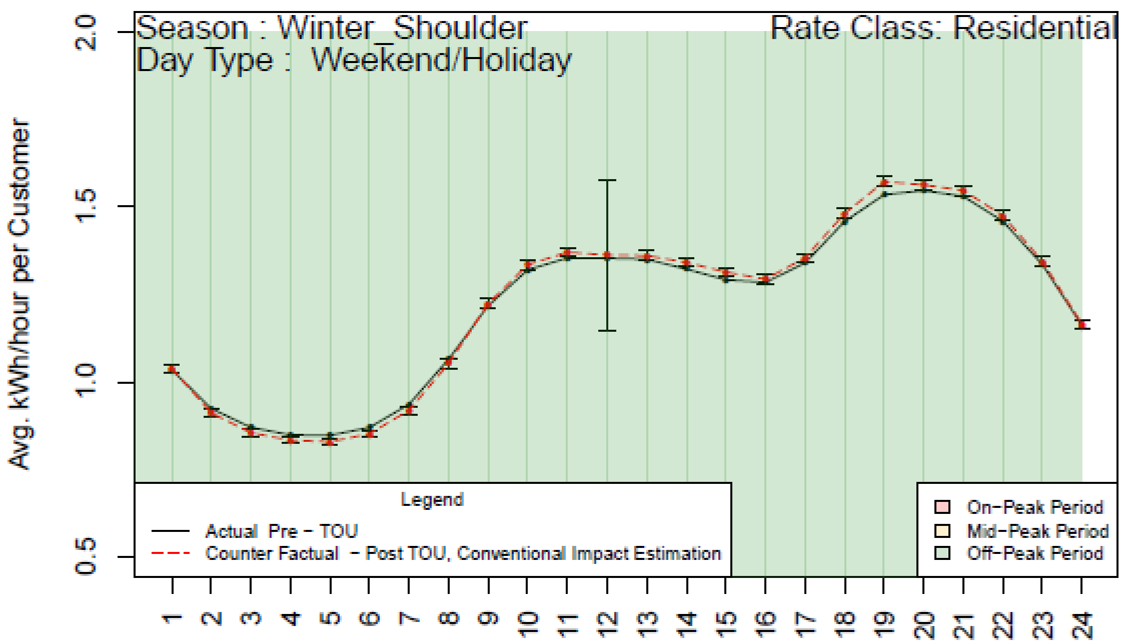
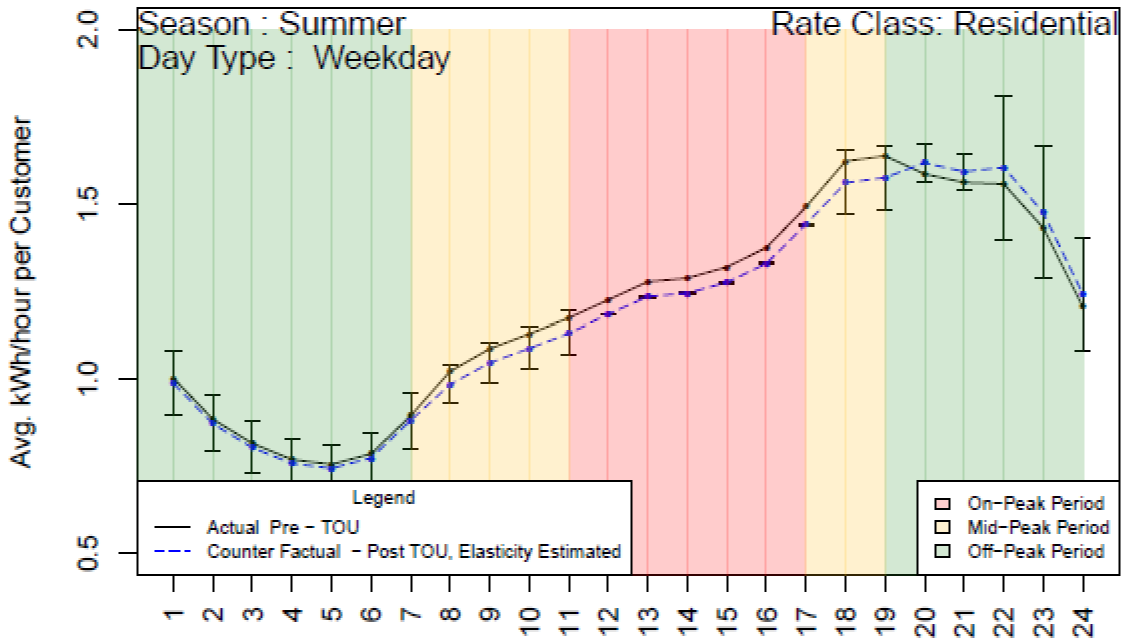


Note: The x-axis is Eastern Standard Time (EST).

1.b. Elasticity Analysis Plots



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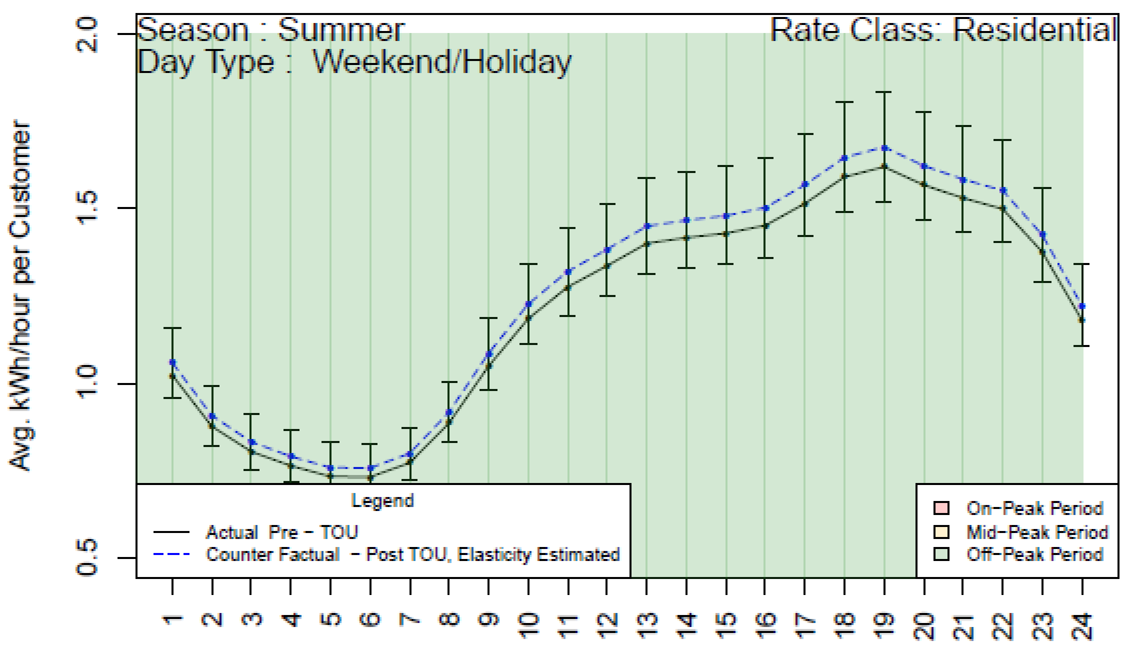

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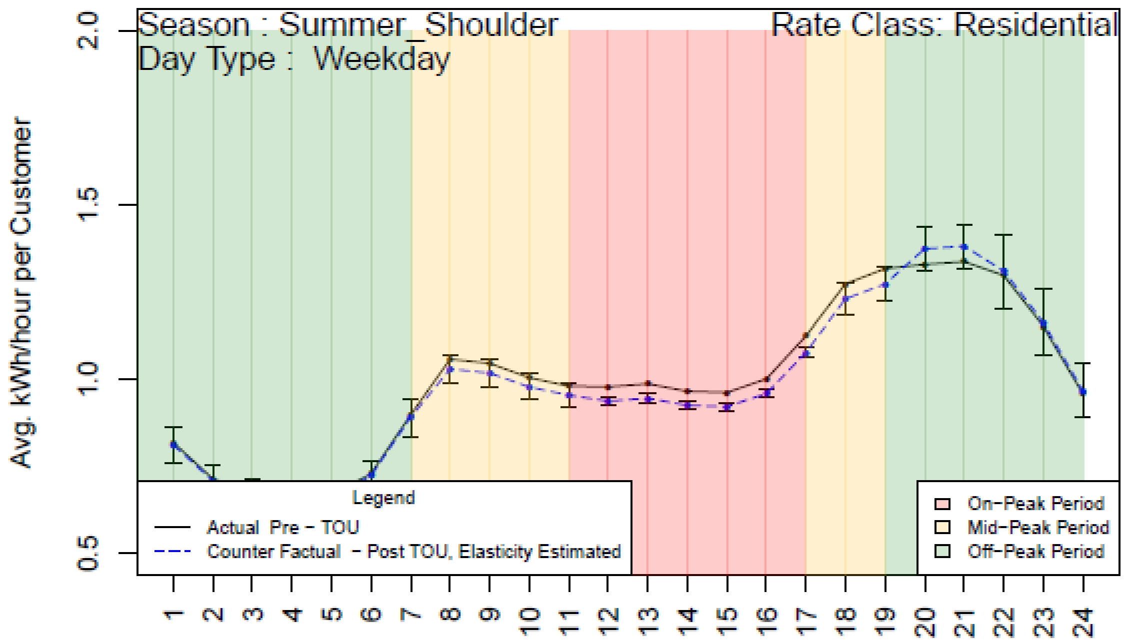
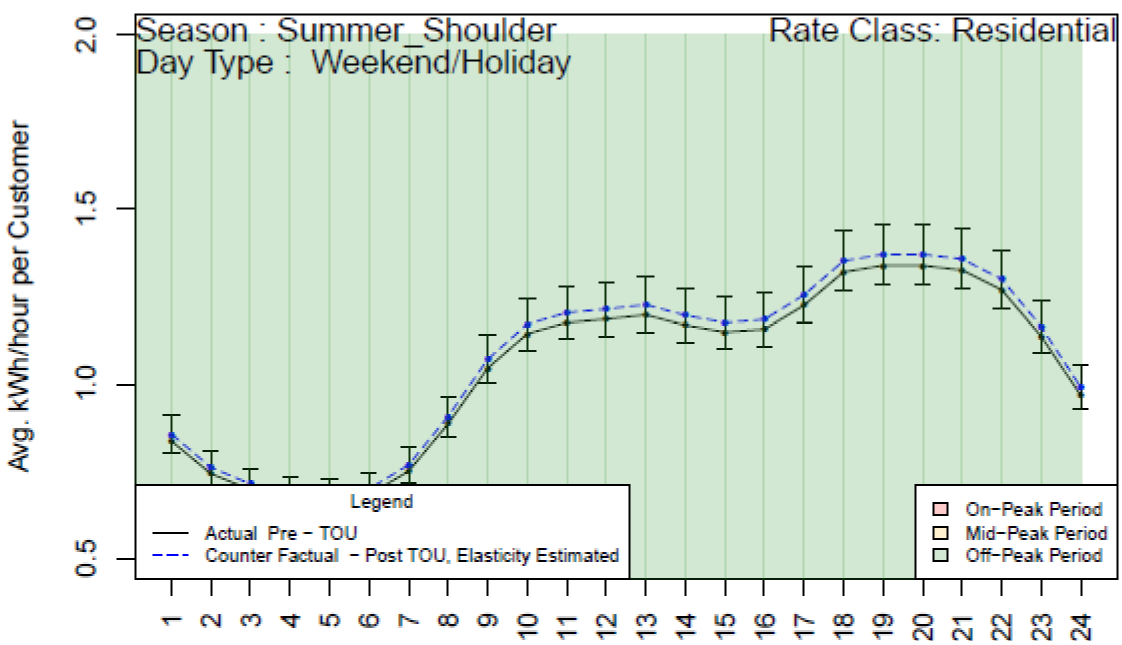


Note: The x-axis is Eastern Daylight Time (EDT).



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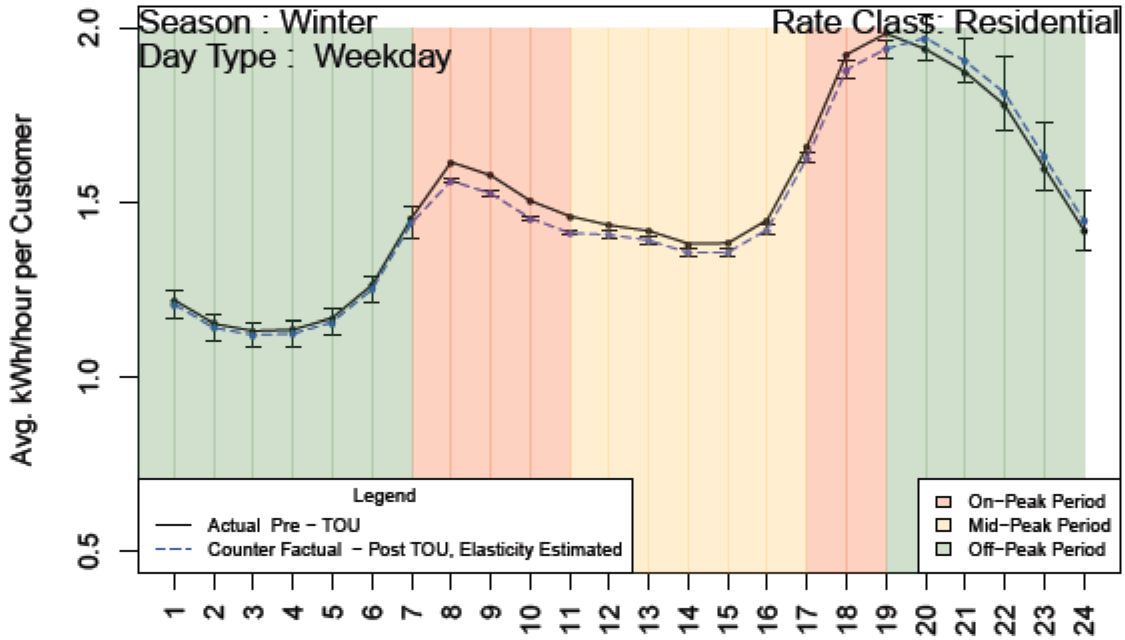

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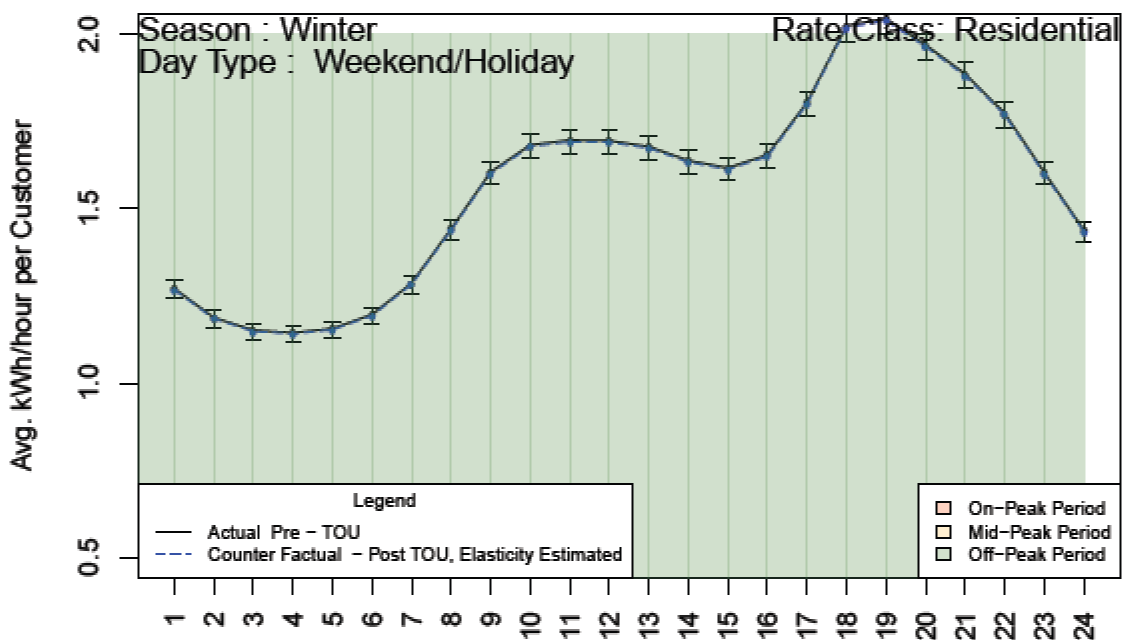

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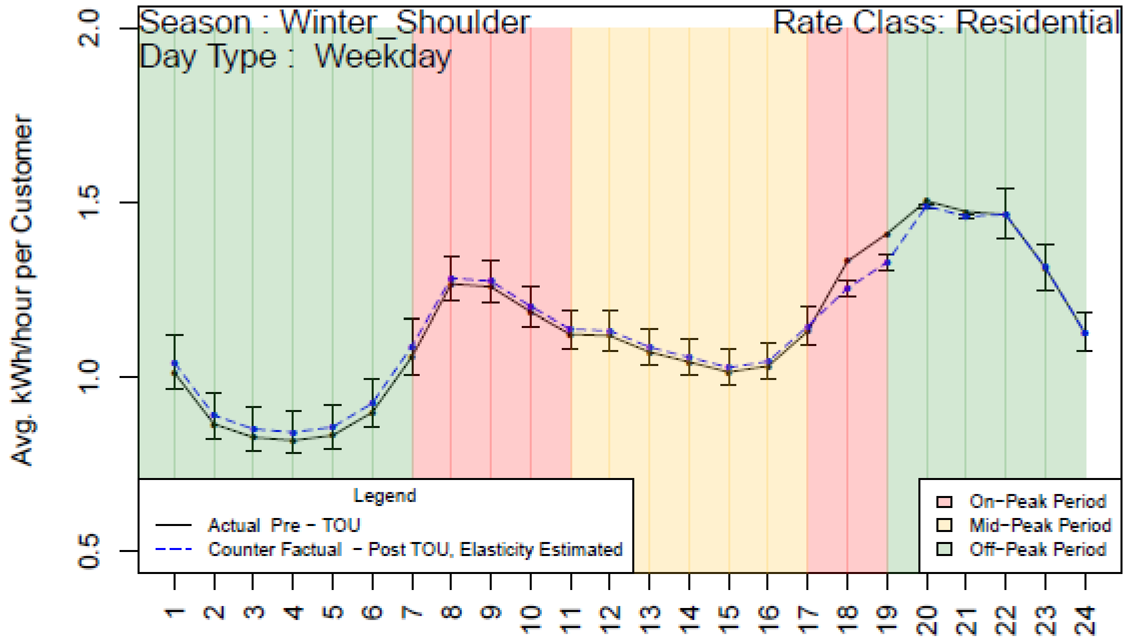

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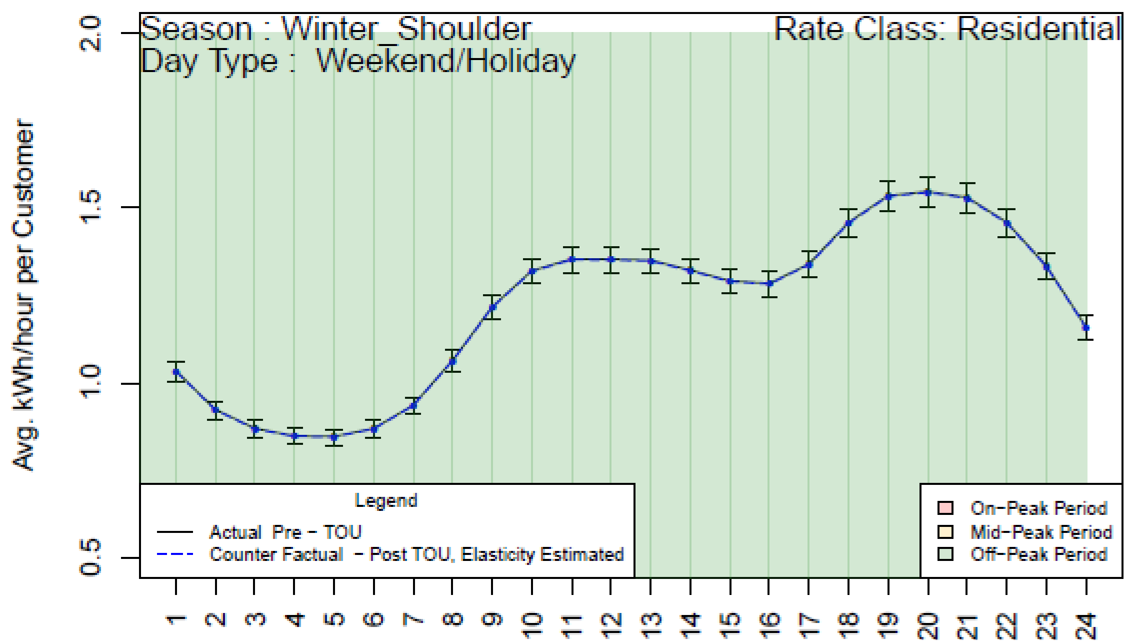

Note: The x-axis is Eastern Standard Time (EST).

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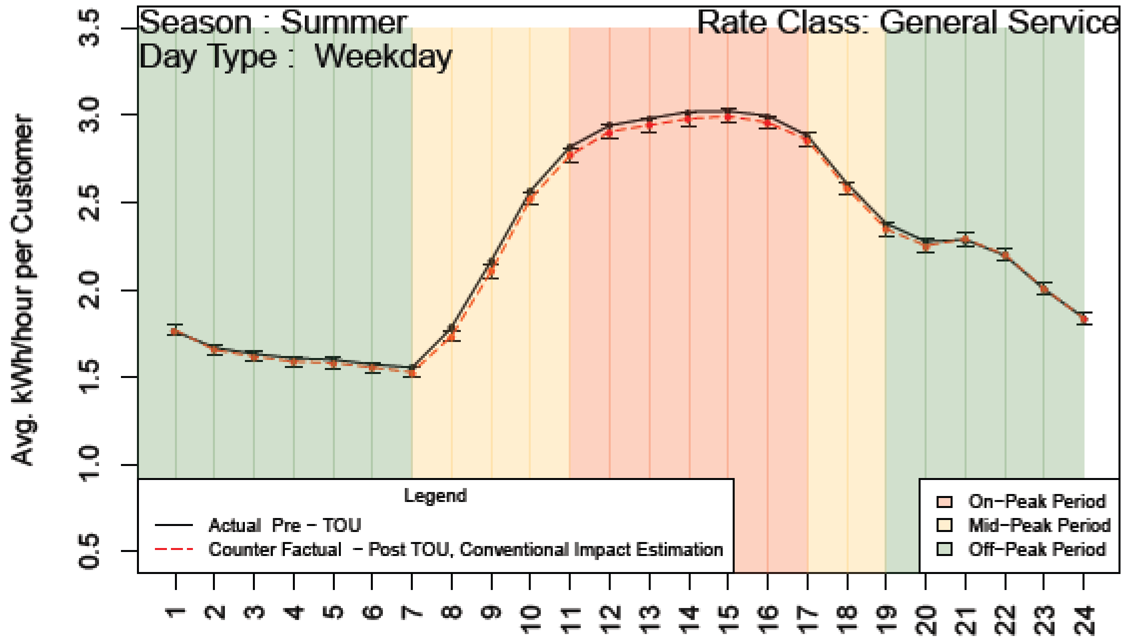
2. General Service Plots

2.a. Conventional Impact Analysis Plots



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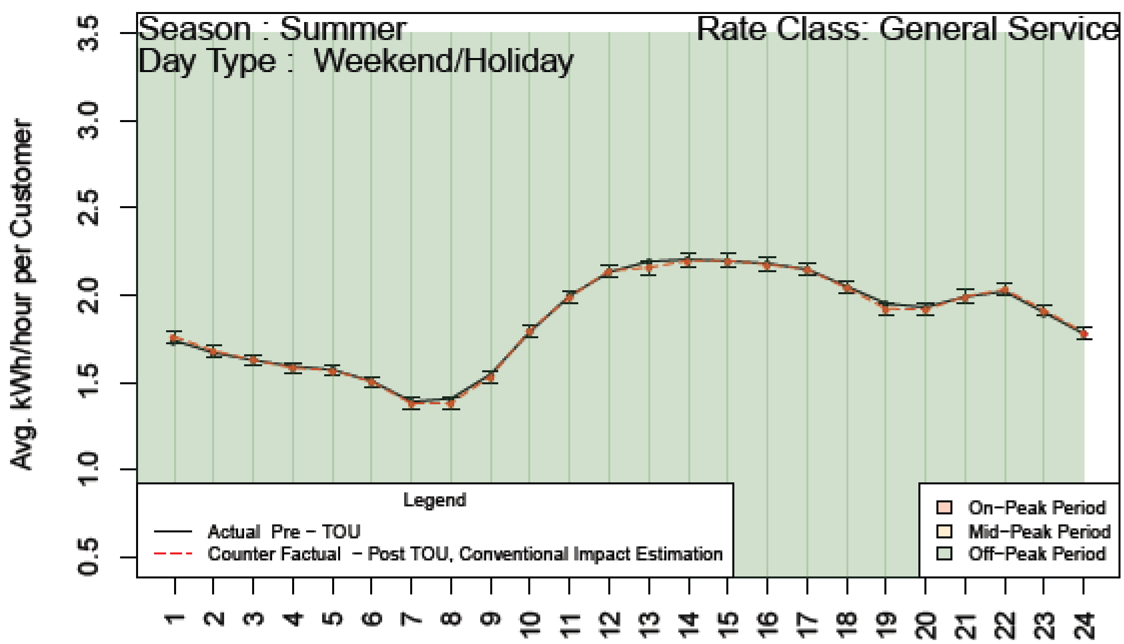

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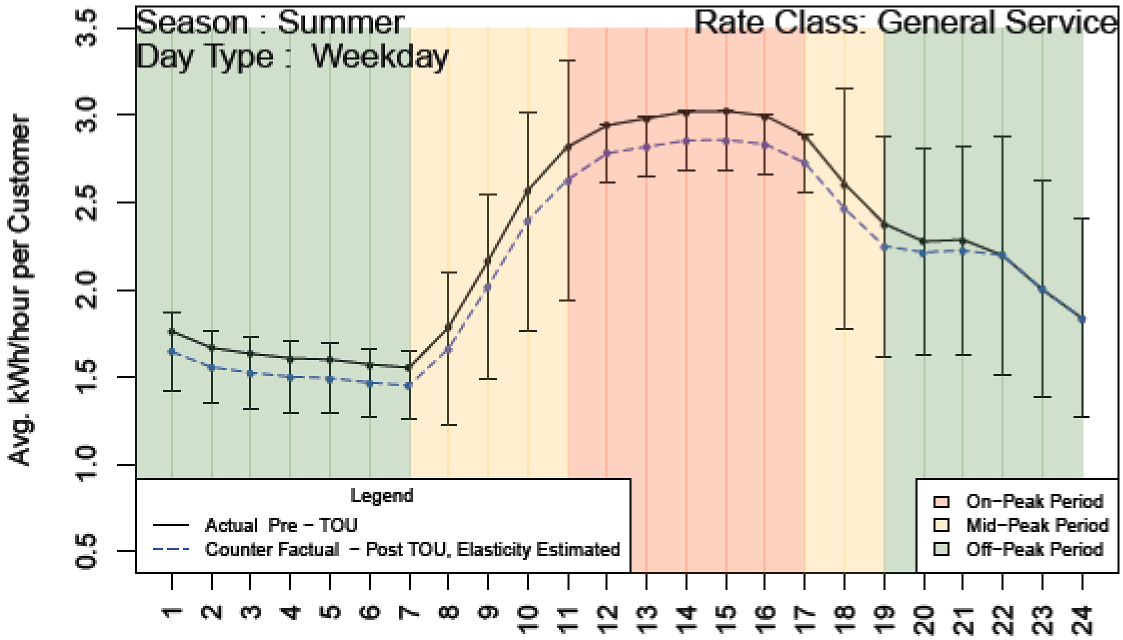
2.b. Elasticity Analysis Plots



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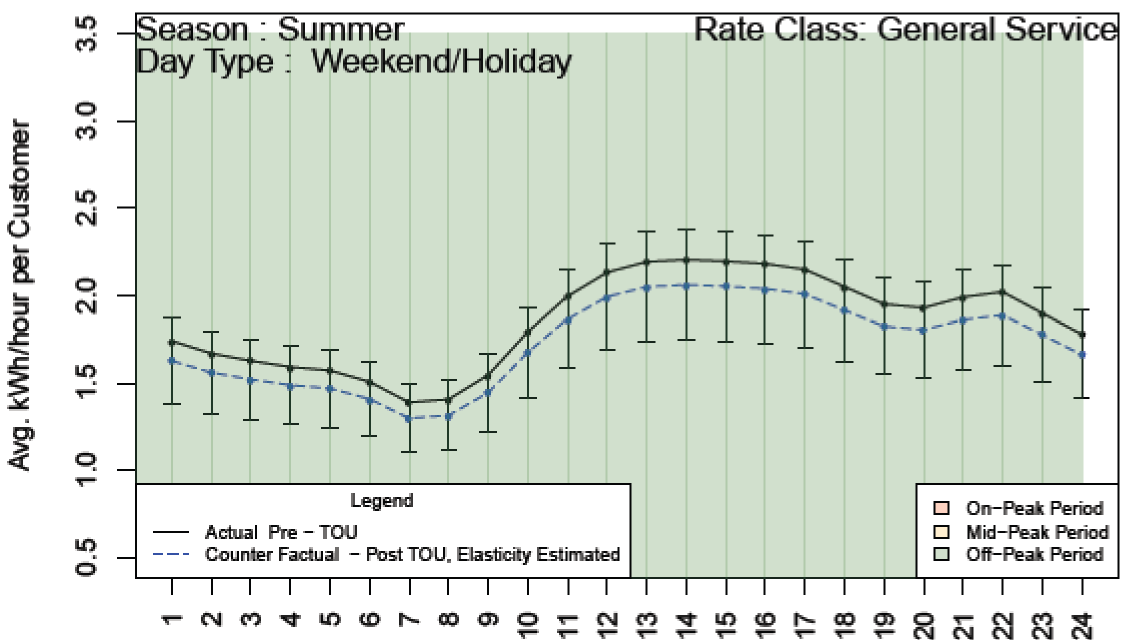


Note: The x-axis is Eastern Daylight Time (EDT).

Appendix B – Actual and Fitted Values

This appendix provides plots of the actual and fitted (or in-sample predicted) values from the conventional impact analysis and the Rotterdam model.

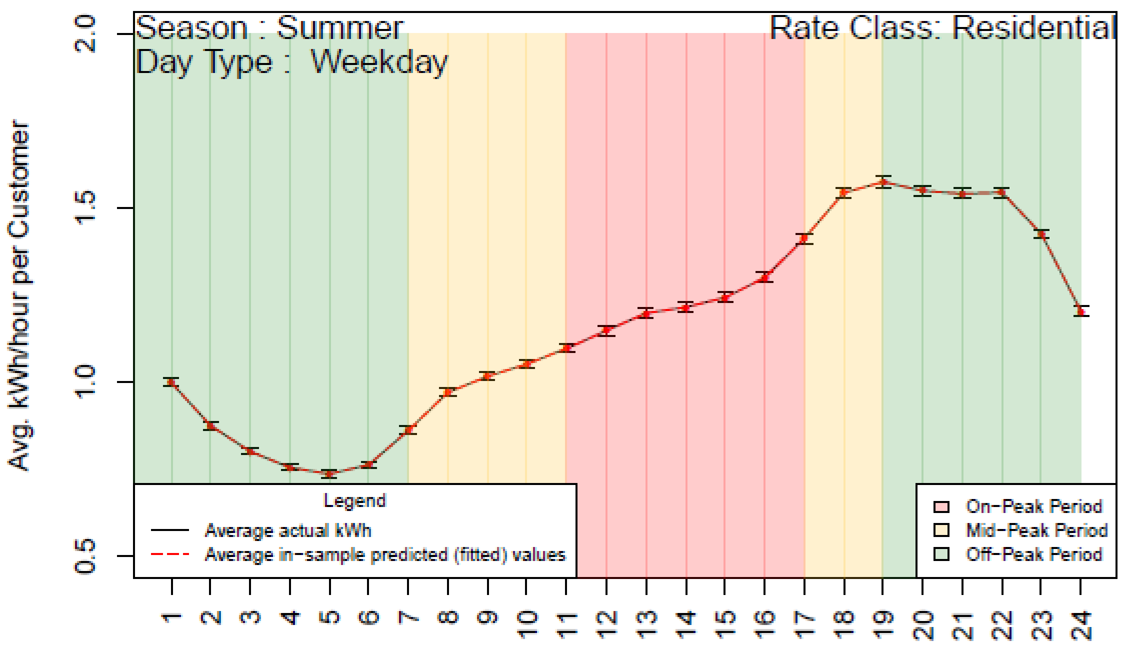
The actual and fitted values shown for the Rotterdam model dependent variables are those defined in Equation 2, above.

These plots are included as evidence of the accuracy of the models used in predicting average hourly electricity consumption (in the case of the conventional impact analysis) and the average value of the Rotterdam dependent variables.

These plots clearly demonstrate that the models used in both the conventional and the elasticity analysis are providing a very accurate in-sample prediction of customer behaviour.

Conventional Impact Analysis Actual and Fitted Values

Residential Plots



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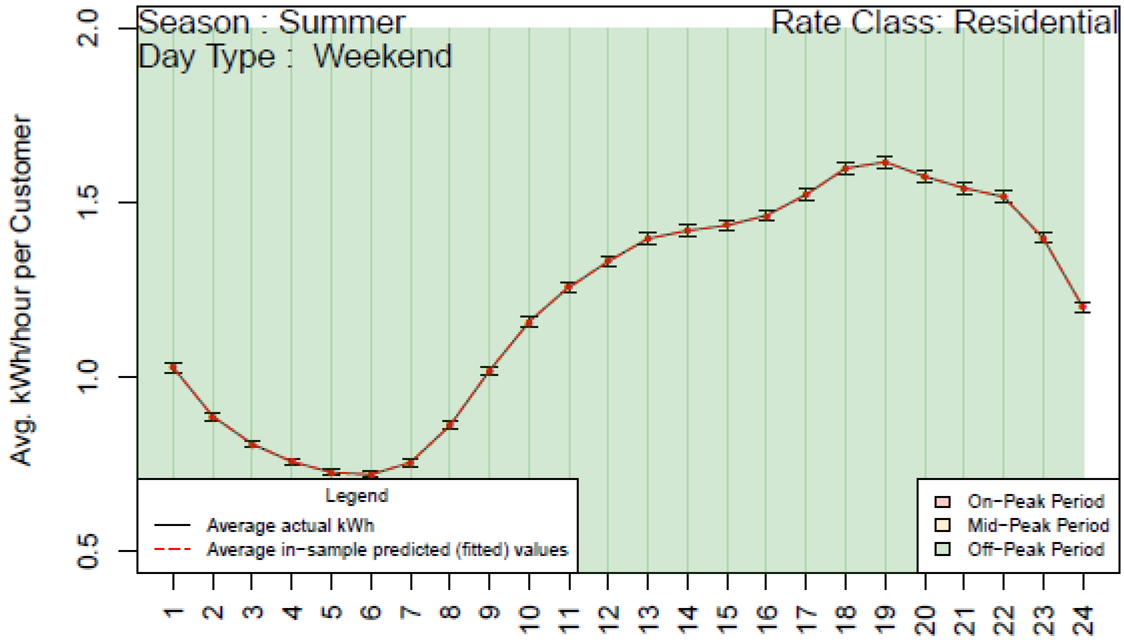

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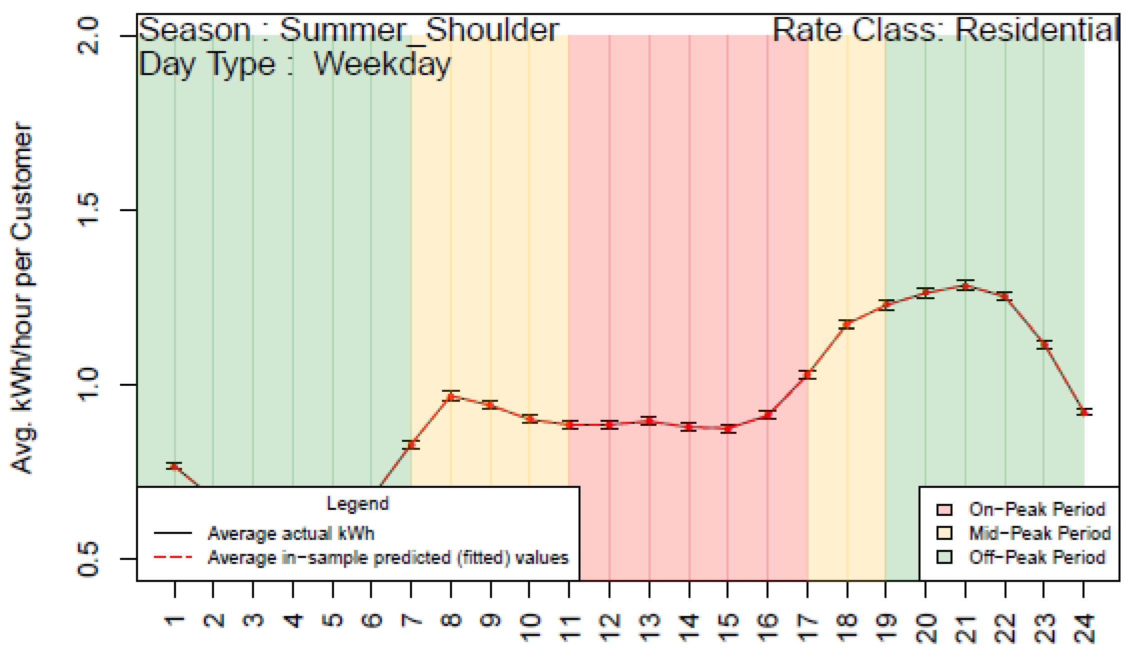

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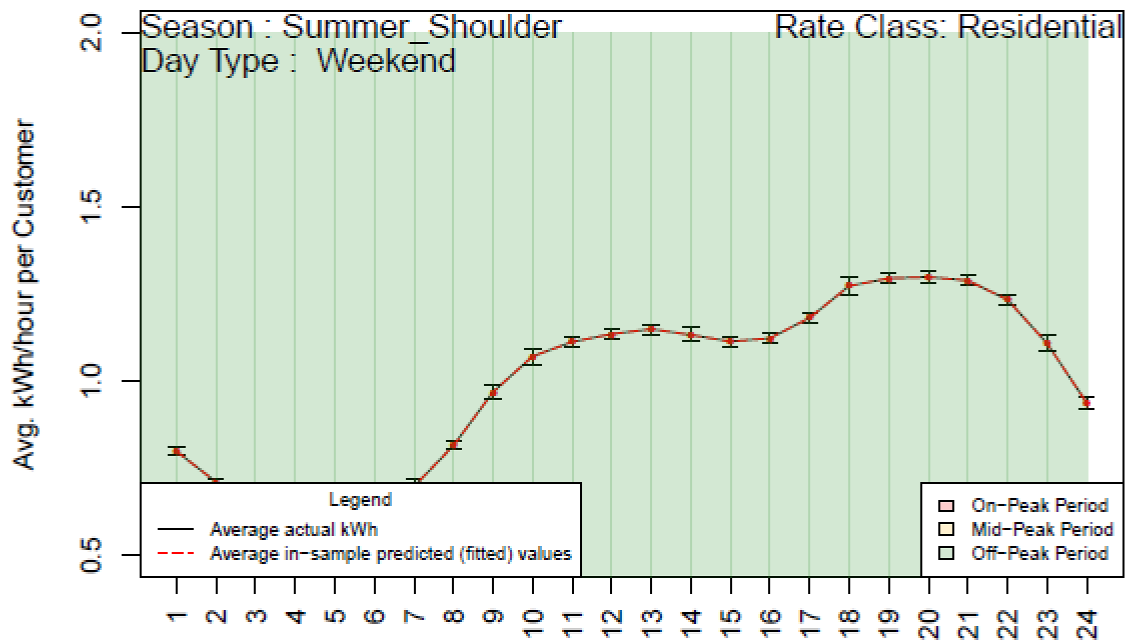
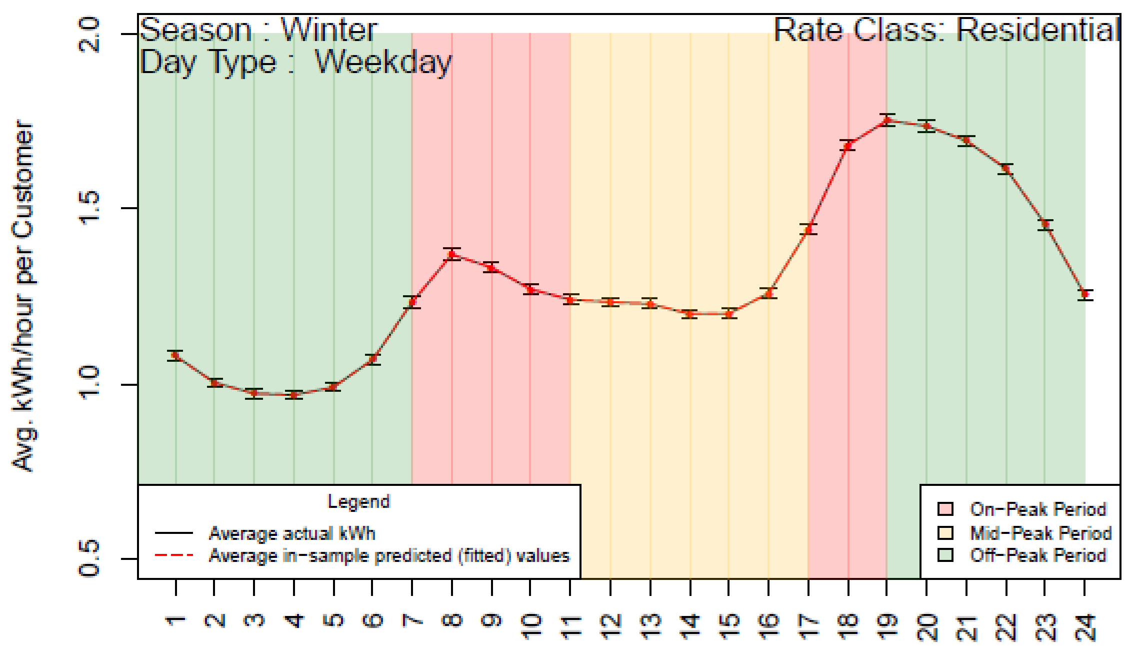


Note: The x-axis is Eastern Daylight Time (EDT).



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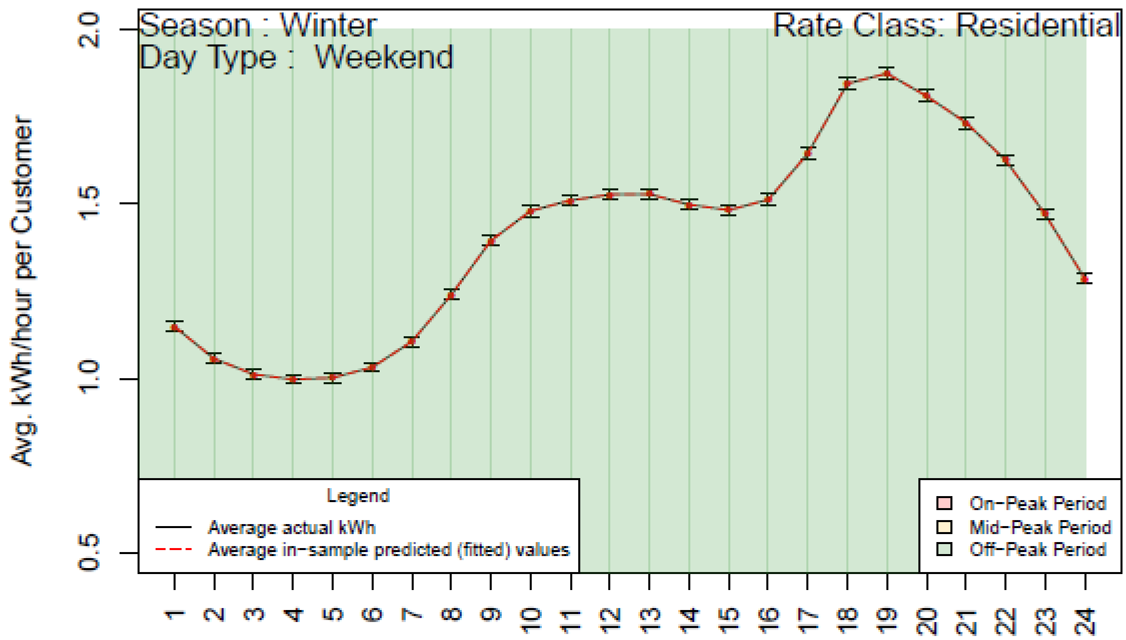

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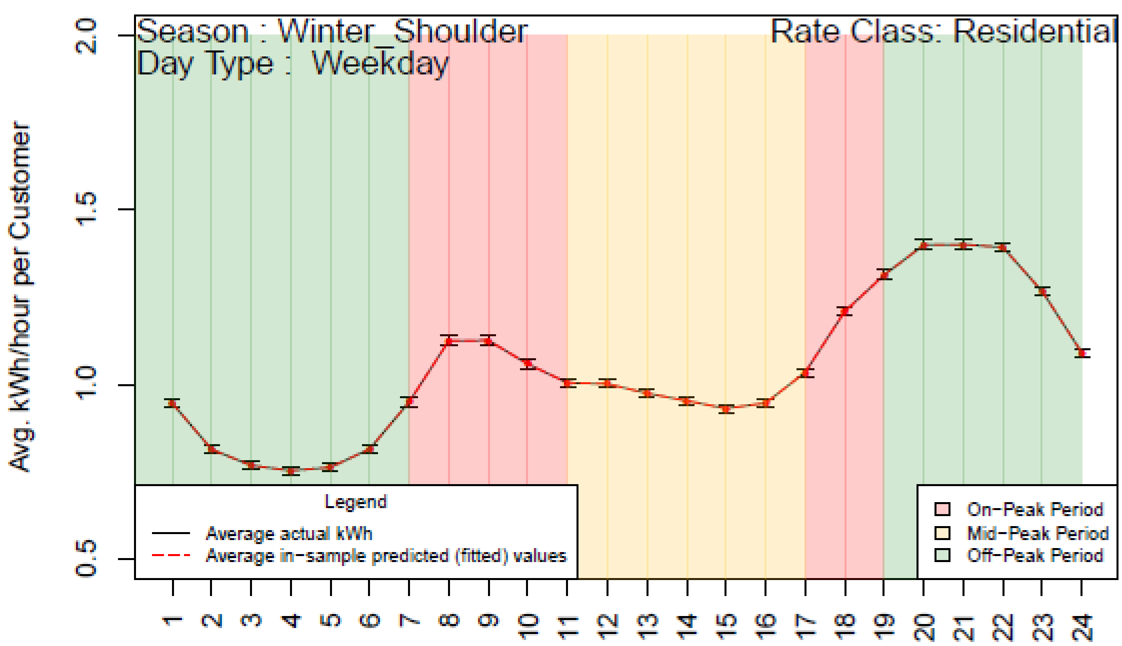

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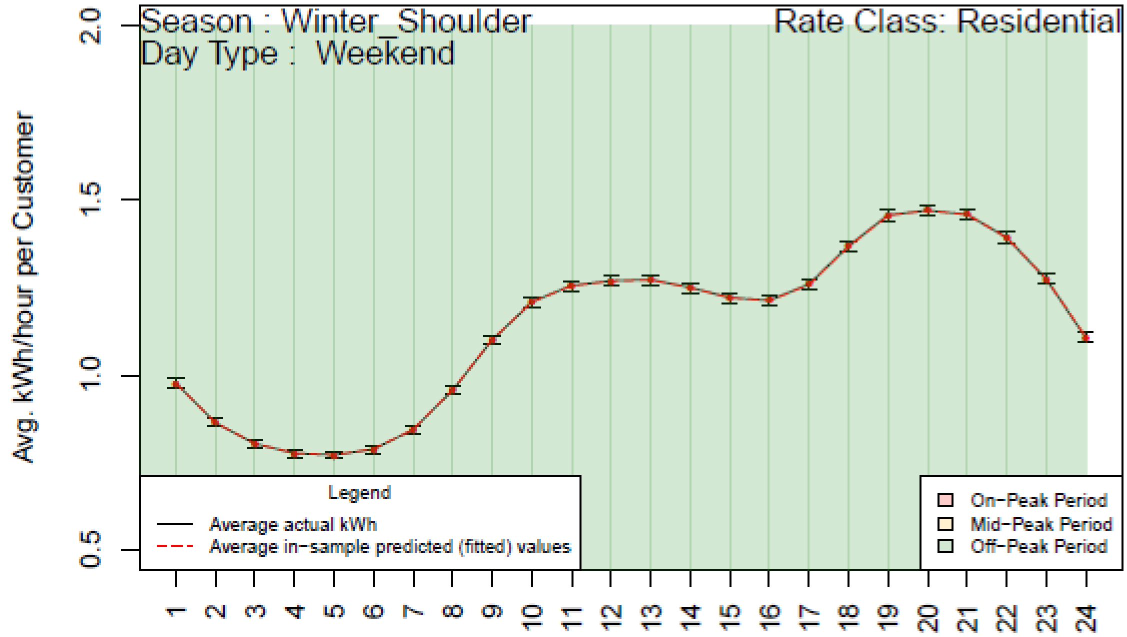
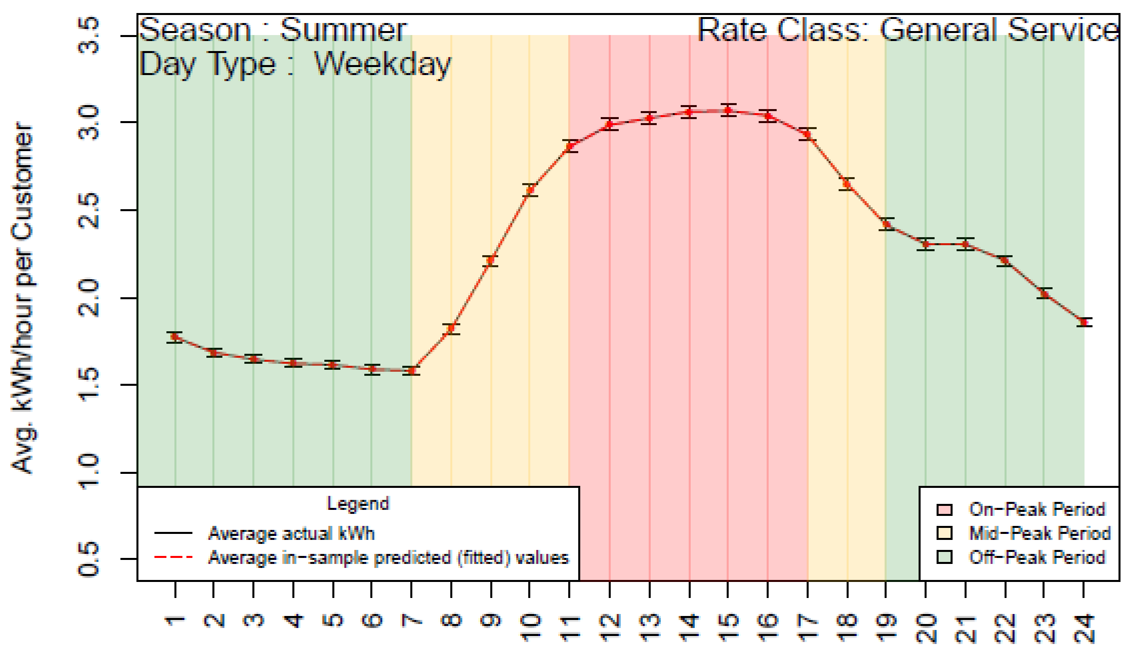


Note: The x-axis is Eastern Daylight Time (EDT).

General Service Plots



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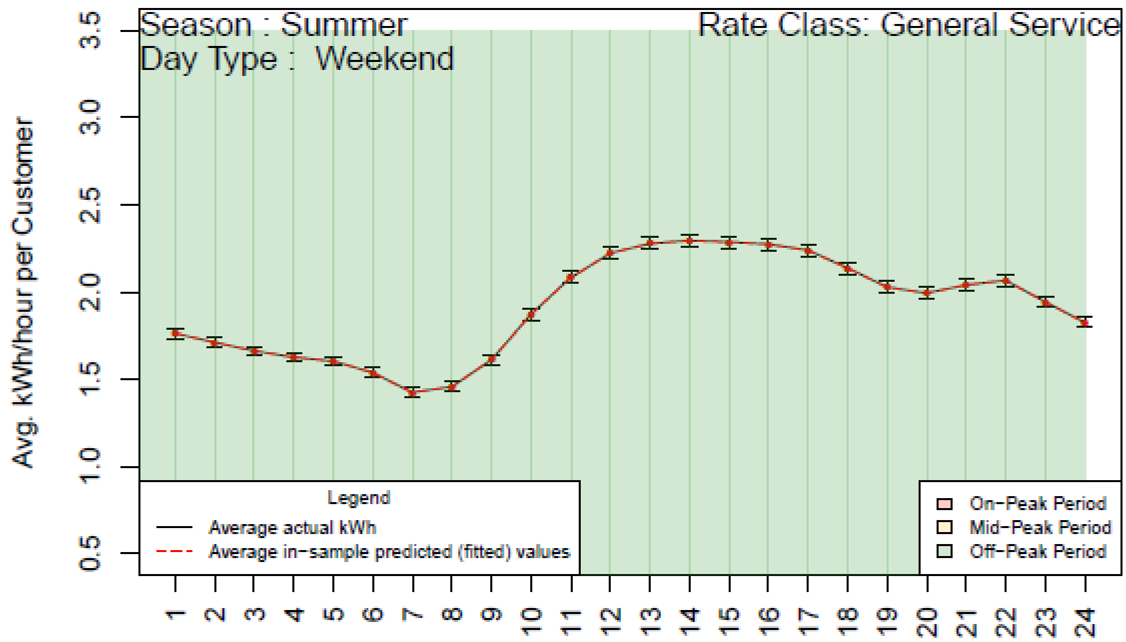
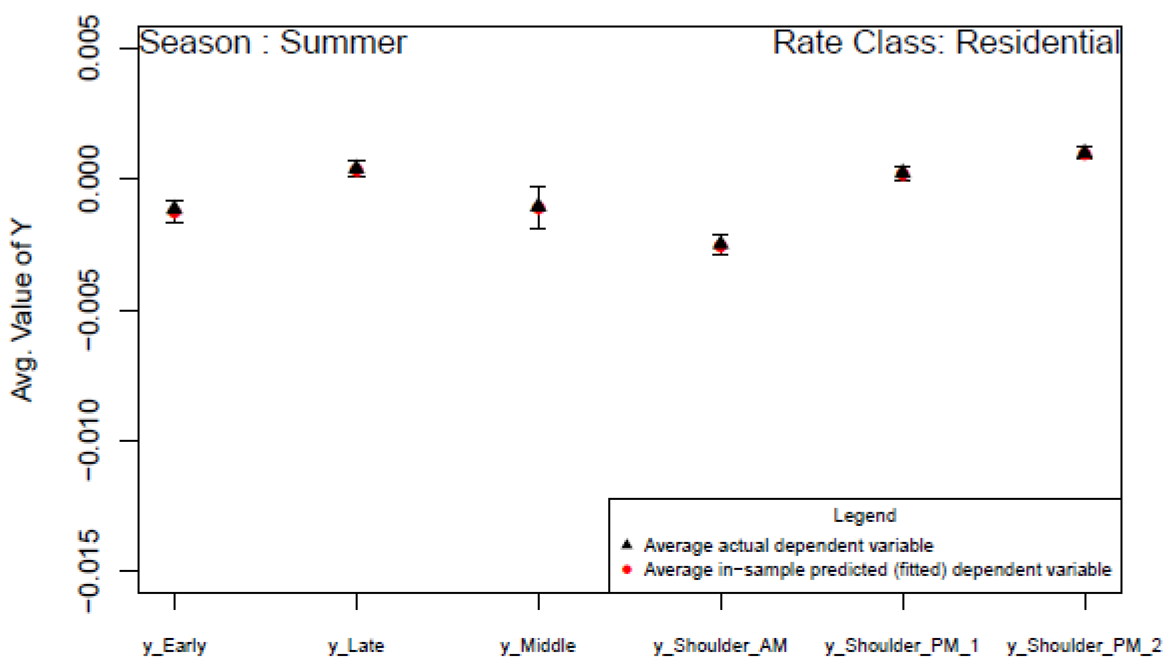
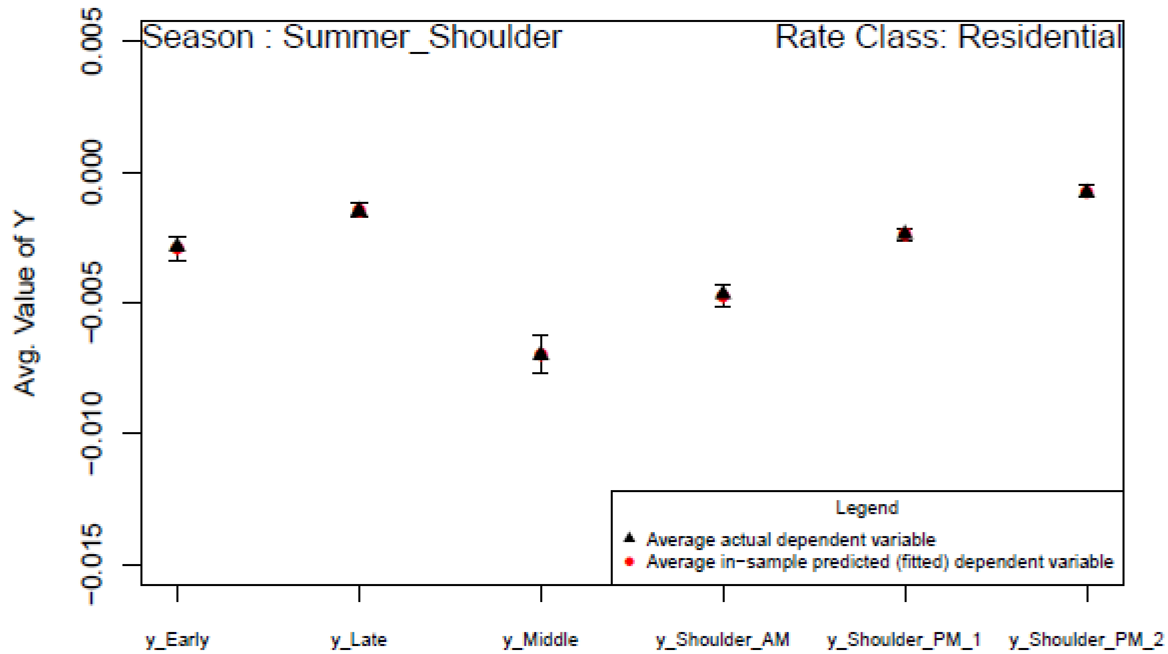


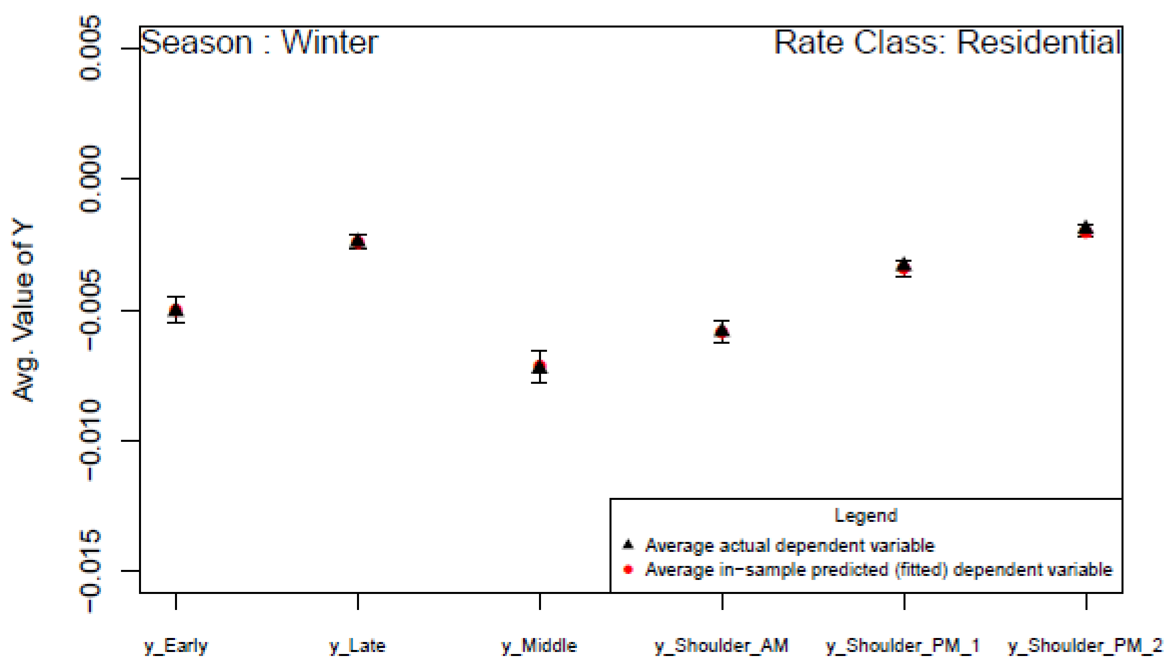
Note: The x-axis is Eastern Daylight Time (EDT).

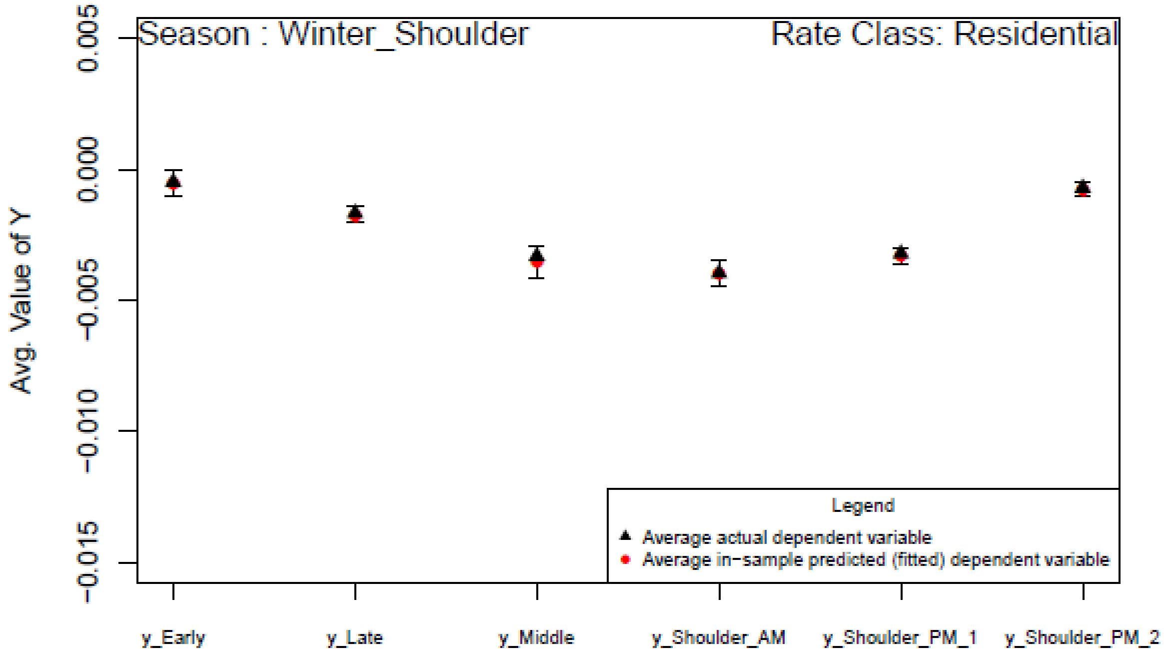
Rotterdam Model Actual and Fitted Values

Residential Plots




Season : Summer_Shoulder
Rate Class: Residential
Avg. Value of Y
0.005
0.000
−0.005
−0.010
−0.015
Legend
Average actual dependent variable
Average in−sample predicted (fitted) dependent variable
y_Early
y_Late
y_Middle
y_Shoulder_AM
y_Shoulder_PM_1
y_Shoulder_PM_2


Season : Winter
Rate Class: Residential
Avg. Value of Y
0.005
0.000
−0.005
−0.010
−0.015
Legend
Average actual dependent variable
Average in−sample predicted (fitted) dependent variable
y_Early
y_Late
y_Middle
y_Shoulder_AM
y_Shoulder_PM_1
y_Shoulder_PM_2



General Service Plots