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Ameren Missouri Program Year 2019 Annual EM&V Report

Volume 4: Demand Response Portfolio Appendices

June 18, 2020

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Appendix A. Residential Demand Response Program Appendix

Detailed Event Season Demand Impact Methodology

Runtime Data Cleaning

Table A-1 summarizes drops, by device manufacturer, made to the analytic data set as part of the data preparation and cleaning process.

Table A-1. Event Day Modeling Data Cleaning Steps

Drop Reason	Thermostat Manufacturer	# Devices Left
Initial	Nest	8,853
Devices not in participant file		8,853
Missing run time data on event and proxy weather days		8,853
Devices without load to drop on event days (run time is zero for all observations)		8,734
Devices with postal code outside of Ameren Missouri's territory		7,957
Initial	ecobee	825
Devices not in participant file		821
Missing run time data on event and proxy weather days		712
Devices without load to drop on event days (run time is zero for all observations)		712
Devices with postal code outside of Ameren Missouri's territory		712
Initial	Emerson	599
Devices not in participant file		599
Missing run time data on event and proxy weather days		548
Devices without load to drop on event days (run time is zero for all observations)		528
Devices with postal code outside of Ameren Missouri's territory		528

Event Season Demand Model Specification and Outputs

Equation A-1 shows model specification used to develop event day demand impacts.

Equation A-1. Event Day Impact Model Specification

$$kW_{it} = \alpha_0 + \alpha_i + \beta_{Event} \cdot \mathrm{Event} + \sum_{H=1}^{23} \beta_{\mathrm{Hour_H}} \cdot \mathrm{Hour_H} + \beta_{\mathrm{CDH}} \cdot \mathrm{CDH_t} + \beta_{Morning\ Load} \cdot \mathrm{Morning\ Load_i}$$
$$+ \beta_{Night\ \mathrm{Load}} \cdot \mathrm{Night\ Load_i} + \sum_{H=1}^{23} \beta_{Event\ \mathrm{Hour\ H}} \cdot \mathrm{Event} \cdot \mathrm{Hour_H}$$
$$+ \sum_{H=1}^{23} \beta_{Morning\ Load\ Hour_H}\ \mathrm{Morning\ Load_i} \cdot \mathrm{Hour_H}$$
$$+ \sum_{H=1}^{23} \beta_{Night\ \mathrm{Load\ Hour}}\ \mathrm{Night\ Load_i} \cdot \mathrm{Hour_H} + \varepsilon_{it}$$

Where:

- α_0 = Overall intercept
- α_i = Device-specific intercept
- $Event$ = Indicator variable for event day
- $Hour$ = Set of 23 indicator variables of hours of the day
- $Event\ by\ Hour$ = The interaction of event day vy hour of the day
- CDH = Base 75 cooling degree hours
- $Morning\ Load$ = The mean load for the device for the hours of midnight to 11 am
- $Night\ Load$ = The mean load for the device for the hours of 6 pm to 12 pm
- ε_{it} = Error term

Table A-2 and Table A-3 provide impact values for each event and event day hour by device manufacturer.

Table A-2. Residential DR Program – Average Hour Ex Post DR kW Impacts by Event, Event Hour (ecobee/Emerson)

Event	Hour Beginning	Baseline Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
1	0	1.05	0.95	0.10	9.58%	0.08	0.82	1.08
	1	0.93	0.62	0.31	33.77%	0.16	0.35	0.88
	2	0.86	0.52	0.35	40.25%	0.16	0.25	0.78
	3	0.76	0.47	0.29	38.48%	0.16	0.20	0.74
	4	0.63	0.47	0.16	25.93%	0.16	0.20	0.74
	5	0.64	0.61	0.02	3.73%	0.16	0.35	0.88
	6	0.70	0.67	0.03	4.39%	0.16	0.41	0.94
	7	0.57	0.75	-0.18	-32.06%	0.16	0.48	1.02
	8	0.70	0.91	-0.22	-30.78%	0.17	0.64	1.19
	9	0.80	1.29	-0.49	-61.07%	0.17	1.01	1.57
	10	1.03	1.44	-0.41	-39.43%	0.19	1.13	1.75
	11	1.11	1.53	-0.42	-38.15%	0.20	1.20	1.86
	12	1.15	1.62	-0.47	-41.13%	0.21	1.28	1.96
	13	1.29	1.37	-0.08	-6.28%	0.21	1.02	1.73
	14	1.26	0.12	1.14	90.57%	0.22	-0.24	0.47
	15	1.39	0.15	1.24	89.30%	0.22	-0.22	0.52
	16	1.61	0.34	1.28	78.99%	0.22	-0.03	0.71
	17	1.66	1.77	-0.11	-6.78%	0.22	1.41	2.13
	18	1.70	1.60	0.10	5.69%	0.21	1.25	1.95
	19	1.51	1.44	0.07	4.96%	0.20	1.11	1.76
	20	1.31	1.37	-0.06	-4.43%	0.17	1.08	1.66
	21	1.29	1.33	-0.03	-2.67%	0.17	1.05	1.61
	22	1.19	1.11	0.08	6.69%	0.17	0.84	1.39
	23	0.97	0.86	0.11	11.57%	0.17	0.59	1.13
2	0	1.36	1.16	0.20	14.98%	0.10	1.00	1.32
	1	1.13	0.89	0.24	20.92%	0.18	0.59	1.19
	2	1.04	0.75	0.29	27.94%	0.18	0.45	1.05
	3	0.94	0.81	0.14	14.36%	0.18	0.51	1.11
	4	0.95	0.84	0.11	11.36%	0.18	0.54	1.14
	5	0.93	0.92	0.01	1.14%	0.18	0.62	1.22
	6	0.94	0.99	-0.06	-6.10%	0.18	0.69	1.29
	7	0.85	1.10	-0.25	-29.99%	0.18	0.80	1.40
	8	0.74	1.17	-0.43	-57.50%	0.18	0.88	1.47
	9	0.76	1.29	-0.54	-70.94%	0.18	0.99	1.59
	10	0.91	1.35	-0.43	-47.23%	0.19	1.04	1.65
	11	1.10	1.59	-0.50	-45.20%	0.19	1.28	1.91

Event	Hour Beginning	Baseline Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
	12	1.36	1.92	-0.56	-40.87%	0.20	1.58	2.25
	13	1.67	2.02	-0.36	-21.29%	0.21	1.68	2.36
	14	1.94	2.06	-0.12	-5.96%	0.22	1.70	2.42
	15	1.91	0.23	1.68	88.07%	0.22	-0.14	0.59
	16	2.18	0.36	1.82	83.55%	0.22	-0.01	0.72
	17	2.28	0.77	1.50	65.96%	0.22	0.41	1.14
	18	2.19	2.44	-0.25	-11.33%	0.21	2.08	2.79
	19	2.08	2.17	-0.09	-4.37%	0.21	1.82	2.52
	20	2.02	2.00	0.02	0.96%	0.20	1.67	2.33
	21	2.02	1.93	0.09	4.46%	0.20	1.61	2.26
	22	1.84	1.66	0.18	9.69%	0.19	1.35	1.97
	23	1.62	1.44	0.19	11.61%	0.19	1.13	1.74
3	0	0.98	0.73	0.25	25.96%	0.08	0.59	0.86
	1	0.71	0.42	0.29	41.14%	0.16	0.15	0.68
	2	0.63	0.33	0.30	47.31%	0.16	0.07	0.60
	3	0.53	0.33	0.20	38.42%	0.16	0.06	0.59
	4	0.48	0.36	0.12	24.63%	0.16	0.10	0.63
	5	0.45	0.40	0.05	11.34%	0.16	0.13	0.66
	6	0.46	0.48	-0.02	-3.25%	0.16	0.21	0.74
	7	0.45	0.59	-0.14	-32.13%	0.16	0.33	0.86
	8	0.47	0.70	-0.23	-47.91%	0.17	0.43	0.97
	9	0.51	1.11	-0.59	-115.21%	0.18	0.81	1.40
	10	0.78	1.38	-0.61	-77.80%	0.20	1.06	1.71
	11	0.93	1.61	-0.68	-73.15%	0.21	1.26	1.96
	12	1.13	1.82	-0.69	-61.19%	0.23	1.44	2.20
	13	1.41	1.97	-0.56	-39.99%	0.24	1.59	2.36
	14	1.74	1.89	-0.15	-8.92%	0.25	1.48	2.30
	15	1.70	0.15	1.55	91.22%	0.25	-0.26	0.56
	16	1.95	0.27	1.67	85.97%	0.25	-0.14	0.68
	17	1.98	0.58	1.40	70.70%	0.24	0.19	0.97
	18	1.83	2.12	-0.30	-16.20%	0.22	1.76	2.48
	19	1.63	1.76	-0.14	-8.31%	0.21	1.42	2.11
	20	1.70	1.64	0.06	3.38%	0.19	1.32	1.96
	21	1.65	1.59	0.05	3.09%	0.18	1.30	1.89
	22	1.55	1.35	0.20	13.02%	0.18	1.06	1.64
	23	1.28	1.10	0.18	14.11%	0.17	0.82	1.38
4	0	1.19	1.22	-0.03	-2.28%	0.09	1.07	1.37
	1	1.00	0.87	0.13	13.29%	0.17	0.59	1.14
	2	1.01	0.75	0.26	26.12%	0.17	0.47	1.02

Event	Hour Beginning	Baseline Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
	3	0.91	0.72	0.19	20.90%	0.16	0.45	0.99
	4	0.87	0.77	0.10	11.19%	0.16	0.50	1.04
	5	0.89	0.85	0.04	4.09%	0.16	0.58	1.12
	6	0.96	0.93	0.03	3.06%	0.16	0.67	1.20
	7	0.91	0.98	-0.07	-7.65%	0.16	0.71	1.25
	8	0.97	1.20	-0.23	-23.46%	0.17	0.92	1.47
	9	1.00	1.47	-0.47	-46.93%	0.18	1.17	1.76
	10	1.24	1.65	-0.41	-33.15%	0.19	1.33	1.97
	11	1.20	1.84	-0.64	-53.68%	0.20	1.51	2.17
	12	1.43	1.79	-0.36	-24.85%	0.21	1.45	2.13
	13	1.27	0.12	1.16	90.79%	0.21	-0.23	0.46
	14	1.55	0.20	1.35	87.26%	0.21	-0.15	0.55
	15	1.68	0.43	1.25	74.20%	0.22	0.08	0.79
	16	1.92	2.07	-0.15	-7.92%	0.21	1.72	2.42
	17	1.91	1.84	0.07	3.81%	0.20	1.51	2.17
	18	1.73	1.62	0.11	6.50%	0.19	1.30	1.93
	19	1.53	1.52	0.01	0.70%	0.19	1.21	1.83
	20	1.48	1.52	-0.04	-2.49%	0.18	1.23	1.81
	21	1.28	1.50	-0.22	-17.20%	0.17	1.22	1.79
	22	1.24	1.22	0.02	1.88%	0.17	0.94	1.50
	23	0.96	1.07	-0.11	-11.04%	0.17	0.79	1.35

Table A-3. Average Hour Ex Post DR kW Impacts by Event, Event Hour (Nest)

Event	Hour Beginning	Reference Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
1	0	0.88	0.92	-0.04	-4.71%	0.01	0.90	0.94
	1	0.70	0.72	-0.03	-3.99%	0.03	0.68	0.77
	2	0.60	0.57	0.03	4.27%	0.03	0.53	0.62
	3	0.49	0.48	0.01	2.70%	0.03	0.44	0.52
	4	0.43	0.41	0.02	3.83%	0.03	0.37	0.46
	5	0.37	0.37	0.01	2.24%	0.03	0.32	0.41
	6	0.34	0.34	0.00	0.53%	0.03	0.29	0.38
	7	0.33	0.37	-0.03	-10.04%	0.03	0.32	0.41
	8	0.32	0.33	-0.01	-1.72%	0.03	0.28	0.38
	9	0.33	0.33	0.00	-0.54%	0.03	0.29	0.38
	10	0.45	0.45	0.01	1.97%	0.03	0.40	0.50
	11	0.60	0.61	-0.01	-1.44%	0.03	0.56	0.66
	12	0.74	0.71	0.03	4.50%	0.03	0.65	0.76
	13	0.97	1.52	-0.55	-56.43%	0.03	1.47	1.58
	14	1.12	0.10	1.01	90.89%	0.03	0.05	0.16
	15	1.38	0.25	1.12	81.57%	0.03	0.20	0.31
	16	1.64	0.51	1.13	69.01%	0.03	0.45	0.57
	17	1.85	2.17	-0.32	-17.55%	0.03	2.12	2.23
	18	1.95	2.01	-0.06	-2.86%	0.03	1.95	2.06
	19	1.83	1.84	-0.02	-0.96%	0.03	1.79	1.89
	20	1.72	1.67	0.04	2.57%	0.03	1.63	1.72
	21	1.64	1.58	0.05	3.21%	0.03	1.54	1.63
	22	1.45	1.40	0.05	3.28%	0.03	1.36	1.45
	23	1.14	1.12	0.02	2.12%	0.03	1.07	1.16
2	0	1.17	1.06	0.11	9.38%	0.01	1.04	1.08
	1	0.97	0.93	0.03	3.58%	0.03	0.89	0.98
	2	0.84	0.85	-0.01	-0.62%	0.03	0.80	0.89
	3	0.72	0.81	-0.09	-12.79%	0.03	0.76	0.85
	4	0.67	0.76	-0.10	-14.64%	0.03	0.72	0.81
	5	0.60	0.71	-0.11	-17.88%	0.03	0.66	0.75
	6	0.55	0.64	-0.10	-17.77%	0.03	0.60	0.69
	7	0.46	0.56	-0.10	-21.51%	0.03	0.52	0.61
	8	0.31	0.45	-0.15	-47.76%	0.03	0.41	0.50
	9	0.31	0.41	-0.09	-29.40%	0.03	0.36	0.45
	10	0.37	0.44	-0.08	-20.53%	0.03	0.40	0.49
	11	0.61	0.65	-0.04	-6.66%	0.03	0.60	0.69
	12	0.93	0.88	0.05	5.03%	0.03	0.83	0.93
	13	1.21	1.14	0.07	5.99%	0.03	1.09	1.19

Event	Hour Beginning	Reference Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
	14	1.52	2.05	-0.53	-34.93%	0.03	2.00	2.09
	15	1.79	0.28	1.51	84.55%	0.03	0.23	0.33
	16	2.07	0.81	1.26	61.01%	0.03	0.76	0.86
	17	2.29	1.26	1.03	45.07%	0.03	1.21	1.31
	18	2.40	2.60	-0.20	-8.27%	0.03	2.55	2.65
	19	2.41	2.45	-0.04	-1.79%	0.03	2.40	2.51
	20	2.38	2.30	0.07	3.10%	0.03	2.25	2.35
	21	2.32	2.18	0.13	5.82%	0.03	2.13	2.23
	22	2.09	1.98	0.11	5.16%	0.03	1.93	2.03
	23	1.76	1.70	0.06	3.29%	0.03	1.65	1.74
3	0	0.73	0.68	0.05	6.54%	0.01	0.66	0.70
	1	0.55	0.53	0.03	4.69%	0.03	0.48	0.57
	2	0.43	0.44	0.00	-0.20%	0.03	0.39	0.48
	3	0.37	0.36	0.01	1.39%	0.03	0.32	0.41
	4	0.31	0.33	-0.02	-6.84%	0.03	0.29	0.37
	5	0.27	0.30	-0.03	-11.73%	0.03	0.26	0.35
	6	0.25	0.29	-0.04	-15.69%	0.03	0.25	0.34
	7	0.26	0.30	-0.04	-16.64%	0.03	0.26	0.35
	8	0.24	0.29	-0.05	-18.88%	0.03	0.24	0.33
	9	0.30	0.32	-0.02	-6.75%	0.03	0.27	0.36
	10	0.41	0.38	0.03	7.79%	0.03	0.33	0.43
	11	0.63	0.53	0.10	15.23%	0.03	0.48	0.59
	12	0.86	0.75	0.11	12.82%	0.03	0.69	0.80
	13	1.08	0.98	0.10	9.36%	0.03	0.92	1.04
	14	1.30	1.86	-0.56	-42.74%	0.04	1.80	1.92
	15	1.54	0.22	1.32	85.75%	0.04	0.16	0.28
	16	1.78	0.60	1.18	66.26%	0.04	0.54	0.66
	17	1.96	0.96	1.00	51.19%	0.03	0.90	1.01
	18	2.05	2.43	-0.37	-18.15%	0.03	2.37	2.48
	19	2.14	2.18	-0.05	-2.16%	0.03	2.12	2.24
	20	2.03	2.01	0.02	0.83%	0.03	1.96	2.07
	21	1.93	1.85	0.08	4.15%	0.03	1.80	1.90
	22	1.70	1.63	0.07	4.10%	0.03	1.58	1.69
	23	1.36	1.34	0.02	1.75%	0.03	1.29	1.39
4	0	1.07	1.08	-0.01	-0.59%	0.02	1.05	1.10
	1	0.90	0.91	-0.01	-0.96%	0.03	0.86	0.96
	2	0.76	0.80	-0.04	-5.44%	0.03	0.75	0.85
	3	0.67	0.70	-0.03	-4.34%	0.03	0.65	0.75
	4	0.58	0.62	-0.04	-6.36%	0.03	0.57	0.67

Event	Hour Beginning	Reference Load (kW)	Event Day Load (kW)	Load Impact (kW)	% Load Impact	Standard Error	Lower Bound (90%)	Upper Bound (90%)
	5	0.52	0.54	-0.02	-4.35%	0.03	0.49	0.59
	6	0.47	0.50	-0.03	-6.61%	0.03	0.45	0.55
	7	0.46	0.46	0.01	1.92%	0.03	0.41	0.51
	8	0.45	0.40	0.04	9.73%	0.03	0.35	0.45
	9	0.50	0.44	0.06	11.78%	0.03	0.39	0.49
	10	0.63	0.55	0.08	12.79%	0.03	0.49	0.60
	11	0.79	0.73	0.06	7.39%	0.03	0.68	0.79
	12	1.00	1.64	-0.64	-64.40%	0.03	1.59	1.70
	13	1.22	0.14	1.08	88.65%	0.03	0.08	0.19
	14	1.40	0.35	1.05	74.79%	0.03	0.30	0.41
	15	1.62	0.65	0.98	60.29%	0.04	0.59	0.70
	16	1.83	2.25	-0.42	-23.00%	0.03	2.19	2.31
	17	1.96	2.11	-0.15	-7.70%	0.03	2.05	2.16
	18	1.94	1.99	-0.05	-2.46%	0.03	1.94	2.04
	19	1.85	1.87	-0.02	-0.93%	0.03	1.82	1.92
	20	1.77	1.81	-0.04	-2.31%	0.03	1.76	1.86
	21	1.71	1.72	-0.01	-0.50%	0.03	1.67	1.77
	22	1.56	1.54	0.02	1.06%	0.03	1.49	1.59
	23	1.31	1.28	0.03	2.10%	0.03	1.23	1.33

Event Season Impacts – Additional Outputs

Figure A-1 and Figure A-2 show the actual event day kW (blue) and predicted kW (gray) for each event and thermostat manufacturer. The gray shaded area surrounding the reference load shows the 90% confidence interval of the estimated reference load while the vertical gray shaded area shows the event hours for each event. All events show clear evidence of kW reduction during event hours. All events also show pre-cooling (an increase in kW prior to the event to increase kW reductions during the event) and a snapback (an increase in demand following the event as temperatures are returned to their pre-event levels). Pre-cooling practices vary considerably by device manufacturer with the ecobee devices having considerably more and longer pre-cooling than the Nest devices.

Figure A-1. Per Thermostat kW Impacts by Event (ecobee/Emerson)

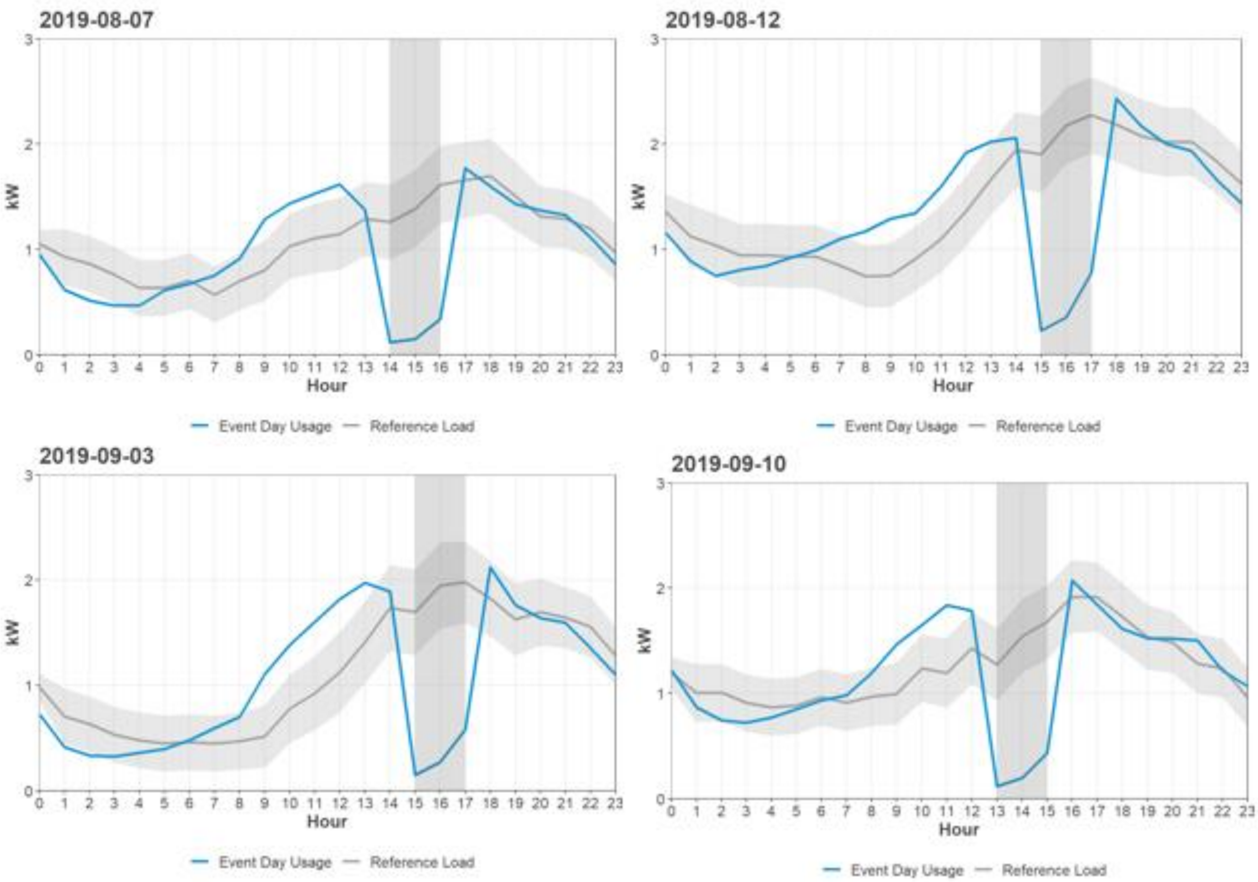
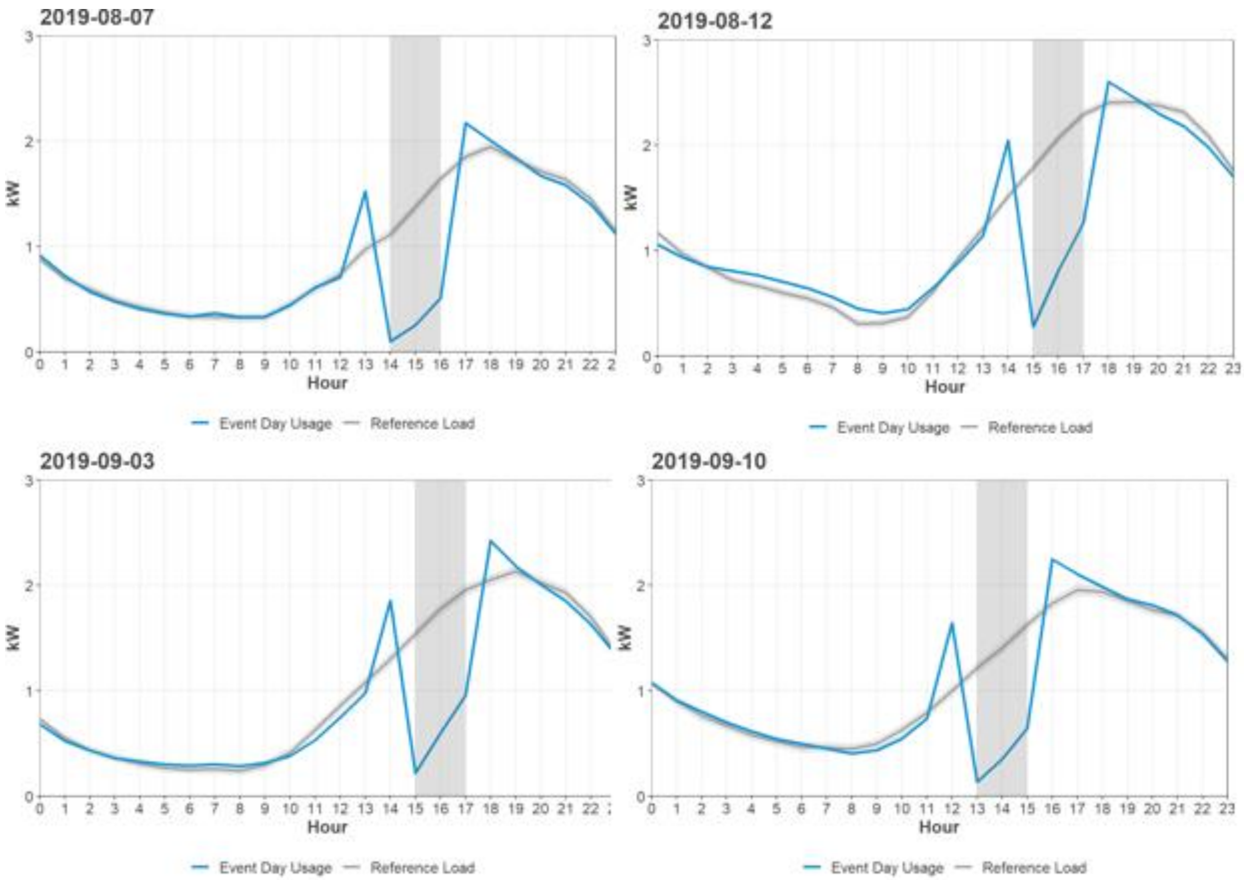


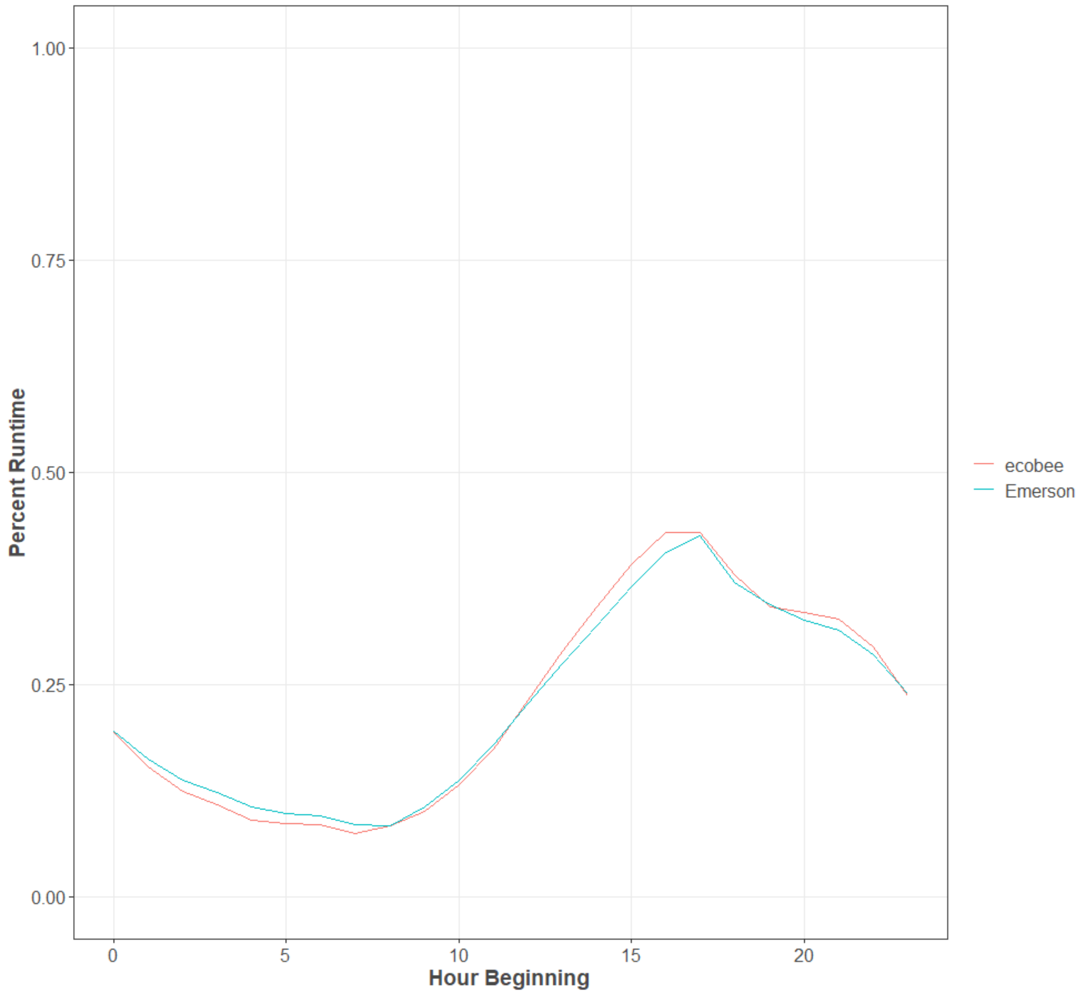
Figure A-2. Per Thermostat kW Impacts by Event (Nest)



Comparison of ecobee and Emerson Device Runtime on Non Event Days

Figure A-3 shows comparison of ecobee and Emerson percent runtime across non-event days as a check of equivalency of runtime patterns across the two device manufacturers.

Figure A-3. Comparison of ecobee and Emerson Runtime on Non-Event Days



Connected Load Assumption Development

We leveraged onsite data collected as part of the Residential Baseline study completed as part of a broader 2020 DSM Market Potential study[1] as a data source to support the development of the connected load assumptions. More specifically, we used the information on the respondents' central air conditioning system SEER rating and size. We reviewed the data and made adjustments to it for more accurate calculations. More specifically, in cases where the central air conditioning system size was missing, we imputed it using home type weighted sample average for missing observations. In cases, when SEER values were missing, we imputed them using other variables available in the data, including home vintage. We made additional adjustments to the SEER for aging and wear based on the central air conditioning system's vintage and tune-ups performed recently.

We calculated connected load for each device associated with the central air conditioning systems. To ensure that per-device connected load assumptions were representative of the population of the Residential DR

[1] GDS Associates. Ameren Missouri 2020 DSM Market Potential Study. Final Report. March 2020. https://efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=936289645

program participants, we checked the differences in connected load results by key observable demographics that were available to us through the participant survey and the baseline study. We applied weights by home type and income to better align the connected load with the distribution of the participant population. Table A-4 details percent distribution of the Residential Baseline study respondents as well as Residential DR participants by those characteristics, and summarizes the resulting weights.

Table A-4. Participant Survey Weighting Scheme

Stratum	% of Residential Baseline Study Participants	% of Residential DR Participants	Weight
Low-income multifamily	22.5%	0.7%	.0317965
Low-income single-family	28.3%	3.7%	.1290564
Non-low-income multifamily	14.2%	6.9%	.4881698
Non-low-income single-family	35.0%	88.7%	2.534636

Table A-1 presents the final weighted per device connected load. We applied the average connected load estimate to all participating device runtime results to convert the runtime reductions into demand reductions.

Table A-5. Per Device Connected Load Results

Metric	Result
Sample size	119
Connected load	3.07

Table A-6 provides a comparison of the connected load estimates without missing data imputations as well as without the weights applied and offers insight into the changes caused by those adjustments. As can be seen in the table, the connected load estimates are comparable across the scenarios and the difference in estimates is driven by the application of weights primarily.

Table A-6. Per Device Connected Load Results

Scenario	Connected Load Estimate
Weighted and with missing data imputations	3.07
Unweighted and without missing data imputations	2.99
Unweighted and with missing data imputations	2.99

Weather Normalized Demand Impact Model Specification and Results

Equation A-2 provides the final weather-normalized resource capability model specification.

Equation A-2. Residential DR Program – Weather Normalized Resource Capability Model Specification

$$kW_{it} = \beta_i + \sum_{h=1}^{23} \beta_{Hour\,h} \cdot Hour_{ht} + \beta_{CDH} \cdot CDH_t + \sum_{eh=0}^{10} \beta_{EventHour\,eh} \cdot EventHour_{eh\,t} + \sum_{h=1}^{23} \beta_{HourCDH\,h} \cdot Hour_{h\,t} \cdot CDH_t + \sum_{eh=0}^{10} \beta_{EventHourCDH\,eh} \cdot EventHour_{eh\,t} \cdot CDH_t + \varepsilon_{it}$$

Where:

- kW_{it} = Demand for customer i at time t
- β_i = Intercept for customer i
- β_x = Coefficient representing the effect of a one unit change in the corresponding variable
- $Hour_{ht}$ = Set of indicators for hour of the day
- CDH_t = Cooling Degree Hours (base temperature 75 degrees F) at time t
- $EventHour_{eh\,t}$ = Set of indicators for hours on event days

Figure A-4 shows the modeled baseline demand (solid red line) and modeled event demand (solid teal line) in addition to actual demand (dotted red line) for each comparison and event day. The most important hours to look at are the event hours, since this is the time period where we use the model to predict future standard event impact. The figure shows that the modeled baseline matches the actual demand on comparison days, and that the modeled event demand matches the actual demand on event days.

Figure A-4. Residential DR Program – Nest Weather Normalized Model Fit

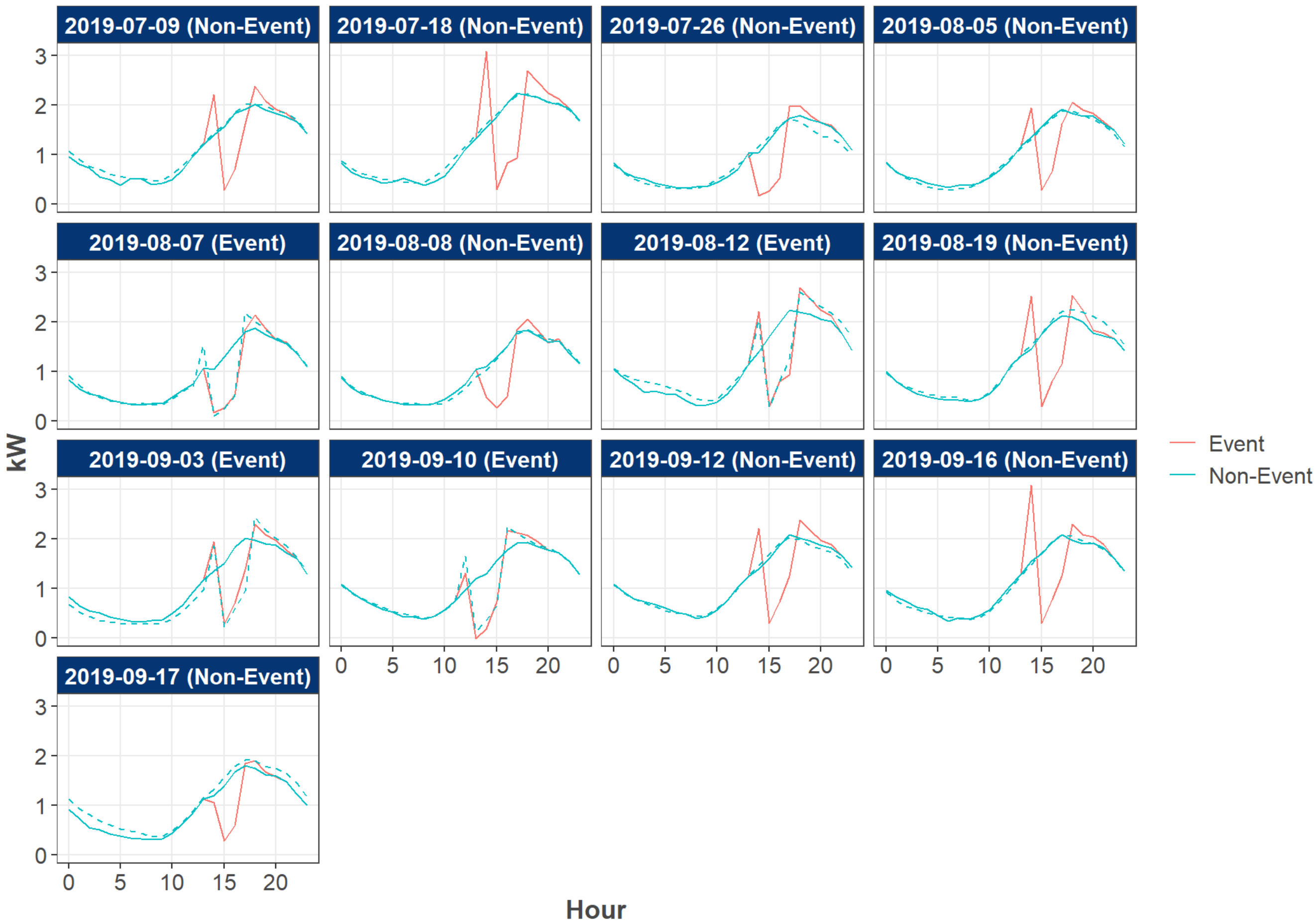
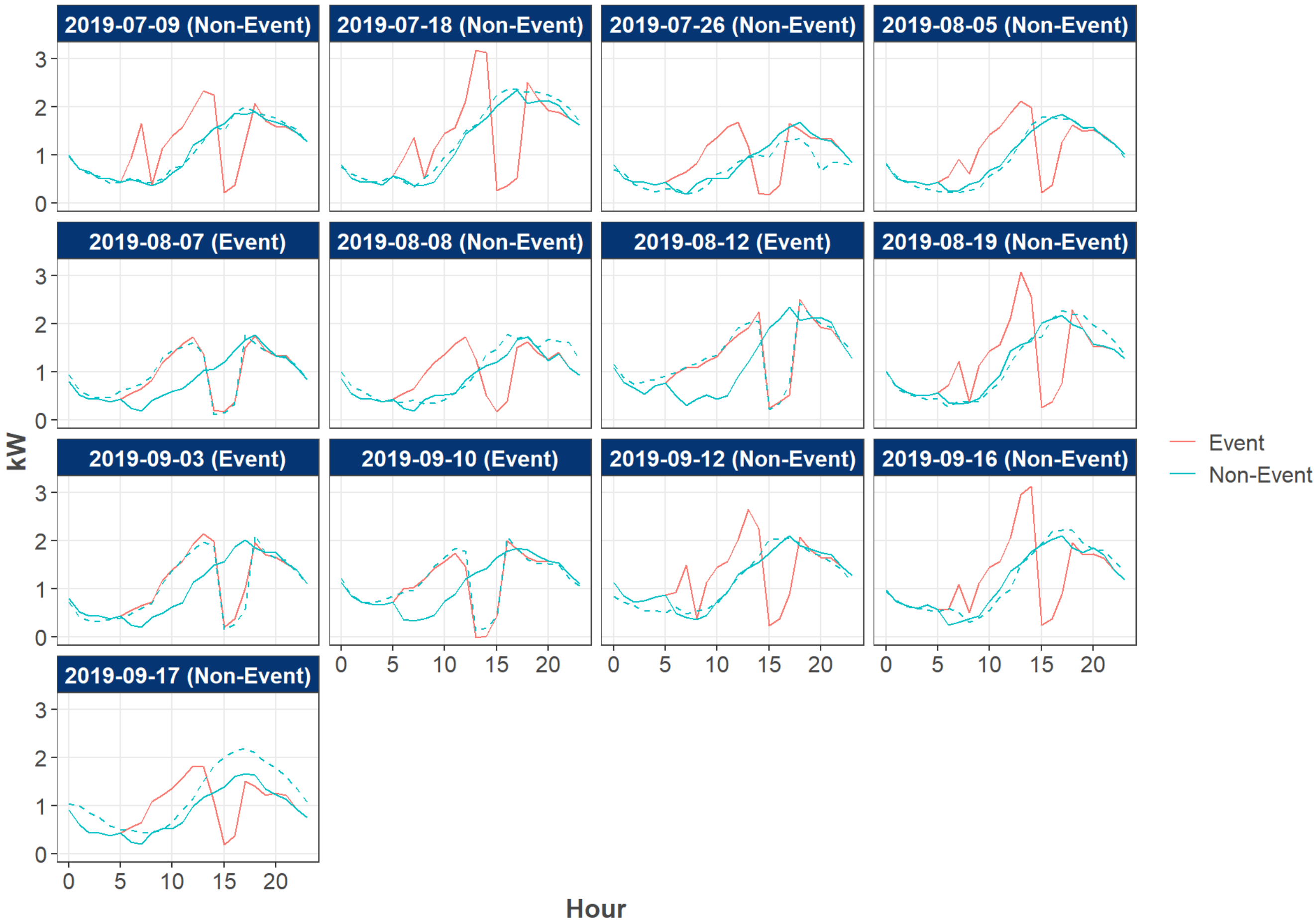


Figure A-5 shows that the modeled baseline matches the actual demand during event hours on comparison days, and that the modeled event demand matches the actual demand during event hours on event days. This model does not fit actual demand as well as the Nest model during non-event hours, likely because the model is based on a smaller number of devices, and Uplight's event day algorithm substantially increases demand in the morning and early afternoon hours on event days.

Figure A-5. Weather Normalized Model Fit (ecobee and Emerson)



Energy Optimization Impacts

Runtime Data Cleaning

Figure A-5 and Figure A-6 summarize the results of the data cleaning steps that we performed to prepare telemetry data for analysis of the energy optimization impacts. Note that for Nest devices, we received participant and telemetry data for more devices than those that participated in the program.

Table A-7. Google Nest Telemetry Data Cleaning

Drop Reason	Number of Rows	Number of Devices
Original	6,017,506	49,268
Merge Telemetry	6,017,506	48,639
Drop devices not Residential DR Program	908,546	7,234
Drop devices marked as both control and participants	908,546	7,234
Drop devices with missing zip codes	906,250	7,212
Drop devices with anonymized zip codes	877,887	6,986

Drop Reason	Number of Rows	Number of Devices
Drop devices with zip codes outside of Ameren Missouri service territory	877,887	6,986
Drop rows with missing intervals	863,227	6,986
Drop rows outside of 2019-05-01 to 2019-09-30	849,456	6,986

Table A-8. Uplight/Ecobee Telemetry Data Cleaning

Drop Reason	Number of Rows	Number of Devices	Number of Accounts
Original	2,329,928	859	724
Drop rows with missing cooling runtime	2,053,572	859	724
Drop rows with total thermostat minutes <30	2,044,509	859	724
Drop event days	1,981,669	859	724
Drop unknown days	1,960,629	859	724
Drop devices without learning days or non-learning days	1,920,725	809	701

Energy Optimization Model Specification

Equation A-3 shows the final model specification used to develop energy optimization impacts for Nest devices.

Equation A-3. Nest Energy Optimization Model

$$Runtime_{it} = \beta_i + \beta_{CDD} \cdot CDD_t + \beta_{Post} \cdot Post_t + \beta_{Treat\ Post} \cdot Treat_i \cdot Post_t + \beta_{Post\ CDH} \cdot Post_t \cdot CDH_t + \beta_{Post\ Treat\ CDH} \cdot Treat_i \cdot Post_t \cdot CDH_t + \sum_{d=1}^{6} \beta_{DOW\ d} \cdot DayOfWeek_{dt} + \sum_{d=1}^{6} \beta_{Post\ DOW\ d} \cdot DayOfWeek_{dt} \cdot Post_t + \sum_{d=1}^{6} \beta_{Post\ Treat\ DOW\ d} \cdot DayOfWeek_{dt} \cdot Treat_i \cdot Post_t + \varepsilon_{it}$$

Where:

- $Runtime_{it}$ = Cooling runtime for device i at time t
- β_i = Intercept for device i
- β_x = Coefficient representing the effect of a one-unit change in the corresponding variable
- $DayOfWeek_{dt}$ = Set of indicators for the day of week
- CDD_t = Cooling Degree Days (base temperature 75 degrees F) at time t
- $Post_t$ = Indicator for the post period
- $Treat_i$ = Indicator for the treatment group

The analysis of ecobee devices was relatively straightforward because Uplight structured their program as a simple crossover design, where devices are treated on most days but have randomly assigned non-treatment days. We calculated savings from this type of experimental design as the simple difference between mean runtime on non-treatment days minus mean runtime on treatment days.

Energy Optimization Impacts – Additional Results

Figure A-6 and Figure A-7 provide a visual of Nest and ecobee runtime differentiating between control and treatment groups for Nest and control and treatment days for ecobee. The teal line shows runtime for the treatment group/treatment days while the red line shows runtime for the control group/control days. The vertical blue line on the Nest graph marks the start of the optimization. The graphs show lower runtime on treatment days and for treatment group. Nest treated device runtime is a lot closer to the control devices than the runtime for ecobee control days as compared to the non-control days.

Figure A-6. Residential DR Program – Mean Runtime for Nest Devices

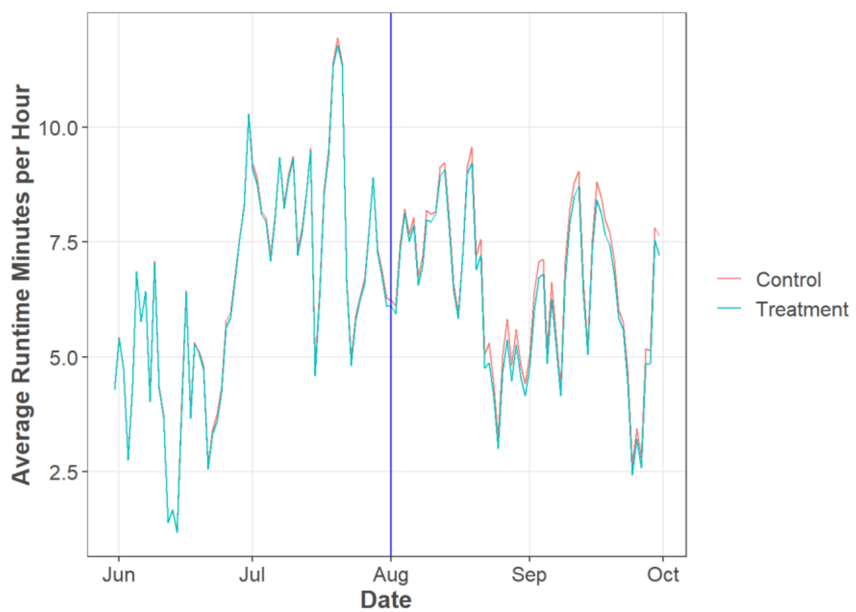
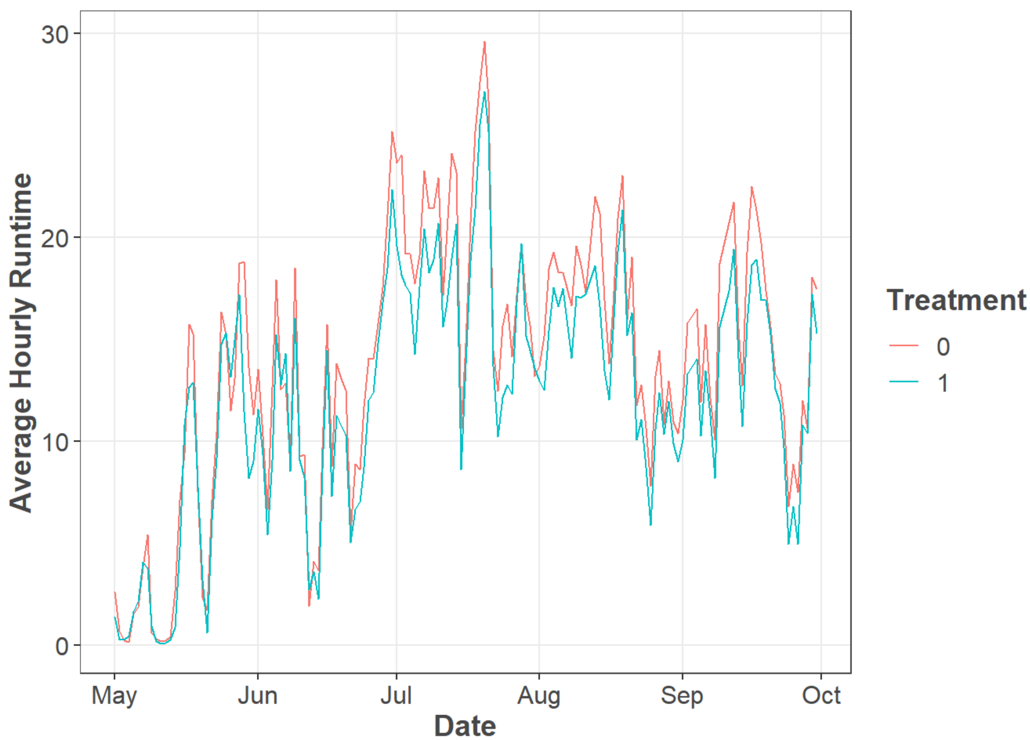


Figure A-7. Mean Hourly Runtime for Ecobee Devices



Appendix B. Business Demand Response Program Appendix

Table B-1 below contains detailed impact results for each participating account.

Table B-1. PY2019 Performance Across Events by Account

ODCID	Nomination (kW)	Average Event Season Performance (kW)	% Average Event Season Performance/ Nomination (kW)	Event 1 (August 16, 2019) Performance (kW)	Event 2 (September 25, 2019) Performance (kW)	Event 3 (December 11, 2019) Performance (kW)
120191	1,500	-254.76	-17%	Event was not called	-254.76	Event was not called
120192	1,000	-17.70	-2%	21.60	-57.00	Event was not called
120193	1,200	729.00	61%	464.00	994.00	Event was not called
120194	600	103.50	17%	599.25	-392.25	Event was not called
120195	300	277.05	92%	338.10	216.00	Event was not called
120196	1,500	3,005.21	200%	2,144.75	3,865.68	Event was not called
120197	500	-62.23	-12%	-73.20	-51.25	Event was not called
120198	400	703.27	176%	640.61	765.94	Event was not called
120199	400	171.48	43%	328.05	14.92	Event was not called
1201910	182	43.13	24%	69.75	16.50	Event was not called
1201911	670	8.29	1%	83.93	-67.35	Event was not called
1201912	670	0.47	0%	15.62	-14.69	Event was not called
1201913	2,000	1,541.21	77%	1,436.93	1645.50	Event was not called
1201914	2,000	515.70	26%	630.00	401.40	Event was not called
1201915	200	73.82	37%	92.50	55.13	Event was not called
1201916	200	167.80	84%	124.22	211.38	Event was not called
1201917	200	85.34	43%	190.90	-20.22	Event was not called
1201918	200	167.06	84%	193.23	140.89	Event was not called
1201919	200	158.70	79%	188.83	128.56	Event was not called
1201920	200	132.99	66%	140.91	125.06	Event was not called
1201921	200	217.94	109%	184.03	251.86	Event was not called
1201922	200	135.24	68%	153.06	117.42	Event was not called
1201923	200	88.05	44%	149.53	26.57	Event was not called
1201924	500	148.20	30%	14.85	281.55	Event was not called
1201925	200	162.93	81%	212.10	113.75	Event was not called
1201926	200	173.44	87%	222.71	124.16	Event was not called

ODCID	Nomination (kW)	Average Event Season Performance (kW)	% Average Event Season Performance/ Nomination (kW)	Event 1 (August 16, 2019) Performance (kW)	Event 2 (September 25, 2019) Performance (kW)	Event 3 (December 11, 2019) Performance (kW)
1201927	200	51.38	26%	69.37	33.39	Event was not called
1201928	600	219.92	37%	337.47	102.38	Event was not called
1201929	600	477.48	80%	446.94	508.02	Event was not called
1201930	2,475	2,702.55	109%	3,011.40	2,393.70	Event was not called
1201931	2,000	2,279.95	114%	2,153.13	2,406.77	Event was not called
1201932	1,000	571.25	57%	352.00	790.50	Event was not called
1201933	860	348.45	41%	346.76	350.14	Event was not called
1201934	860	184.62	21%	219.16	150.07	Event was not called
1201935	860	486.22	57%	519.05	453.38	Event was not called
1201936	860	820.62	95%	867.22	774.01	Event was not called
1201937	860	65.67	8%	78.36	52.99	Event was not called
1201938	860	1,568.89	182%	1,462.10	1,675.67	Event was not called
1201939	860	1,228.36	143%	1,236.40	1,220.32	Event was not called
1201940	300	52.16	17%	86.58	17.73	Event was not called
1201941	1,062	524.40	49%	626.40	422.40	Event was not called
1201942	100	5.34	5%	10.31	0.37	Event was not called
1201943	100	85.80	86%	153.11	18.48	Event was not called
1201944	250	4.71	2%	21.84	-12.42	Event was not called
1201945	250	-71.17	-28%	-106.44	-35.90	Event was not called
1201946	100	94.43	94%	133.63	55.22	Event was not called
1201947	750	464.08	62%	561.56	366.60	Event was not called
1201948	1,100	815.62	74%	783.82	847.43	Event was not called
1201949	400	36.74	9%	72.19	1.30	Event was not called
1201950	3,000	723.08	24%	487.73	958.43	Event was not called
1201951	200	149.81	75%	170.55	129.07	Event was not called
1201952	400	-0.75	0%	Event was not called	-0.75	Event was not called
1201953	535	22.05	4%	Event was not called	22.05	Event was not called
1201954	384	-39.29	-10%	Event was not called	Event was not called	-39.29
1201955	1,181	903.06	76%	Event was not called	Event was not called	903.06
1201956	875	-61.88	-7%	Event was not called	Event was not called	-61.88

ODCID	Nomination (kW)	Average Event Season Performance (kW)	% Average Event Season Performance/ Nomination (kW)	Event 1 (August 16, 2019) Performance (kW)	Event 2 (September 25, 2019) Performance (kW)	Event 3 (December 11, 2019) Performance (kW)
1201957	307	64.80	21%	Event was not called	Event was not called	64.80
1201958	2,400	2,080.50	87%	Event was not called	Event was not called	2080.50
1201960	1,771	1,420.80	80%	Event was not called	Event was not called	1420.80
1201961	1,785	1,309.80	73%	Event was not called	Event was not called	1309.80
1201962	300	306.20	102%	Event was not called	Event was not called	306.20
1201963	500	223.68	45%	Event was not called	Event was not called	223.68
1201964	1,100	301.50	27%	Event was not called	Event was not called	301.50
1201965	714	182.88	26%	Event was not called	Event was not called	182.88
1201966	2,131	33.99	2%	Event was not called	Event was not called	33.99
1201967	2000	-65.61	-3%	Event was not called	Event was not called	-65.61
1201968	1,190	970.80	82%	Event was not called	Event was not called	970.80
1201969	400	148.86	37%	Event was not called	Event was not called	148.86
1201970	430	88.76	21%	Event was not called	Event was not called	88.76
1201971	3,000	482.00	16%	Event was not called	Event was not called	482.00
1201972	600	379.50	63%	Event was not called	Event was not called	379.50
1201973	500	308.77	62%	Event was not called	Event was not called	308.77

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