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August 11, 2021

VIA ELECTRONIC FILING

Ms. A. Shonta Dunston
Chief Clerk
North Carolina Utilities Commission
4325 Mail Service Center
Raleigh, North Carolina 27699-4300

Re: Duke Energy Progress, LLC's DSM/EE Cost Recovery Rider – Supplemental Testimony and Exhibits
Docket No. E-2, Sub 1273

Dear Ms. Dunston:

Enclosed for filing is Duke Energy Progress, LLC's Supplemental Testimony of Robert P. Evans and Evans Supplemental Exhibit E for filing in connection with the referenced matter. Fifteen (15) paper copies of the Supplemental Testimony and Supplemental Exhibits will be delivered to the Clerk's Office by close of business today.

Please do not hesitate to contact me if you have any questions or require additional information.

Sincerely,

Kendrick C. Fentress

Kendrick C. Fentress

Enclosures

cc: Parties of Record

CERTIFICATE OF SERVICE

I certify that a copy of Duke Energy Progress, LLC's Supplemental Testimony of Robert P. Evans and Evans Supplemental Exhibit E, in Docket No. E-2, Sub 1273, has been served by electronic mail, hand delivery, or by depositing a copy in the United States Mail, 1st Class Postage Prepaid, properly addressed to parties of record.

This the 11th day of August, 2021.

Kendrick C. Fentress

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STATE OF NORTH CAROLINA
UTILITIES COMMISSION
RALEIGH

DOCKET NO. E-2, SUB 1273

BEFORE THE NORTH CAROLINA UTILITIES COMMISSION

In the Matter of Application of Duke Energy Progress, LLC for Approval of Demand-Side Management and Energy Efficiency Cost Recovery Rider Pursuant to N.C. Gen. Stat. § 62-133.9 and Commission Rule R8-69	))))))	**SUPPLEMENTAL TESTIMONY OF ROBERT P. EVANS FOR DUKE ENERGY PROGRESS, LLC**

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Robert P. Evans. My business address is 410 South Wilmington Street, Raleigh, North Carolina.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by Duke Energy Corporation ("Duke Energy") as Senior Manager-Strategy and Collaboration for the Carolinas in the Regulatory Strategy Portfolio Analysis and Regulatory Strategy group.

Q. DID YOU PREVIOUSLY FILE DIRECT TESTIMONY IN SUPPORT OF DUKE ENERGY PROGRESS, LLC'S APPLICATION IN THIS DOCKET?

A. Yes.

Q. WHAT IS THE PURPOSE OF YOUR SUPPLEMENTAL TESTIMONY?

A. The purpose of my supplemental testimony is to provide the Commission with an exhibit that was inadvertently left out of Duke Energy Progress, LLC's (the "Company") original filing in this proceeding.

Q. PLEASE DESCRIBE THIS EXHIBIT.

A. The exhibit, identified as Evans Supplemental Exhibit E, is an EM&V report associated with the Summer 2019 evaluation, measurement, and verification ("EM&V") Report for the Company's EnergyWise Home Program ("EnergyWise Home"), a residential demand response program. This EM&V report was finalized on August 19, 2020.

Q. WERE ANY OTHER ELEMENTS OF THE COMPANY'S FILING IMPACTED BY THE OMISSION OF THIS EXHIBIT?

A. No. The omission of this exhibit did not impact any other elements of the Company's filing.

Q. DOES THIS CONCLUDE YOUR PRE-FILED SUPPLEMENTAL TESTIMONY?

A. Yes.

Guidehouse

EM&V Report for the EnergyWise Home Demand Response Program

Summer PY2019

Prepared for:

Duke Energy Progress

DUKE ENERGY®

Submitted by:

Stuart Schare
Partner

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August 19, 2020

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Included as Separate Documents

Appendix C: EM&V Sample Event-Day Load Profiles

Filename: "*Appendix C - EMV Sample Plots 2020-02-14.pdf*"

Description: Includes plots of average EM&V participant profiles and baselines on the 17 EM&V event days.

Appendix D: Output Summary

Filename: "*DEP EnergyWise Appendix D - Output Summary 2020-05-19.xlsx*"

Description: Includes all modeling outputs and graphics referred to in the report below.

Appendix E: Output Summary

Filename: "*DEP EnergyWise Appendix E – Ex Ante Tool 2020-05-19.xlsx*"

Description: Excel tool to allow user to generate ex ante predictions of DR impacts per participant under varying weather conditions, operability assumptions and times of day.

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Evaluation Summary

The EnergyWise Home (EnergyWise) demand response (DR) program offers Duke Energy Progress (DEP) residential customers the opportunity to earn credits on their electricity bill by allowing DEP to remotely cycle and curtail air conditioners (A/C) during times of peak seasonal load in the summer months (available system wide) and space- and water-heating equipment in winter months (Western region customers only). This report covers the evaluation, measurement, and verification (EM&V) activities for the summer of 2019. For this evaluation, Guidehouse Inc. (Guidehouse, formerly Navigant Consulting, Inc.)[1] performed a data logger study and parallel analysis using DEP's recently deployed Advanced Metering Infrastructure (AMI) to estimate program impacts.

At the time of the final program-wide summer event of 2019, the program had nearly 187,000 participants, representing nearly 240,000 controlled appliances. DEP called two program-wide curtailment events in the summer of 2019, the first being a 30-minute full shed (100% cycling) event, and the second being a two and a half hour 65% cycling event. In addition, DEP called 17 EM&V events that were applied only to the sample of participants who were involved in the data logger study, known as the "EM&V sample". The estimated program impacts for the two program-wide events are shown in Table 1.

Table 1. Program-Wide Event Impacts

Event Date	Cycling Strategy	Temperature (ºF)	Impact Per Participant (kW)	Relative Precision +/-% (90% Confidence)	Disconnection Rate	Pop. Avg. Impact per Participant (kW)	Total Program Impact (MW)
2019-07-02	100%	93.8	1.81	16%	11%	1.61	300
2019-07-17	65%	93.9	1.17	17%	11%	1.04	194

In addition to estimating program capability (known as "ex-ante") impacts and historical (known as "ex-post") impacts for the EM&V events and program-wide curtailment events, a key objective of this evaluation was a comparison of the data logger and participant AMI data for the purposes of evaluation. The approach to this task and the results of this analysis are reported below.

Evaluation Methods

Guidehouse used three core components for the evaluation approach:

- Sample Selection and Experimental Design
- EM&V Regression Estimation
- Comparison of AMI and Logger-Estimated Impacts

[1] Guidehouse LLP completed its acquisition of Navigant Consulting, Inc. and its operating subsidiaries on October 11, 2019. For more information, see: https://guidehouse.com/news/corporate-news/2019/guidehouse-completes-acquisition-of-navigant

Sample Selection and Experimental Design

The estimated impacts presented in this evaluation report are based on a sample of participants from the overall population that agreed to have data loggers installed so that each curtailed A/C unit's consumption could be monitored in isolation of the rest of the household load. This sample of participants was also subjected to more EM&V events than the overall population to provide Guidehouse with more data points from which impacts could be estimated.

A key feature of this evaluation is the parallel analysis undertaken by Guidehouse of the EM&V sample using both logger and AMI data. Guidehouse's goal was to produce two analyses that were virtually identical, differentiated only by the input data used: quarter-hourly logger data, or quarter-hourly AMI data. By eliminating all differences except for the input data for the dependent variable, Guidehouse's goal was to isolate only those differences that were due to the different data sources.

As in all previous evaluations since 2016, Guidehouse worked with DEP to carefully select EM&V events to maximize the value of information they provided for the estimation of program capability and used a robust experimental design to ensure estimates of impacts are unbiased. In this case the experimental design requires that for any given EM&V event only half of the EM&V sample are curtailed, ensuring a contemporaneous control group for all events.

EM&V Regression Estimation

As in previous years, impacts were estimated through the use of panel data fixed-effects regression. Guidehouse took great care in preparing the analytical work to eliminate any differences between the analysis applied to the EM&V participants' logger data and their AMI data. An observation of demand for a given point in time was included only if it was available in both data sets, and the regression specification applied to both data sets is identical. The estimation data sets are of identical dimensions.

Comparison of AMI and Logger-Estimated Impacts

Guidehouse compared impacts estimated using both sets of data closely. When differences were observed, despite being statistically non-significant, Guidehouse carefully considered the relative benefits of the two sources of data, and concluded that—for the purposes of evaluating the overall program impacts and capability—the AMI data are more suitable.

In considering the two data types, and the relative advantages each of them offer and the fact that the estimated impacts derived from both sources of data are very similar, Guidehouse has concluded that:

- **AMI data delivers more accurate impacts.** It is likely that for this evaluation the AMI-estimated impacts drawn from the EM&V sample of participants are a more accurate reflection of the average impact per participant than those derived from the logger data (since AMI data tracks true power and accounts for any secondary effects, such as the use of fans to provide additional cooling during events).

- **AMI data are much less costly to collect than logger data.** DEP could reduce future evaluation costs by not deploying data loggers in years in which an empirical analysis is required, and instead use the data provided by the existing (and continually expanded) AMI network.

Finally, in addition to the above, Guidehouse undertook an ad hoc analysis of DEP system load data to compare with estimated population impacts derived from the EM&V sample's AMI data. Guidehouse's simplified system load analysis appears to validate the EM&V estimation, delivering an estimated impact of 296 MW for the July 2 full shed event, very close to the estimated 300 MW delivered by the parameters estimated using the EM&V sample's AMI data.

Findings and Conclusions

The principal EM&V findings and conclusions regarding the summer event demand impacts for PY2019 are as follows:

- **AMI data will provide a more accurate estimate of program impacts.** Logger data obtained from outdoor loggers that do not monitor true power but rely on spot measurements of compressor power factor will not match the accuracy delivered by the AMI network. Furthermore, there may be other event-related impacts not captured by outdoor loggers such as supplemental cooling by non-controlled HVAC equipment (window AC units) or changes in AHU fan runtime. Guidehouse recommends that future evaluations be undertaken using AMI data.

- **Estimated impacts for 100% cycling population event are in line with previously estimated per participant program capability.** Guidehouse has estimated that the average per participant impact during the program population 100% cycling event was 1.61 kW (approximately 1.26 kW per A/C unit curtailed). This is consistent with the predicted capability delivered by the "Ex Ante Tool" (Appendix B of the Summer 2018 evaluation) which predicts an average demand impact of 1.51 kW when the disconnection rate, event temperatures and times are applied to that tool.

- **The 100% cycling (full load shed) population event delivered approximately 300 MW of demand response.** The average temperature during this event was approximately 94°F . The participant average impact of 1.61 kW multiplied by the 186,285 participants enrolled at the time delivers 300 MW. An additional validation exercise carried out with system-level minute-by-minute data provides an estimated system impact for this event of 296 MW (see Appendix B).

- **Estimated impacts for the 65% cycling population event are in line with previously estimated per participant program capability.** The average temperature during this event was approximately 94°F. Guidehouse has estimated that the average per participant impact during the program population 65% cycling event was 1.04 kW (approximately 0.81 kW per A/C unit curtailed). This is approximately 7% lower than the impact delivered by the "Ex Ante Tool" referred to above, well within the band of relative precision (+/- 17%) for this estimate.

- **The estimated program capability at design criteria temperature (100°F) for a connected switch is 1.44 kW per participant when applying 65% cycling and 2.29 kW per participant when applying 100% cycling.** On a per A/C unit basis, these estimates are 1.12 kW (65% cycling) and 1.79 kW (100% cycling). These values must be de-rated by the assumed disconnection rate of 11% before scaling them to the participant population size. This derating results in a capability of 1.28 kW per participant when applying 65% cycling and 2.04 kW when applying 100% cycling. Caution must be exercised when using these values as they consist of predictions outside the range of temperatures observed in the summer of 2019, in which the highest event temperature was 96°F. These impacts, as with all those included in this report, are at the meter, and do not account for losses.

- **A strong experimental design and rigorous regime of test events are crucial to delivering robust estimates of program capability.** Analysis in Appendix B demonstrates the importance of an experimental design, a carefully selected estimation sample, and a large diversity of test events for obtaining accurate estimates of program capability. The benefits of this approach are demonstrated by contrasting the EM&V estimates of population impacts with estimated impacts derived from overall system demand.

All impacts provided in this report should be considered at the meter and should be scaled up by the appropriate loss factor when, for example, determining avoided cost benefits for cost-effectiveness testing.

1.0 Introduction

The EnergyWise program provides residential customers the opportunity to earn credits on their electricity bill by allowing DEP to remotely cycle and curtail air conditioning (in the summer) and water heater and heat pump auxiliary heating strips (in the winter, Western region customers only) during times of seasonal peak load. This report covers the evaluation, measurement and verification (EM&V) activities for the summer of 2019. At the time of the final program-wide summer event of 2019, nearly 187,000 customers were participating in the AC curtailment program, representing nearly 240,000 controlled appliances.

EM&V is a term adopted by DEP and refers generally to the assessment and quantification of the energy and peak demand impacts of an energy efficiency or DR program. For DR, estimating reductions in peak demand is the primary objective, as energy impacts are generally negligible. EM&V also can encompass an evaluation of program processes and customer feedback typically conducted through participant surveys. The summer PY2019 EM&V cycle did not include a process evaluation.

DEP has been deploying residential AMI since late 2017. Certain geographic areas within the DEP service territory received AMI earlier than others. When this evaluation began in the early summer of 2019, about half of the EnergyWise participants were equipped with AMI. A key objective of this evaluation was to leverage data from the new AMI to calculate DR impacts for comparison with data loggers deployed by Guidehouse.

Guidehouse estimated impacts using quarter-hourly AMI data from a sample of 87 participating households (the EM&V sample), which also received data loggers installed by Guidehouse staff. Participating households were split randomly into two separate samples, and only one group was curtailed for each of the 17 EM&V events called by DEP throughout the summer. These groupings are referred to as Group A and Group B throughout this report. In 2019, the overall EnergyWise program population was subject to two DR events.

1.1 Objectives of the Evaluation

This EM&V report is intended to support program improvements and to verify program impacts as per the requirements established by the North Carolina Utilities Commission and the Public Service Commission of South Carolina.

The key objectives for the impact analysis conducted as part of this evaluation were identified in Guidehouse's evaluation plan; these include the following:

- **Logger Data Analysis.** Guidehouse has estimated the ex-post (actual event) and the ex-ante (projected capability under a range of temperatures) DR impacts of the EM&V sample using data collected by data loggers deployed by Guidehouse for the summer of 2019. Event-level impacts are presented in this report, and quarter-hourly impacts are included in Appendix E, an Excel spreadsheet attached as a separate document.
- **AMI Data Analysis.** Guidehouse has estimated the ex-post and ex-ante DR impacts of the EM&V sample using whole-house AMI data. Event-level impacts are presented in this report, and quarter-hourly impacts are included in Appendix E, an Excel spreadsheet attached as a separate document.
- **Comparing Impacts.** Guidehouse has compared the two sets of estimated impacts, discussed the differences between them, identified which data series is most appropriate for ongoing EM&V, and supported this assertion with evidence from some ancillary analysis.

- **Snapback Impacts.** Guidehouse has estimated the snapback impacts of events and presented them below in the same format as in previous evaluations. Quarter-hourly estimates of snapback impact are included in Appendix E, an Excel spreadsheet attached as a separate document.
- **Providing a clear technical description of the analytic approach.** A detailed description of the approach Guidehouse used may be found in Appendix E. This is most suitable for technical reviewers or those interested in reproducing the analysis. A higher-level description of Guidehouse's approach may be found in Chapter 2.0 of this report.

Guidehouse also performed an additional task to help validate the estimated program capability derived from the EM&V sample. DEP provided Guidehouse with high-frequency system demand data as well as AMI data for the EnergyWise participants for whom such data are available. These sets of data have been used to develop an ad hoc "top-down" validation procedure intended to provide readers with greater confidence in the magnitude on Guidehouse's estimated impacts. The approach and results of this analysis may be found in Appendix B.

1.2 Program Overview

The EnergyWise program was developed in response to DEP's determination that a curtailable load program would be a valuable resource for the company, and that it would provide an opportunity to engage directly with customers to help reduce costly seasonal peak demand. The program seeks to attract DR resources by providing incentives to residential customers to allow DEP to remotely cycle and curtail the most important driver of summer peak demand typically found in the home: central air conditioning.

The program offers an annual bill credit of $25 (per appliance type controlled) to customers that choose to allow DEP to cycle their central air conditioners (summer only), electric auxiliary heat strips, and/or water heaters (winter only).

Eligibility. To be eligible for participation in the summer component of the EnergyWise program, a household must meet the following criteria:

- Participants must occupy the residence where the controls are installed. Renters must complete a Tenant Authorization Form and the landlord/property owner must approve.
- Residential electricity service must be in the name of the participant, and the participant must be subject to an approved residential rate.
- Participants must be in an area that can receive the EnergyWise Home paging signal.
- Participation also requires that participants have electric central air conditioning or a centrally ducted heat pump.

Incentives. Each participant receives a $25 yearly bill credit upon joining the summer program, and then an additional $25 bill credit every 12 months they remain on the program.

Marketing. DEP is responsible for all marketing of the EnergyWise program. Participant enrollments are generated through a mix of direct mail, bill inserts, email, outbound calling, and door-to-door canvassing.

1.3 Reported Program Participation

This section reports the overall program participation for the summer EnergyWise program in the summer of PY2019. In total, approximately 186,285 individual customers participated in the 100% full shed test event on July 2, and 186,844 individual customers participated in the 65% event on July 17. The date, time, and length of each event and other characteristics are provided in Table 1-1.

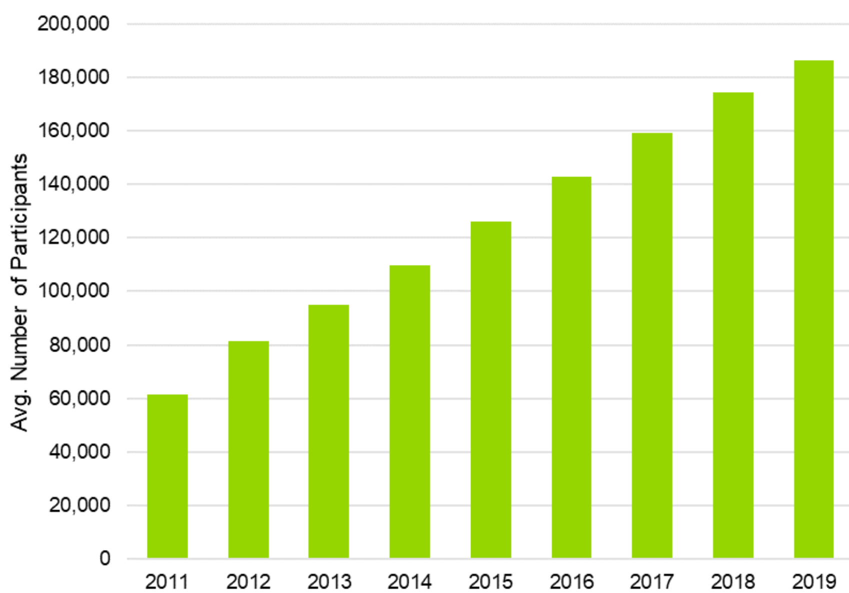
Table 1-1. Overall Summer PY2019 Program Participation by Event

Date	Start Time	End Time	Event Length (Hours)	Number of Participants	Number of A/C Units	Cycling Strategy	Temperature (°F)
2019-07-02	16:30	17:00	0.5	186,285	238,588	100%	94
2019-07-17	15:30	18:00	2.5	186,844	239,323	65%	94

Source: DEP

Since 2011, program growth has been stable and consistent at approximately 15,000 incremental participants joining per year (see Figure 1-1).

Figure 1-1. Historical EnergyWise Summer Participation



Source: DEP

Altogether the 186,844 participants that were enrolled for the last event of 2019 have a total of 239,323 central air-conditioning units enrolled, or approximately 1.28 per participant. This ratio has not changed meaningfully over time; in the first year Guidehouse evaluated this program there were approximately 1.3 enrolled central air conditioners enrolled for each participant, a statistically identical value to that in PY2019.

2.0 Evaluation Methods

This chapter of the evaluation report provides a description of the approaches used to conduct the impact evaluation. Additional technical details of the approach used may be found in Appendix A.

Guidehouse estimated demand reduction and snapback impacts using a fixed effects regression analysis applied to participant interval data (logger and AMI data), weather data, and data flags indicating the intervals in which events took place. The remainder of this chapter details the data and the econometric method used in the analysis. Appendix A provides further discussion of the regression models used.

This chapter is divided into three sections:

- **EM&V Sample Participants and Events.** This section describes the sample of participants exposed to the EM&V events, and the timing and temperatures associated with those events.
- **Data Used for Impact Evaluation.** This section describes the data used to estimate impacts and, where relevant, how it was collected.
- **Method for Estimating Capability and Impacts.** This section describes the empirical approach used by Guidehouse to estimate the relationship between event periods and event impacts required to deliver ex-ante (capability) and ex-post (historical) impacts.

2.1 EM&V Sample Participants and Events

The estimated impacts presented in this evaluation report are based on the AMI data from a sample of participants from the overall population that also agreed to have data loggers installed so that each curtailed device's consumption could be monitored in isolation of the rest of the household's demand. This sample of participants was also subjected to more events than the overall population to provide Guidehouse with more data points from which impacts could be estimated.

Altogether, Guidehouse obtained useable logger data from 87 participating homes with controlled AC units (out of 104 homes at which loggers were installed).[2] In addition to logger data, Guidehouse was provided with quarter-hourly AMI data for these participating homes to allow the parallel analysis described below.

A key feature of this evaluation is the parallel analysis undertaken by Guidehouse of the EM&V sample using both logger and AMI data. Guidehouse's goal was to produce two analyses that were virtually identical, differentiated only by the input data used: quarter-hourly logger data, or quarter-hourly AMI data. By eliminating all differences except for the input data for the dependent variable, Guidehouse's goal was to isolate only those differences that were due to the different data sources. This is discussed in greater detail below.

Guidehouse randomly allocated each EM&V participant site to one of two groups: Group A and Group B. This enabled a randomized control trial (RCT) experimental design, where when one group is subject to curtailment, the other is not. This means that only event days needed to be included in the analysis. Guidehouse then randomly assigned participants to one group or the

[2] The data for the remaining homes was discarded during the QC process for a variety of reasons, including logger failure, significant gaps in data, and several A/C units that had been replaced during the duration of the study.

other by using summer energy usage strata. The purpose of this approach (discussed in greater detail below) was to improve estimation accuracy.

A key concern of DR evaluations when all participants are subject to the same events is that there remain some non-event days that sufficiently resemble (in terms of temperature and other factors) the event days. This is required to allow for the estimation of a robust baseline. One problem with this approach is that often events are highly correlated with extreme weather events, meaning that baselines are often projected out of sample (i.e., baselines are predicted over temperature conditions that may not actually have been observed on non-event days).

Subjecting only half of all EM&V participants to each event ensures the existence of event-like, non-event days in the sample and provides additional information (from the non-curtailed devices) that helps estimate the counterfactual event demand (the baseline). These factors improve model accuracy by substantially reducing the likelihood of model specification bias compared to a purely within-subject approach.

EM&V participants were subjected to 17 DR events, Seven for Group A, 10 for Group B. The date, time, event length, EM&V group controlled, appliances controlled, and mean event temperature (in °F) are shown in Table 2-1.

Table 2-1. Air Conditioner EM&V Sample Participation

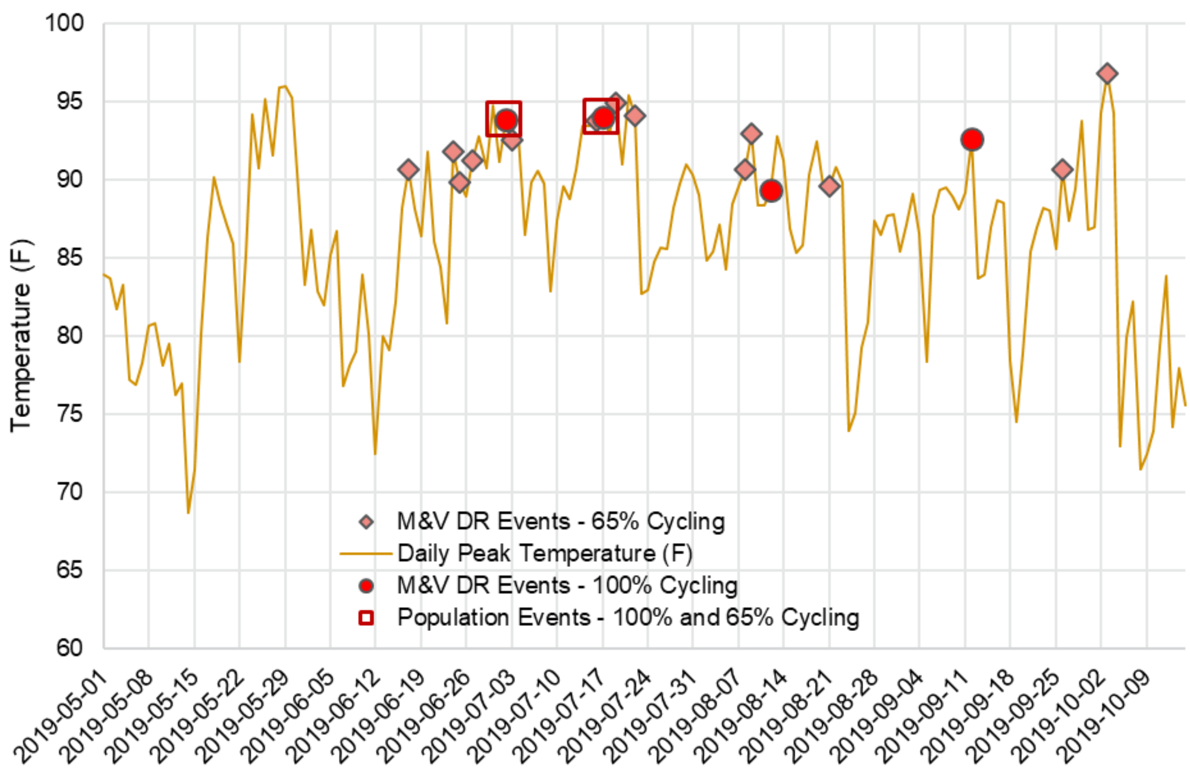
Date	Start Time	End Time	Event Length (Hours)	Number of Participants	Number of A/C Units	Cycling Strategy	Temperature (°F)	M&V Group
2019-06-17	16:00	18:00	2	44	58	65%	90	A
2019-06-24	17:00	19:00	2	42	55	65%	92	A
2019-06-25	16:00	18:00	2	40	56	65%	89	B
2019-06-27	16:00	18:00	2	40	56	65%	91	B
2019-07-02	16:30	17:00	0.5	43	59	100%	94	B
2019-07-03	16:00	18:00	2	44	58	65%	92	A
2019-07-16	16:00	18:00	2	43	59	65%	90	B
2019-07-17	16:30	17:00	0.5	44	58	100%	94	A
2019-07-19	16:00	18:00	2	44	58	65%	94	A
2019-07-22	16:00	18:00	2	43	59	65%	92	B
2019-08-08	17:00	19:00	2	42	58	65%	90	B
2019-08-09	17:00	19:00	2	42	55	65%	93	A
2019-08-12	16:30	17:00	0.5	42	58	100%	87	B
2019-08-21	16:00	18:00	2	39	54	65%	89	B
2019-09-12	16:30	17:00	0.5	40	53	100%	92	A

Date	Start Time	End Time	Event Length (Hours)	Number of Participants	Number of A/C Units	Cycling Strategy	Temperature (ºF)	M&V Group
2019-09-26	17:00	19:00	2	37	52	65%	89	B
2019-10-03	17:00	19:00	2	35	50	65%	96	B

Sources: Guidehouse logger data, DEP event schedule data, and National Oceanic and Atmospheric Administration (NOAA) temperature data

Figure 2-1 illustrates the timing of the EM&V and population events across the summer. The daily peak temperature is shown as the yellow line. EM&V events are indicated by pink diamonds (65% cycling events) or red circles (100% cycling). The two population events are indicated by the transparent red squares.

Figure 2-1. Timing and Temperature of EnergyWise DR Events



Sources: DEP event schedule data and DEP-provided temperature data

2.2 Data Used for Impact Evaluation

The impact evaluation made use of four sources of data:

- **Logger data.** Five-minute interval logger data from loggers connected to each participating HVAC unit in an EM&V participant's home. These data were aggregated to quarter-hourly frequency for the analysis.
- **AMI data.** Quarter-hourly interval AMI data from EM&V participants' AMI meters.

- **Event scheduling data.** The schedule of events deployed to the program population and the EM&V groups.
- **Weather data.** DEP provided hourly weather data to ensure the impact analysis weather data are consistent with the weather DEP uses for load forecasting. The weather file contains timeseries dry bulb temperature data for multiple cities in the service territory. DEP provided a set of weights for each city which Guidehouse used to average the temperature into a single dataset. To align the data with the logger and AMI datasets which are both at 15-minute intervals, Guidehouse interpolated the hourly weather to quarter-hourly values, assuming the value in each hour was recorded at 15 minutes past the hour.

In May 2019, Guidehouse installed loggers on 133 outdoor AC compressors at 104 participant homes. The field technicians enclosed the data loggers inside the AC unit's electronics access panel. The data loggers were set to log at 5-minute intervals and remained in the field from mid-May through mid-October, or approximately 5 months.

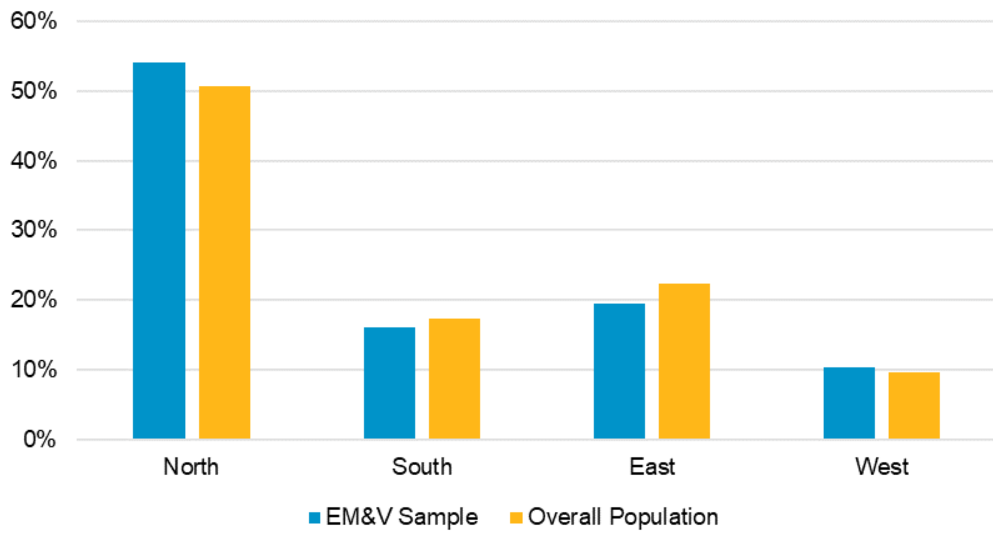
Data logger installers visited 121 residences during the deployment of the data loggers. Of these:

- There were two sites at which data logger installation was not possible due to poor access, no accessible disconnecting means, impending AC replacement planned, etc.
- There were 15 sites (each with a single EnergyWise switch) at which the switch that controls equipment cycling was either non-functional or disconnected. Based on the 135 switches inspected and the discovery of the 15 non-functioning switches (that were not logged), this delivers an operability rate of 88.9%.[3] This value has been applied to aggregate program-level savings values included in this report.

The selection of EM&V participants was made to ensure that the sample had a reasonably representative mix of number of appliances controlled, that the sample was geographically representative of the participant population, and that all EM&V participants had AMI data available to enable the comparative analysis described below. Figure 2-2 shows the geographic distribution by DEP region of the EM&V sample (yellow columns) and the overall population (blue columns).

[3] This operability rate is lower than in 2016 when the study was last conducted. Anecdotally there were a number of switches that were disconnected due to AC replacements, which may have been due to flooding and other damage caused by hurricanes or other storms that have occurred since the 2016 study took place, especially Florence in 2018 which saw widespread flooding.

Figure 2-2. Geographic Distribution of EM&V Sample and Population



Source: Guidehouse analysis

2.3 Method for Estimating Capability and Impacts

As noted above, a distinguishing feature of the summer 2019 evaluation is the parallel analysis applied to EM&V participant logger and AMI data. This analysis was structured by Guidehouse such that any differences in estimated impacts would be attributable only to qualities of the input data themselves. As such, when pursuing the two analyses, Guidehouse ensured that:

- The model specification (i.e., the regression equation) applied to both the AMI and logger data was identical.
- The time series for each participant was identical across both series. That is, an observation for a given participant in a given quarter hour was only included in the logger data estimation set when it was also present in the AMI data set, and vice versa.

Guidehouse used an econometric technique known as a fixed effects regression to estimate the impacts of the devices curtailed. Fixed effects regression is a form of linear regression commonly used to estimate the impact of DR programs. The technique is applied to a set of observations of some variable of interest (in this case electricity demand) from several different individuals (i.e., program participants)—also known as longitudinal or panel data—over time.

Fixed effects regression assigns each individual appliance its own dummy variable. In this way, Guidehouse may control for each individual's time-invariant characteristics such as the size of a participant's home, its orientation, etc. The fixed effects regression equation was estimated twice; once using the logger data, once with the AMI data.

EM&V events with two different cycling strategies were deployed in the summer of 2019. There were four 100% cycling events (30 minutes each), and thirteen 65% cycling events (two hours each). A separate regression was estimated for each of the two types of event. Event impacts were estimated as a function of the quarter-hour of the day in which the event took place and the 3-hour exponential moving average of cooling degree quarter hours. Impacts are estimated as a function of temperature in order that program capability can be projected for any given set of temperatures.

Formal model specifications with additional input variable detail may be found in Appendix A of this report.

All estimates of uncertainty presented in this report are derived from standard errors that have been clustered at the individual participant level.

3.0 Impact Findings

The discussion of program impacts on winter demand is divided into the following sections:

1. **Comparison of AMI and Logger-Estimated Impacts.** This section provides graphics demonstrating the quality of the baseline estimated using both AMI and logger data, compares the estimated impacts derived from each set of data, notes the differences, provides a reasonable hypothesis for explaining these differences and concludes by recommending which data set is likely to deliver impacts that are more accurate.
2. **Historical (Ex-Post) Impacts.** This section provides the estimated impacts of A/C curtailment during the 17 EM&V events as well as the two population events.
3. **Forecast Curtailment Capability.** This section provides the estimated DR capability of A/C curtailment across a variety of different temperatures.
4. **Net-to-Gross.** This section outlines why the appropriate net-to-gross factor for this program should be 1.

All impacts reported in this chapter should be considered “at the meter” and should be scaled up by the appropriate loss factor when, for example, determining avoided cost benefits for cost-effectiveness testing.

3.1 Comparison of AMI and Logger-Estimated Impacts

Historically, ex-post and ex-ante EnergyWise demand response impacts have been estimated using data collected from data loggers deployed to a representative sample of participating households (see Section 2.2). With the recent availability of AMI data for some participants, DEP requested that Guidehouse continue to select an EM&V sample (so that a relatively large number of test events could be called), deploy data loggers, but also collect AMI data. Guidehouse then produced side-by-side estimates using both sets of data to help DEP understand what the potential implications could be if future evaluations were to be undertaken with AMI data only. As noted in Section 2.3, Guidehouse explicitly designed the estimation process so as to ensure that the only difference between the two analyses was the data used in the estimation.

Note that all the impacts presented in this section are the directly estimated impacts from the two data sources, and do not reflect two important adjustments that are applied in order to scale EM&V sample per-participant impacts to the population: the disconnection rate (Guidehouse does not deploy loggers to homes where it is found that the load switch has been disconnected) and the average number of controlled appliances per home (on average participants in the EM&V sample have 1.36 controlled appliances each, whereas the average program participant in the program as a whole has 1.28 controlled appliance).

This section is divided into four sub-sections:

1. Comparison of 65% Cycling Impacts
2. Comparison of 100% Cycling Impacts
3. Identifying the Most Appropriate Data for Analysis: Logger vs. AMI
4. Recommendations for this and Future Evaluations

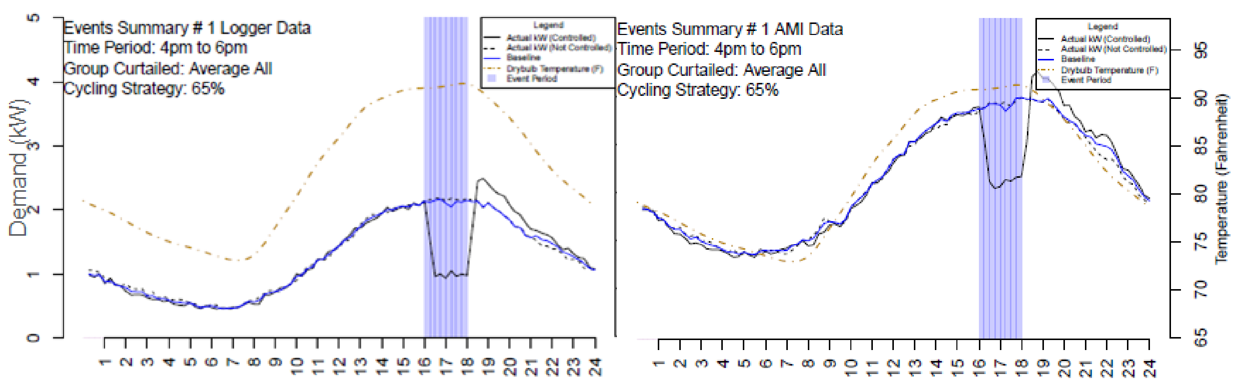
3.1.1 Comparison of 65% Cycling Impacts

For the 65% cycling events, both AMI and logger data appear to be delivering strong baselines, as may be seen in Figure 3-1.

This figure provides two plots. The profile and baseline on the left is derived from participant logger data, and the profile and baseline on the right is derived from participant AMI data. Both plots show the average observed demand of curtailed participants (black solid line) and of un-curtailed participants (black dotted line). Also shown by the blue solid line is the estimated counterfactual demand from curtailed participants—the baseline. This is the demand predicted by the regression-estimated model parameters under the assumption that no event takes place. The average difference between these two lines delivers the estimated impact. These three lines are all read against the left axis, which shows average kW. The dark yellow dashed line shows the average dry bulb temperature in each period in Fahrenheit, and is read against the right axis.

The difference in magnitude between the streams of data is that the logger data on the left-hand side of the figure above shows only the demand from the controlled (curtailed) A/C compressors in EM&V participant households, whereas the graph on the right shows the demand used by the whole home.

Figure 3-1. Baselines and Load Profiles – 65% Cycling



Sources: Guidehouse logger data, DEP EnergyWise participant AMI data, DEP event schedule data, DEP-provided temperature data, and Guidehouse analysis

Plots for each event individually, for both logger and AMI data analyses may be found in Appendix C, in a separate document.

The average estimated impact of the thirteen 65% EM&V cycling events delivered by the AMI data is 1.12 kW, with a relative precision of +/-17.06%. The relative precision indicates that the 90% confidence interval that surrounds the point estimate of 1.12 kW extends from 0.93 kW to 1.32 kW.[4]

The average estimated impact of the same thirteen EM&V events delivered by the logger data is 1.04 kW, approximately 6.8% less than that delivered by the AMI data. The relative precision of

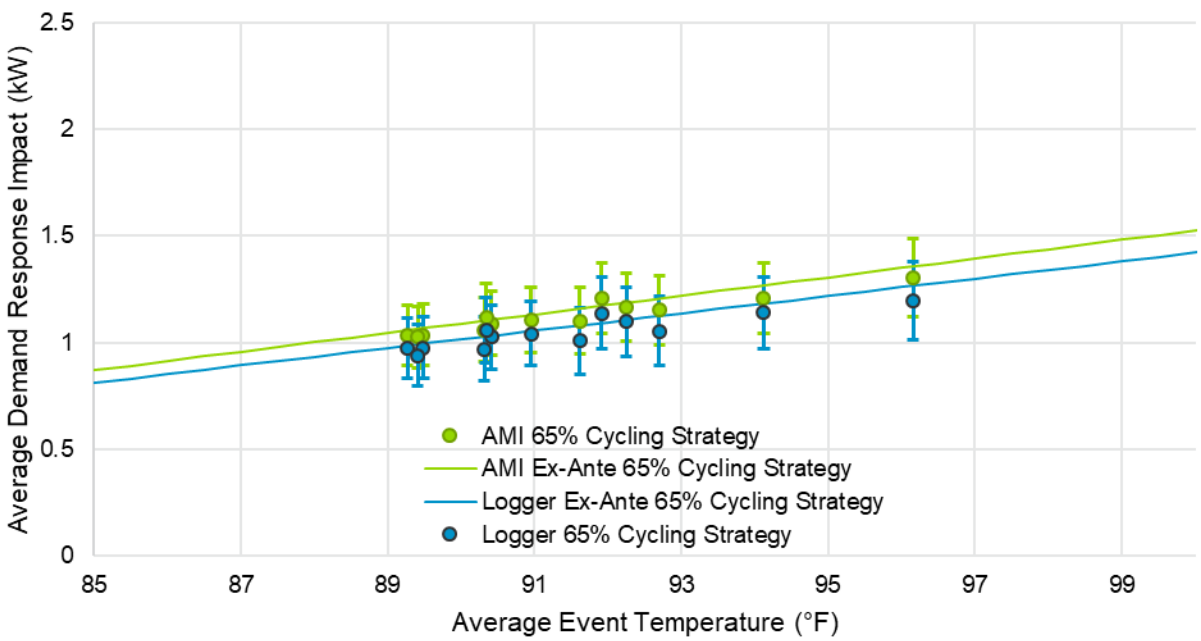
[4] As per the requirements of the DOE's Universal Methods Project for evaluation with panel data, all standard errors are clustered at the individual participant level.

U.S. Department of Energy, *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures January 2012 – September 2016,* August 2018 the logger data estimate is +/- 14.98%, meaning that the 90% confidence interval that surrounds the point estimate of 1.04 kW extends from 0.89 kW to 1.2 kW.

The difference between the two sets of average impacts is not statistically significant at the 90% level of confidence. This means that we cannot reject the hypothesis that there is no difference between the two sets of estimated values. The proximity of the results and their confidence intervals are shown in Figure 3-2.

In this graph, the ex-post impact/event temperature pairs are represented by blue (logger data) and green (AMI data) circle markers. The whiskers represent the 90% confidence interval around each estimate, and the lines running through the markers represent the ex-ante predictions for the series of temperature values shown in the x-axis.

Figure 3-2. Comparison of 65% Cycling Impacts, AMI vs. Logger Data



Sources: Guidehouse logger data, DEP EnergyWise participant AMI data, DEP event schedule data, DEP-provided temperature data, and Guidehouse analysis

As shown above, the distance between the two sets of estimates is very small, and the confidence intervals of the ex-post estimates show considerable overlap, indicative of the statistical non-significance of the difference highlighted above.

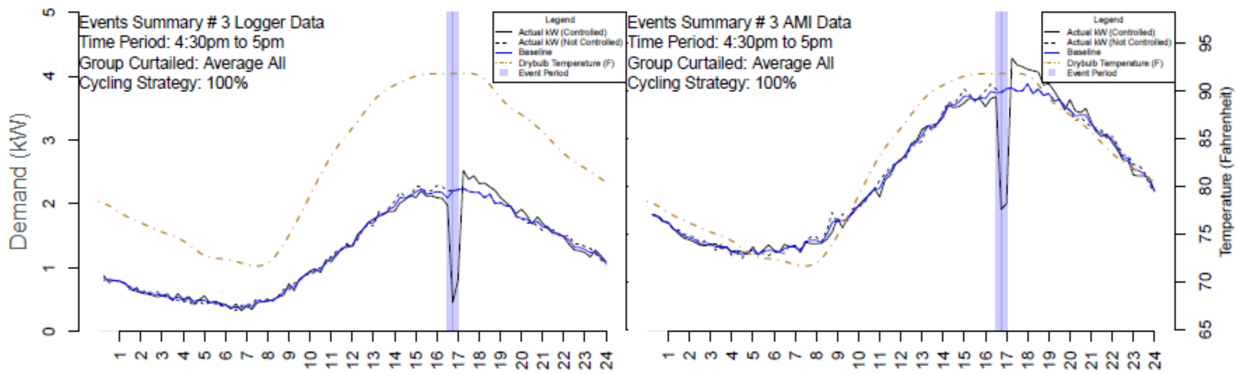
3.1.2 Comparison of 100% Cycling Impacts

For the 100% cycling events, both AMI and logger data appear to be delivering strong baselines, as seen in Figure 3-3.

This figure provides two plots. The profile and baseline one the left is derived from participant logger data, and the profile and baseline on the right is derived from participant AMI data. As above, both plots show the average observed demand of curtailed participants (black solid line) and of un-curtailed participants (black dotted line), as well as the estimated baseline (blue line) and the temperature (yellow dashed line, read off the right-hand axis).

The difference in magnitude between the streams of data is that the logger data on the left-hand side of the figure above shows only the demand from the controlled (curtailed) A/C compressors in EM&V participant households, whereas the graph on the right shows the demand used by the whole home.

Figure 3-3. Baselines and Load Profiles – 100% Cycling



Sources: Guidehouse logger data, DEP EnergyWise participant AMI data, DEP event schedule data, DEP-provided temperature data, and Guidehouse analysis

Plots for each event individually, for both logger and AMI data analyses may be found in Appendix C, in a separate document.

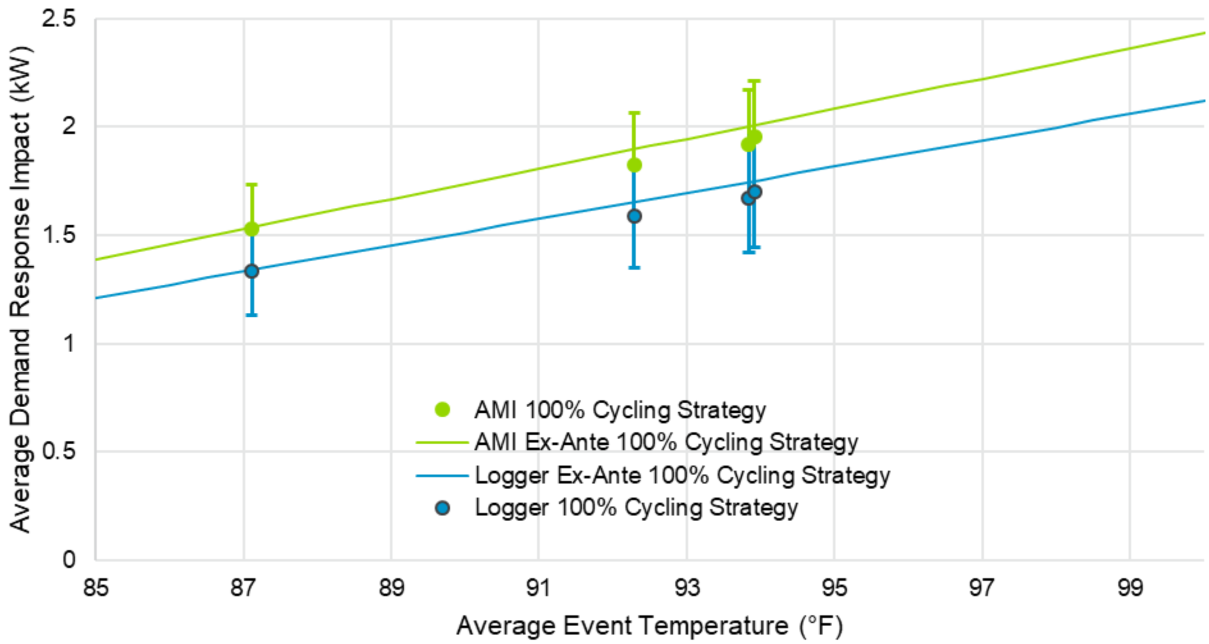
The average estimated impact of the four 100% cycling events delivered by the AMI data is 1.81 kW, with a relative precision of +/-15.7%. The relative precision indicates that the 90% confidence interval that surrounds the point estimate of 1.81 kW extends from 1.52 kW to 2.09 kW.

The average estimated impact of the same four events delivered by the logger data is 1.58 kW, approximately 12.8% less than that delivered by the AMI data. The relative precision of the logger data estimate is +/- 15.14%, meaning that the 90% confidence interval that surrounds the point estimate of 1.58 kW extends from 1.34 kW to 1.81 kW.

The difference between the two sets of average impacts is not statistically significant at the 90% level of confidence. This means that we cannot reject the hypothesis that there is no difference between the two sets of estimated values.

The proximity of the results and their confidence intervals are shown in Figure 3-4, below. In this graph, the ex-post impact/event temperature pairs are represented by blue (logger data) and green (AMI data) circle markers. The whiskers represent the 90% confidence interval around each estimate, and the lines running through the markers represent the ex-ante predictions for the series of temperature values shown in the x-axis.

Figure 3-4. Comparison of 100% Cycling Impacts, AMI vs Logger Data



Source: Guidehouse analysis

As shown above, the distance between the two sets of estimates is small, but not as small as the distance between the 65% cycling events. Although the confidence intervals of the ex-post estimates show considerable overlap, indicative of the statistical non-significance of the difference highlighted above, Guidehouse believes that the difference between the two sets of values is sufficiently material to warrant additional consideration. Often (though not always), in empirical evaluation, a non-significant result is treated as a no impact. In this case, however, despite the statistical non-significance of the difference between the two sets of impacts, the difference is substantial enough to warrant some additional consideration. The possible reason for this difference is discussed in the section that follows this one.

3.1.3 Identifying the Most Appropriate Data for the Analysis: Logger vs. AMI

Guidehouse carefully designed its parallel analysis of the logger and AMI data ensure that any differences between the estimates provided by the two sets of data could be attributable only to physical processes underlying the data, and not some artifact of the analysis itself. Despite finding that the differences between the estimated impacts derived from the two sets of data are not statistically significant, the magnitude of the absolute difference made it clear that this report should include some analysis to identify which source of data would be most appropriate for delivering evaluated impacts for PY2019, and for future evaluations of this program. Table 3-1 provides a summary of different factors that affect the results based on the source of the data (i.e., AMI vs. logger).

Table 3-1. AMI vs Logger Data by Characteristic

Characteristic	AMI Data	Logger Data	Advantage
Observed Value	AMI meters measure true power on a quarter-hourly basis.	Data loggers[5] measure amperage not true power.[6] Power values are estimates obtained by applying observed amps to spot-measurements of A/C compressor power factor.	**AMI Data.** True power is observed, vs. estimated.
Appliance Demand	AMI data measure whole-house demand. The demand of the controlled appliance cannot be observed in isolation.	Each logger provides an appliance-specific time series of demand. This enables analyses such as identifying non-response or partial response for connected devices.[7] This can be helpful to program staff as the program develops to better understand and observe technical issues associated with load switches.	**Logger Data.** With AMI data the appliance demand can only be estimated (disaggregated) not observed.
Program Impacts	AMI data measure whole-house demand, which is the combined effect of A/C curtailment (demand reductions) as well as any indirect effects (e.g., additional use of fans or window units to maintain preferred indoor temperature).	A logger data analysis considers only the appliance demand. There is a risk here that estimated impacts may not capture interactions between the appliance curtailed, and other equipment/behaviors.	**AMI Data.** If there are secondary effects impacting DR, the analysis should account for these..
Deployment and Data Collection	Data are collected automatically on an ongoing basis, and so are available at relatively low cost. Careful sampling is required, including over-sampling in some strata, as the sample of AMI-equipped participants may not be representative of the overall participant population (those with and without AMI data).	Logger deployment is very expensive. Field work is typically the single highest cost of a logger-enabled evaluation. Logger deployment (dedicated customer visits) is helpful, however, in identifying participant connectivity and operability (i.e., what portion of the population's load switch remains connected).	**AMI Data.** Though the information gathered by site visits is useful in understanding impacts, it is not sufficiently valuable to offset logger deployment costs.

To summarize, the advantage in using AMI data to estimate impacts is that:

- AMI data provides measured true power instead of an estimate of true power via logged amps and spot measurements of voltage and power factor.
- AMI data includes all loads in the home. All possible impacts are therefore taken into account in the analysis, whereas the logger data only provides estimated impacts from the primary controlled load, ignoring possible secondary effects of the event elsewhere in the home.

[5] Of the type historically deployed for the evaluation of this and other demand response programs.

[6] True power logging is more expensive and involved, so many DR evaluations utilize current transducer (CT) loggers coupled with power factor and voltage measurements. Since power factor spot measurements are only taken during logger deployment and collection (spring and fall, respectively), and compressor power factor is a function of the compressor load, spot measurements may understate A/C demand (and potentially) impacts on very hot days.

[7] In previous years' evaluations, Guidehouse has identified what proportion of A/C units (and in winter auxiliary heat strips) have failed to curtail or only partially curtailed, in response to Duke Energy's control signal.

- AMI data are much less costly to collect than logger data, though site visits for logger install can also yield useful information beyond just the logger data.

3.1.4 Recommendations for this and Future Evaluations

Given that AMI data measure true power and capture any potential secondary or offsetting effects (e.g., increased fan usage) during events, Guidehouse believes that the prudent approach for this year's evaluation is to treat the AMI data-estimated impacts as the best available estimates of demand response impacts on a per-participant basis. Given this finding along with the cost of deploying data loggers to an EM&V sample and the increasing availability to participant AMI data, Guidehouse recommends that all future evaluations of the EnergyWise home program be conducted with AMI data obtained from an EM&V sample of program participants.

Guidehouse would further recommend that DEP consider recruiting an EM&V sample of participants every year to be subjected to EM&V curtailment events, given the substantial reduction in evaluation costs from foregone fieldwork. The impacts of these EM&V events (and resulting project capability) could then be produced on either an annual basis, or processed and evaluated every 3 years (if the current triannual evaluation cycle is maintained).

This would enable DEP to better understand the evolving capability of its program in response to the changing characteristics of the program population or other exogenous events (e.g., identifying changes in estimated switch disconnection rates in response to flooding).

3.2 Historical (Ex-Post) Impacts

The ex-post impacts are the estimated impacts for the actual events that were called in the summer of 2019. This section is divided into three sub-sections.

1. **Population Event Impacts.** This sub-section summarizes the estimated program-level impacts of the two events called for the entire program population.
2. **EM&V Event Impacts.** This sub-section summarizes the estimated impacts of the 17 events called for the EM&V sample.
3. **Quarter-Hourly DR and Snapback Impacts.** This sub-section summarizes the average quarter-hourly EM&V event and snapback across the three types of events: the 65% cycling strategy events that began at 4pm and ended at 6pm, the 65% cycling strategy events that began at 5pm and ended at 7pm, and the 30-minute 100% cycling strategy events.

Note that, per the findings of Section 3.1, above, all results presented in the remainder of this chapter are derived from those estimated using EM&V participant AMI data.

3.2.1 Population Event Impacts

This sub-section provides detail regarding the average event impacts for the two events to which the entire program population was subject in the summer of 2019.

The full population of EnergyWise participants was subject to two events in the summer of 2019:

- July 2, from 4:30 to 5pm, 100% cycling
- July 17, from 3:30 to 6pm, 65% cycling

Table 3-2 summarizes the average event impact for each of these events, when extrapolated out to the population. The average temperature during both events was approximately 94°F. The population event on July 2 began at 4:30pm and ended at 5:00pm and the population event on July 17 began at 3:30pm and ended at 6:00pm.

Table 3-2. Population Event Estimated Impacts

Event Date	Cycling Strategy	Temperature (°F)	Impact Per Participant (kW)	Relative Precision +/-% (90% Confidence)	Disconnection Rate	Pop. Avg. Impact per Participant (kW)	Total Program Impact (MW)
2019-07-02	100%	93.8	1.81	16%	11%	1.61	300
2019-07-17	65%	93.9	1.17	17%	11%	1.04	194

Source: Guidehouse analysis

Note that the 65% population event began at 3:30 pm, 30 minutes prior to the first quarter hour (4 pm to 4:15 pm) of the earliest EM&V event. There are, therefore, no quarter-hourly parameters available to deliver the impact in the period between 3:30 and 4:00 pm based on the estimated relationship between temperature and demand. Guidehouse applied the average estimated impact between 4 pm and 6 pm for this time period.

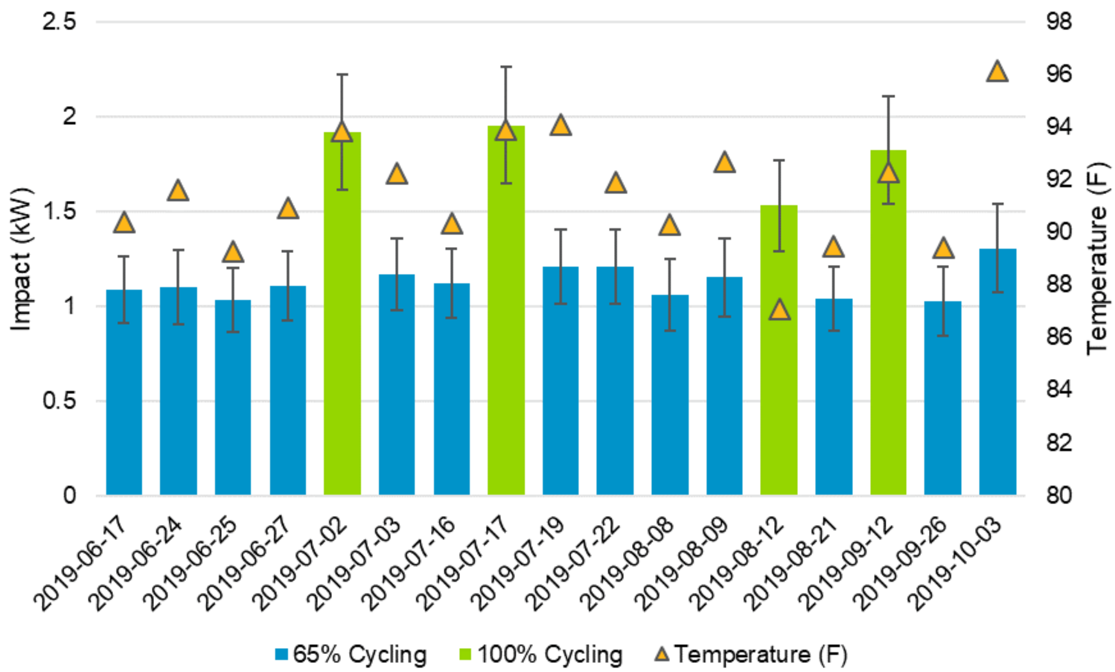
The table above reflects two key adjustments made to the estimated per-participant impact. One impact is explicit in that table—the adjustment to reflect the disconnection rate described in Section 2.2. The other is implicit and, when applied, delivers the estimated values included in the "Impact Per Participant (kW)." Guidehouse has, when using the EM&V sample impacts for projecting population impacts, scaled them to reflect the difference in the average number of controlled A/C units per participant. In the EM&V sample there are an average of approximately 1.36 controlled A/C units per participant. In the population as a whole, however there are only an average of approximately 1.28 controlled A/C units per participant.[8] The impacts in the "Impact Per Participant (kW)" reflect this adjustment. Accounting for the average of 1.28 controlled A/C units per participant, the average 100% cycling event impact of 1.61 kW per participant becomes 1.26 kW per A/C unit, and the average 65% cycling event impact of 1.04 kW per participant becomes 0.81 kW per A/C unit.

3.2.2 EM&V Event Impacts

Figure 3-5 provides a graphical summary of the estimated DR impact of A/C curtailment for all 17 of the events in the summer of 2019. Each vertical bar represents the average estimated event impact of either a 65% cycling event (blue bars) or a 100% cycling event (green bars). The 90% confidence interval is identified by the whiskers, and the yellow triangles (to be read off the right axis) identify the average event dry bulb temperature.

[8] The inputs required to replicate this value may be found in Appendix E attached as a separate document.

Figure 3-5. Average Event Impacts by Cycling Strategy



Source: Guidehouse analysis

Note that none of these impacts (nor those in the tabular summary shown in Table 3-3) have been adjusted to reflect the estimated disconnection rate or the population average number of A/C appliances per household.

The results shown above in Figure 3-5 are also summarized in a tabular fashion in Table 3-3. Note that there are three distinct type of event:

- 4 pm to 6 pm 65% cycling events
- 5 pm to 7 pm 65% cycling events
- 4:30 pm to 5 pm 100% cycling events

The values included in Table 3-3, as well as the graphic above may be found in the spreadsheet Appendix E, attached as a separate document.

Table 3-3. Average Event Impacts

Event Date	Start Time	End Time	Cycling Strategy	Estimated Impact (kW)	Relative Precision +/-% (90% Confidence)	Temperature (ºF)
2019-06-17	16:00	18:00	65%	1.09	16.3%	90
2019-06-24	17:00	19:00	65%	1.10	17.9%	92
2019-06-25	16:00	18:00	65%	1.03	16.2%	89
2019-06-27	16:00	18:00	65%	1.11	16.2%	91
2019-07-02	16:30	17:00	100%	1.92	15.7%	94
2019-07-03	16:00	18:00	65%	1.16	16.2%	92
2019-07-16	16:00	18:00	65%	1.12	16.3%	90
2019-07-17	16:30	17:00	100%	1.95	15.7%	94
2019-07-19	16:00	18:00	65%	1.21	16.2%	94
2019-07-22	16:00	18:00	65%	1.21	16.3%	92
2019-08-08	17:00	19:00	65%	1.06	17.9%	90
2019-08-09	17:00	19:00	65%	1.15	17.9%	93
2019-08-12	16:30	17:00	100%	1.53	15.7%	87
2019-08-21	16:00	18:00	65%	1.04	16.2%	89
2019-09-12	16:30	17:00	100%	1.82	15.7%	92
2019-09-26	17:00	19:00	65%	1.03	17.9%	89
2019-10-03	17:00	19:00	65%	1.31	17.9%	96

Source: Guidehouse analysis

These results may be further summarized by averaging them by type of event (cycling strategy and time span). This coarser summary is provided in Table 3-4. As noted above, these impacts have not been adjusted for the estimated disconnection rate or to reflect differences in the average number of A/C units curtailed per participant between the EM&V sample and the population. Rather these reflect the estimated values derived directly from the EM&V sample's AMI data.

Table 3-4. Average Impact by Type of Event

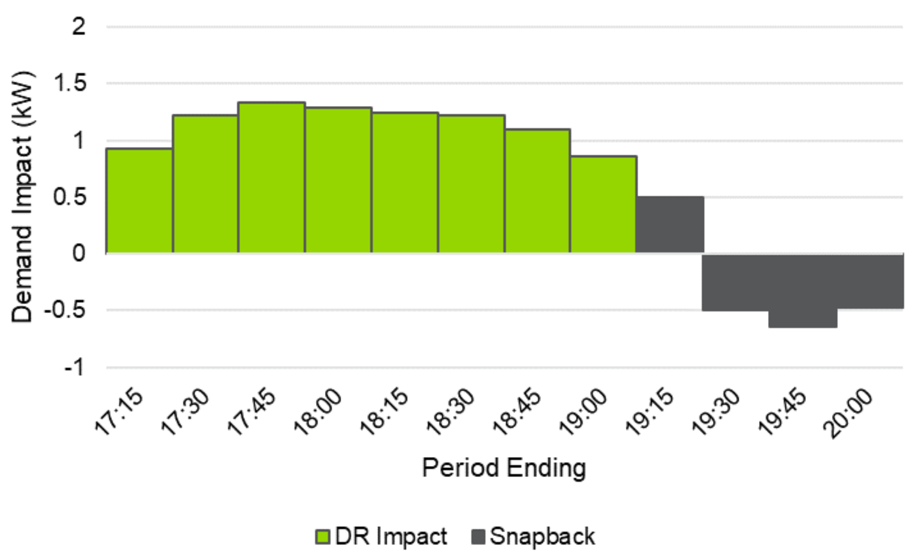
Number of Events	Start Time	End Time	Cycling Strategy	Estimated Impact (kW)	Relative Precision +/-% (90% Confidence)	Temperature (ºF)
8	16:00	18:00	65%	1.12	16%	91
5	17:00	19:00	65%	1.13	18%	92
13	All 65% Events		65%	1.12	17.06%	92
4	16:30	17:00	100%	1.81	15.7%	92

Source: Guidehouse analysis

3.2.3 Quarter-Hourly DR and Snapback Impacts

Average quarter-hourly program impacts for 65% cycling events are illustrated graphically in Figure 3-6. Although snapback is estimated for more than just a single hour following the event, only a single hour is shown in the graphics below. As may be seen, as in previous evaluations, there continue to be demand response impacts during the first hour of the snapback period. As noted in previous years, this is a result of ramping; controlled appliances are released gradually from curtailment in the period following the end of the DR event.

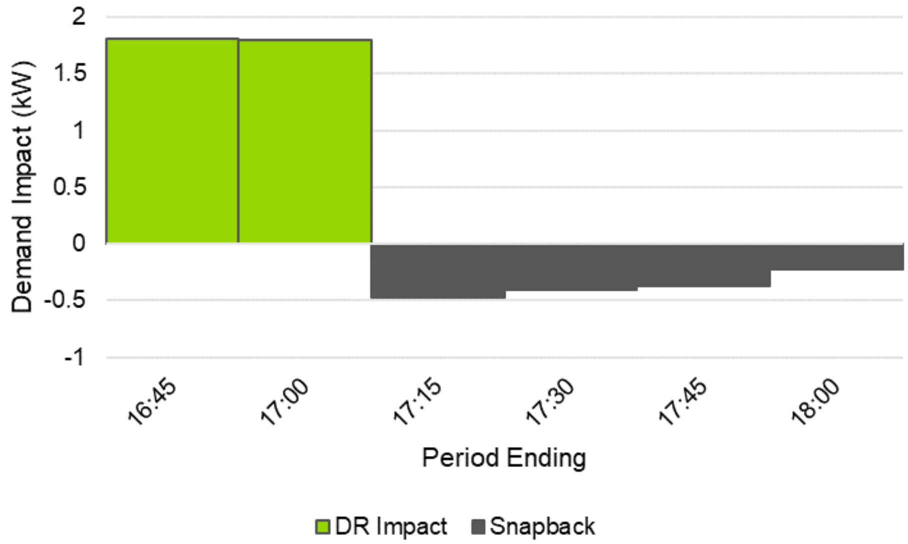
Figure 3-6. Average Quarter-Hourly Impacts – 65% Cycling



Source: Guidehouse analysis

Figure 3-7 presents the average quarter-hourly impacts across the four 100% cycling events, both during the four 30-minute test events, as well as in the first hour of the snapback period immediately following the end of the DR event. Note that unlike the longer 65% events (intended to mimic economic curtailment) there does not appear to be the same gradual relaxing of control in the snapback period, with snapback (demand increases) appearing immediately following the end of the event. The data underlying these charts may be found in Appendix E, the spreadsheet accompanying this report.

Figure 3-7. Average Quarter-Hourly Impacts – 100% Cycling



Source: Guidehouse analysis

3.3 Forecast Curtailment Capability

This section provides the estimated EnergyWise DR capability, or ex-ante impacts. These estimates are Guidehouse's projection of how much DR the program could offer under a range of different possible temperatures at different cycling levels. This estimate of capability is based on the regression-estimated relationships between DR impacts and outdoor temperature from which the ex-post impacts were also developed.

It is this forecast of capability that provides the truest estimate of a given DR program's value as a system resource because it provides DEP staff with an understanding of how much of a demand reduction the program may be counted on to deliver in future system peak conditions. This is also why it is the forecast DR capability that should be used to calculate the benefits for any cost-benefit ratio test (e.g., total resource cost test, or TRC).

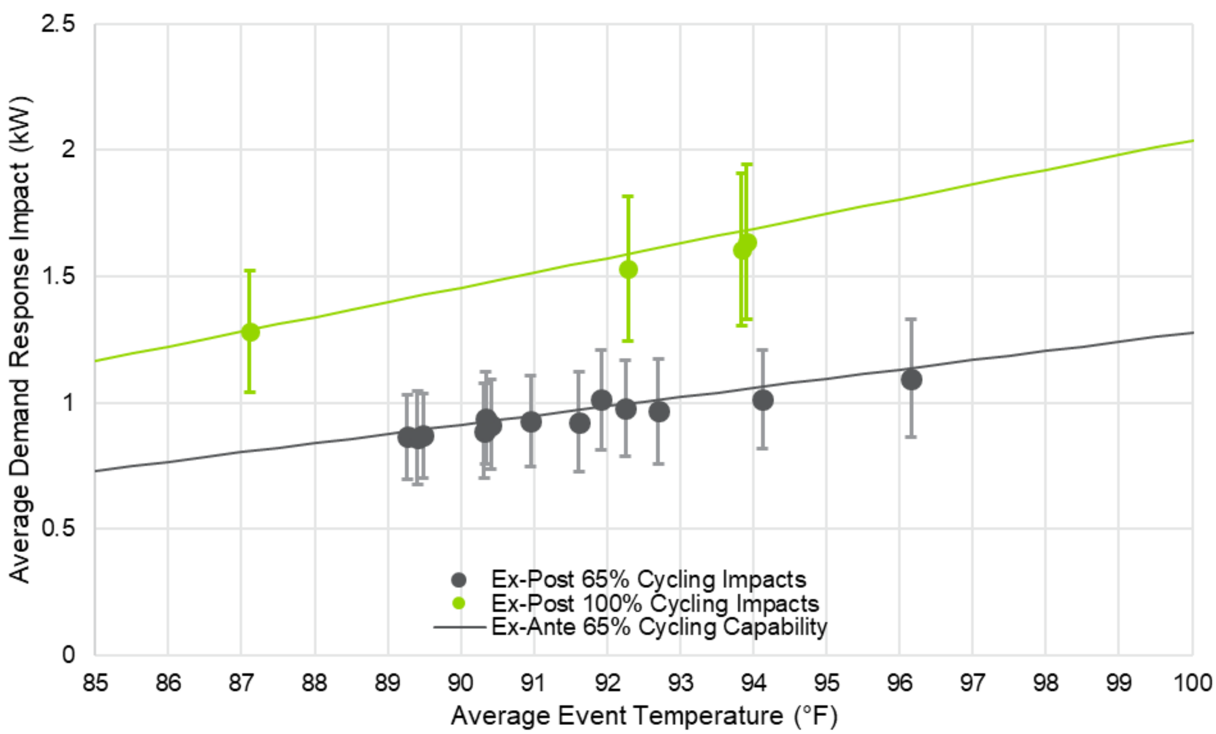
Forecast program capability per participant is projected by applying a series of temperature values to the estimated model parameters. Guidehouse's projected capability (shown in Figure 3-8) assumes that the temperature at which the capability is estimated lasts the entire length of the event and is the same as the temperature in the 3 hours leading up to the event.

This second assumption is required due to the manner in which impacts are estimated. Because homes have thermal mass, a sudden swing in outdoor temperature does not immediately provoke a concomitant swing in cooling load—it takes time for the building's indoor temperature to rise above the setpoint temperature because of that outdoor temperature swing. This is reflected in Guidehouse's estimation approach (see Appendix A for more details), where impacts are modeled as a function of a 3-hour exponential moving average of cooling degree quarter-hours (outdoor temperature). Therefore, projecting capability requires an assumption of what the temperature is in the 3 hours leading up to the event.

Figure 3-8 provides the average projected capability per participant of the program from 80°F to 100°F for 65% cycling (grey line) and 100% cycling events (green line).[9] Actual estimated EM&V event impacts are represented on this chart as grey (65% cycling) or green (100% cycling) circles, with the 90% confidence interval around each estimate represented by the whiskers. The values underlying this plot may be found in Appendix E, the Excel spreadsheet that accompanies this report.

Note that the values shown on this graph have been adjusted to reflect the two adjustments referenced in Section 3.2.1: the disconnection rate (11%) and the difference between the average number of controlled A/C units per participant in the EM&V sample (1.36) and the average number of controlled A/C units per participant in the population (1.28).

Figure 3-8. Estimated Ex-Ante Program Capability per Participant



Source: Guidehouse analysis

3.4 Net-to-Gross

Evaluations of demand-side management programs typically estimate a net-to-gross (NTG) ratio based on the evaluated percentage of demand reductions that may be ascribed either to free ridership (which increases the NTG ratio) or to program spillover (which reduces it). Free ridership is typically defined as the percentage of demand reductions that would have occurred anyway, absent the presence of the program. Spillover is typically defined as incremental demand reductions undertaken by a program's participants not directly incented or promoted by the program administrator. In this case, because demand reductions are estimated in contrast to

9 All values underlying this plot may be found in the spreadsheet appendix attached to this report as a separate document. Ex-ante values in this document go as high as 104°F.

an implied estimated baseline[10] that captures expected participant behavior absent an event, Guidehouse can confidently state that the free ridership is 0: absent the EnergyWise program, none of the observed demand reductions would have taken place. It is possible that there may have been some spillover resulting from the program (from participants becoming more aware of their sites' consumption profiles, for example). However, it is likely impossible to estimate such an effect in a sufficiently robust manner and the assessment of such impacts is beyond the scope of this report.

Since spillover cannot be robustly estimated and because free ridership must, by program design, be considered 0, Guidehouse considers the EnergyWise program to have a NTG ratio of 1.

10 That is, the average level of behavior implied by the estimated parameter values of the regressions used.

4.0 Findings, Conclusions, and Recommendations

This chapter is divided into two sections:

1. Findings and Conclusions
2. Recommendations

4.1 Findings and Conclusions

The principal EM&V findings and conclusions regarding the summer event demand impacts for PY2019 are as follows:

- **AMI data will provide a more accurate estimate of program impacts.** Logger data obtained from outdoor loggers that do not monitor true power but rely on spot measurements of compressor power factor will not match the accuracy delivered by the AMI network. Guidehouse recommends that future evaluations be undertaken using AMI data.

- **Estimated impacts for 100% cycling population event are in line with previously estimated per participant program capability.** The average temperature during this event was approximately 94°F. Guidehouse has estimated that the average per participant impact during the program population 100% cycling event was 1.61 kW (approximately 1.26 kW per A/C unit curtailed). This is consistent with the predicted capability delivered by the “Ex Ante Tool” (Appendix B of the Summer 2018 evaluation) which predicts an average demand impact of 1.51 kW when the disconnection rate, event temperatures and times are applied to that tool.

- **The 100% cycling (full load shed) population event delivered approximately 300 MW of demand response.** The average temperature during this event was approximately 94°F. The participant average impact of 1.61 kW multiplied by the 186,285 participants enrolled at the time delivers 300 MW. An additional validation exercise carried out with system level minute-by-minute data provides an estimated system impact for this event of 296 MW (see Appendix B).

- **Estimated impacts for the 65% cycling population event are in line with previously estimated per participant program capability.** Guidehouse has estimated that the average per participant impact during the program population 65% cycling event was 1.04 kW (approximately 0.81 kW per A/C unit curtailed). This is approximately 7% lower than the impact delivered by the “Ex Ante Tool” referred to above, well within the band of relative precision (+/- 17%) for this estimate.

- **The estimated program capability at design criteria temperature (100°F) for a connected switch is 1.44 kW per participant when applying 65% cycling and 2.29 kW per participant when applying 100% cycling.** On a per A/C unit basis, these estimates are 1.12 kW (65% cycling) and 1.79 kW (100% cycling). These values must be de-rated by the assumed disconnection rate of 11% before scaling them to the participant population size. This derating results in a capability of 1.28 kW per participant when applying 65% cycling and 2.04 kW when applying 100% cycling. Caution must be exercised when using these values as they consist of predictions outside the range of temperatures observed in the summer of 2019, in which the highest event temperature was 96°F. These impacts, as with all those included in this report, are at the meter, and do not account for losses.

- **A strong experimental design and rigorous regime of test events are crucial to delivering robust estimates of program capability.** Analysis in Appendix B demonstrates the importance of an experimental design, a carefully selected estimation sample, and a large diversity of test events for obtaining accurate estimates of program capability. The benefits of this approach are demonstrated by contrasting the EM&V estimates of population impacts with estimated impacts derived from overall system demand.

4.2 Recommendations

Based on the first finding above, that whole-house AMI data delivers a more accurate estimate of impacts (when the estimation sample is carefully selected, a robust experimental design applied, etc.) than logger data, Guidehouse recommends that DEP consider:

- Using AMI data for impact evaluation going forward. This will substantially reduce evaluation costs.
- Expanding the size of the EM&V sample. With a much lower per-participant cost, DEP may wish to consider expanding the size of the EM&V sample, perhaps to several thousand individuals (~1-2% of the participant population). This would allow:
  - **Greater precision.** Larger samples will mean smaller standard errors and more precise estimated impacts.
  - **Greater granularity.** With a larger sample, proportionately distributed, robust estimates of impacts can be obtained on a region-by-region basis, providing DEP with greater insight into how this resource can be used for local constraints.
  - **A more continuous insight into how capability is evolving.** If a new EM&V sample is selected every year and subjected to 12 to 20 EM&V events, DEP can more closely monitor program capability, or at least better understand how it is evolving over time. Currently, empirical evaluations of this program are conducted only approximately every 3 years (2011, 2013, 2016, 2019), largely due to the cost involved in logger deployment. With that cost eliminated, DEP might either use an annually selected EM&V sample to update its projected capability each year, or more granularly evaluate changes in capability over time every 3 years (continuing the current evaluation cycle). This could provide DEP with a better understanding of the ongoing viability of the program and opportunities it offers.

5.0 Summary Form

EnergyWise Home

Summer PY2019

Completed EMV Fact Sheet

Description of Program

Duke Energy's EnergyWise program is a DR program offered to residential customers in the DEP territory.

EnergyWise is a direct load control program. Participants receive an incentive to allow DEP to control their air conditioners (in the summer), their heat pump auxiliary heat strips (in the winter), or their electric water heaters (winter or summer). Only participants in the Western region are curtailed in the winter.

This report evaluates the capability of the program as of the summer of 2019. In summer 2019, two events were called for the entire program population (100% cycling and 65% cycling, and 17 events were called for the M&V sample used to evaluate capability.

Date:	2020-08-19
Region:	DEP
Evaluation Period	Summer 2019
DR Event Impact per Participant (kW)	
Central Air Conditioner	1.61 (100% Cycling) 1.04 (65% Cycling)
DR Event Program Impact (MW)	
Central Air Conditioner	300 (100% Cycling) 194 (65% Cycling)
Net-to-Gross Ratio	1

Evaluation Methods

Guidehouse estimated DR impacts for central air conditioners by applying regression analysis to an EM&V sample of program participants selected to be representative of the overall population.

Guidehouse applied a randomized control style experimental design, randomly allocating sample participants to one of two groups, with each group acting as a treatment or control group for different events. This ensures a robust contemporaneous control group and unbiased estimate of impacts. Impacts were estimated with panel data regression analysis.

Guidehouse has compared the estimated impacts of the two program population events with observed demand at the system level and found that changes in system level demand were consistent with the impacts estimated.

Impact Evaluation Details

- **Full load shed of A/C units delivered an average impact of 1.61 kW per household.** The total estimated program impact of the 186,285 households participating in that event was 300 MW. The relative precision is +/-16% at the 90% confidence level.

- **Cycling A/C units at 65% delivered an average impact of 1.04 kW per household.** The total estimated program impact of the 186,844 households participating in that event was 194 MW. The relative precision is +/-17% at the 90% confidence level.

- **AMI data measures true power and accounts for any secondary, non-compressor effects on demand response of A/C curtailment and should therefore be considered (when derived from a representative sample of participants) to deliver a more accurate estimate of per-participant impacts than logger data from the same participants.** Guidehouse's side-by-side analysis found that impacts estimated using the EM&V sample group's AMI data were slightly (non statistically significantly) higher than impacts estimated using the same group's logger data. A few alternative hypotheses for what might be driving these differences are identified in the text. It is recommended that future evaluations use AMI data for impact analysis.

Appendix A. Regression Model Specification

This appendix provides additional technical details regarding the model specification used by Guidehouse to estimate the impact of the 100% and 65% cycling events.

Four estimation sets were employed: one for each cycling strategy and input data combination. So:

- 65% cycling with logger data
- 65% cycling with EM&V participant AMI data
- 100% cycling with logger data
- 100% cycling with EM&V participant AMI data

In each case, only the relevant event days were included; no non-event days are included in the estimation set.

The model specification is presented, with variable descriptions, below.

$$y_{i,t} = \alpha_i + \sum_{h=1}^{H=96} \beta_1^h \cdot qhe_t^h + \sum_{m}^{M=5} \sum_{h=1}^{H=96} \beta_2^h \cdot qhe_t^h \cdot month_t^m + \sum_{h=1}^{H=96} \beta_3^h \cdot qhe_t^h \cdot hbu_t + \sum_{h=1}^{H=96} \beta_4^h \cdot qhe_t^h \cdot EMAcdqh_t + \sum_{h=1}^{H=96} \gamma_1^h \cdot qhe_t^h \cdot c_{i,t} \cdot EMAcdqh_t + \sum_{s=1}^{S=156} \gamma^s \cdot s_{it}^s + \varepsilon_{it}$$

Where:

$y_{i,t}$	=	Customer *i's* demand (kW) in quarter hour of sample *t*.
qhe_t^h	=	A set of 96 dummy variables, one for each quarter hour of the day, equal to 1 when hour of sample t falls in quarter hour of day h, and zero otherwise.
$month_t^m$	=	A set of five dummy variables, each one equal to one when quarter hour of sample t falls month m and zero otherwise.
hbu_t	=	The average heat build-up hour of sample t. This is a 72-hour geometrically decaying average of cooling degree hours. It is calculated in the following manner: $cbu_t = \sum_{h=1}^{72} 0.96^h \cdot cdh_{t-h} \Big/ 1{,}000$. This value is calculated on an hourly basis and values are then interpolated across the higher frequency quarter hours using the same approach as for the temperature data (see Section 2.2).

$EMAcdqh_t$	=	The 3-hour exponential moving average of cooling degree hours observed in quarter hour of sample t.
$c_{i,t}$	=	A dummy variable equal to one if participant i is subject to curtailment in quarter-hour of sample t, and zero otherwise.
$prekWh_{idh}$	=	Customer i's average demand during hour of day h, in day-type d of the pre-program (i.e., summer 2017) period. The day-type is that of the day on which hour of sample t falls. See A.1 for more details.
s_{it}^{s}	=	A set of 156 dummy variables to capture the effects of snapback. Each variable is equal to 1 when quarter hour of sample t is the s-th hour observed since the end of the event observed on the day on which hour of sample t occurs. For example, if the event occurs between 4:30 pm and 5:00 pm, in the interval from 5:00 pm to 5:15 pm $s_{it}^{s=1} = 1$, and all other dummies are zero; in the interval from 5:15 pm to 5:30 pm $s_{it}^{s=2} = 1$ and all other dummy variables are equal to zero, etc.

Appendix B. System-Level Validation

In previous years of the EnergyWise Home summer evaluations, Guidehouse undertook a system-level validation exercise. This was performed in the mini-analysis evaluation cycles, those years in which impacts of actual events were estimated by applying parameter estimates estimated in the logger data analysis years to observed temperature and time of day variables.

These analyses (performed for program years 2014 and 2015) were typically inconclusive, providing evidence of curtailment, but with limited precision. Since that time, the program population has grown significantly, meaning that program impacts (particularly of emergency events) are much more apparent when observing system-level data. Given this, Guidehouse and DEP determined that it would be a useful validating exercise to once more undertake a system-level analysis, identifying indicative impacts estimated based on a comparison of one-minute frequency system load data with a day-matched baseline and day-of symmetric baseline adjustment.

As implied above, this analysis depends only on two curtailment events (each with a different cycling strategy) and should be understood to be ancillary to the core analysis of the EM&V sample, which makes use of a much more sophisticated experimental design and estimation approach and includes more than eight times as many test events.

The indicative results of the system data analysis align reasonably closely with the impacts projected for the overall program population for the two events to which all participants were subject: the 100% cycling event from 4:30 to 5:00 pm on 2019-07-02 and the 65% cycling event from 3:30 to 6:00 pm on 2019-07-17. These results are reproduced from Section 3.2.1 in Table B-1 for convenience.

Table B-1. Population Event Estimated Impacts

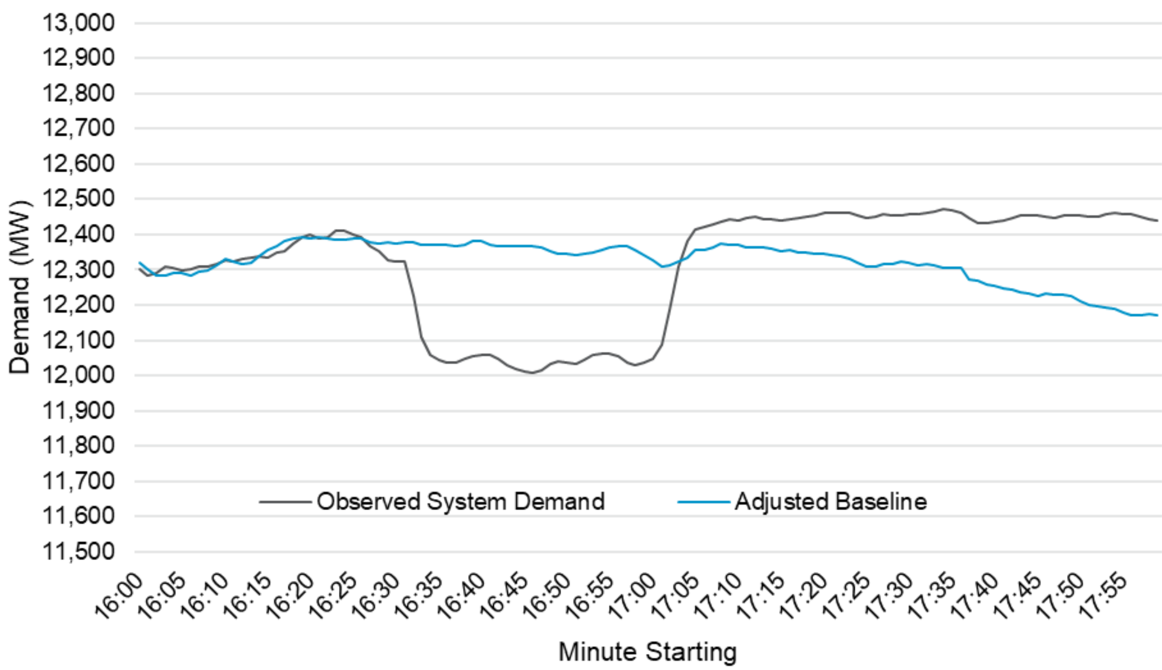
Event Date	Cycling Strategy	Temperature (°F)	Impact Per Participant (kW)	Relative Precision +/-% (90% Confidence)	Disconnection Rate	Pop. Avg. Impact per Participant (kW)	Total Program Impact (MW)
2019-07-02	100%	93.8	1.81	16%	11%	1.61	300
2019-07-17	65%	93.9	1.17	17%	11%	1.04	194

Source: Guidehouse analysis

Figure B-1 plots the actually observed minute-by-minute DEP system demand (gray line) beginning 30 minutes prior to the July 2 100% cycling event, and extending for an hour following the 30-minute event. This plot also shows a baseline (blue line) providing an approximate estimation of the counterfactual demand (i.e., what demand might have been, absent an event).[11]

[11] The approach for estimating the baseline is described in greater detail below.

Figure B-1. System Demand and Estimated Baseline – 2019-07-02



Source: DEP System Data and Guidehouse analysis

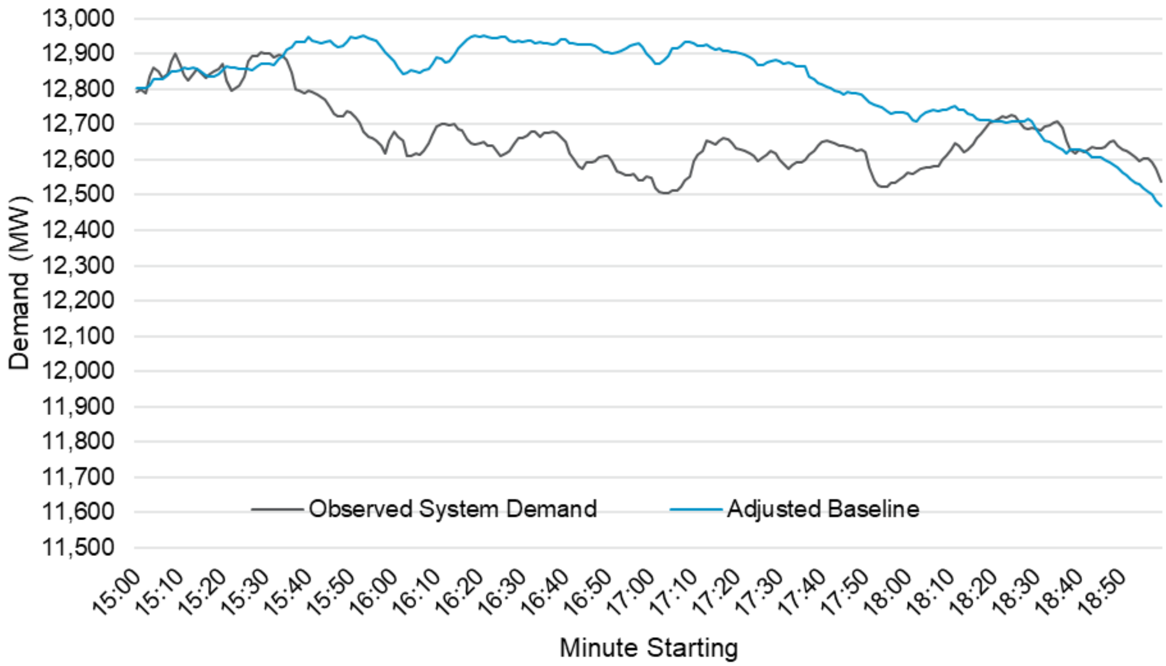
The baseline appears reasonable, in context of the observed actual and estimated counterfactual demand of the EM&V groups during events (e.g., as seen in Figure 3-3), showing alignment with actuals in the hours immediately preceding the event and evidence of some snapback in the hours following the event.

The average difference in demand between the baseline and actual demand values in this period is 296 MW. Although caution must be used to avoid over-interpreting this result (per the description below, this approach is relatively simple and does not control for non-program curtailment by other DEP customers, etc.), the estimated value here aligns very closely with the 300 MW (+/- 16%) estimated based on the EM&V sample. This alignment of results, and the intuitively appealing shape of the baseline in Figure B-1 provide additional confidence in the robustness of the estimate delivered by the EM&V data.

Figure B-2 plots the actually-observed minute-by-minute system demand (gray line) beginning 30 minutes prior to the July 17 65% cycling event and extending for an hour following the two-and-a-half-hour event. This plot also shows a baseline (blue line) providing an approximate estimation of the counterfactual demand (i.e., what demand might have been, absent an event).[12]

[12] The approach for estimating the baseline is described in greater detail below.

Figure B-2. System Demand and Estimated Baseline – 2019-07-02



Source: DEP System Data and Guidehouse analysis

The baseline appears reasonable if perhaps a bit high. The baseline and actuals are closely aligned in the hour preceding the event, but there is very little evidence of any snapback in the hour following the event.

The average difference in demand between the baseline and actual demand values in this period is 247 MW. This is higher than the estimate delivered by the analysis of the EM&V group – that impact is approximately 21% less than the value derived here. Despite this, after considering the relative uncertainty of the EM&V sample estimate (+/- 17%), system losses (the EM&V sample results are "at the meter") and other potential sources of uncertainty inherent in the relatively unsophisticated baseline approach applied to the system data, the system level results are sufficiently well-aligned to provide some additional confidence in the robustness of the estimate delivered by the EM&V data.

The baseline in both of the cases above was developed in the following way:

- Estimate an unadjusted baseline – the average demand by minute of the day across the two hottest non-event non-holiday weekdays in July and August (2019-07-19 and 2019-08-09)[13]
- Calculate the difference between the average baseline and system demand in the 30 minutes immediately preceding the event.

[13] Guidehouse had originally planned to use the *three* hottest non-event non-holiday weekdays July or August – consistent with the regression analysis applied to the AMI data of the population of participants for whom such data are available (see below). Unfortunately, upon inspection of the data, it became clear from the load shape that on one of the three day selected (2019-07-15) there appeared to be some meaningful amount of non-program peak shaving taking place. This day was therefore discarded from the baseline pool.

- Scale the entire baseline (for the given event) linearly based on that difference.

This is very similar to day-matching customer baseline (CBL) with symmetrical day-of adjustment often used for settlement in large consumer demand response programs (e.g., DEP's Demand Response Automation, DRA program). This analysis is ancillary to the core work performed with the EM&V sample, and should be understood to be an ad hoc validation exercise intended to provide Guidehouse, DEP, and readers of this report with some additional confidence in the values reported. This analysis is not, nor is intended to be, a sophisticated decomposition of DEP's system loads. Such an analysis is out of scope, and would require the use of a considerable volume of additional data.