DR-READY LED LIGHTING SYSTEMS WITH ADVANCED CONTROLS IN FAST FOOD RESTAURANTS

DR12SCE2.06 Report

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EXECUTIVE SUMMARY

This study conducted field measurements to evaluate the Demand Response (DR) capabilities of four different advanced lighting controls systems (ALCS). This evaluation specifically relates to Light Emitting Diode (LED) interior lighting in fast food restaurants.

The main objectives of the project were to:

- Determine whether the ALCS can be scheduled for reliable control of lighting loads as part of Manual DR test events
- Determine whether the ALCS can be scheduled for reliable control of lighting loads as part of an Automated Demand Response (AutoDR) test events

The study was conducted at five chain fast food restaurants. The interior lighting at the sites had previously been upgraded to dimmable LED with occupancy and daylighting controls. The DR was expected to be an added benefit to the selection of the control systems. The four ALCS evaluated for this test were: WattStopper, Enlighted, Daintree Networks, and Acuity nLight. Two sites had the Enlighted controller.

Manual DR testing implemented by the manufacturer's representative was conducted on three separate days. The testing planned to change the DR level to five different settings: 15%, 20%, 25%, 30%, and 50% reductions in power from the commissioned level. Each setting lasted for one hour, after which it returned to the baseline DR level of 0%. Southern California Edison (SCE) conducted AutoDR tests at low, medium, and high demand reduction modes.

All four control systems successfully reduced interior lighting demand through the manual DR strategy. The results for the manual DR testing showed the demand reduction at the 50% DR level ranged from 0.35 kilowatt (kW) to 0.63 kW and averaged 0.50 kW per site. The results were also normalized to the size of the facility in Watts per square foot (W/sf). All products showed a reduction for the interior lights, ranging from 0.15 W/sf to 0.23 W/sf reduced at the 50% DR level and averaged 0.19 W/sf per site. The average, normalized manual DR lighting demand reduction across all five sites is shown in Figure 1. All four control systems reduced demand and performed similarly.

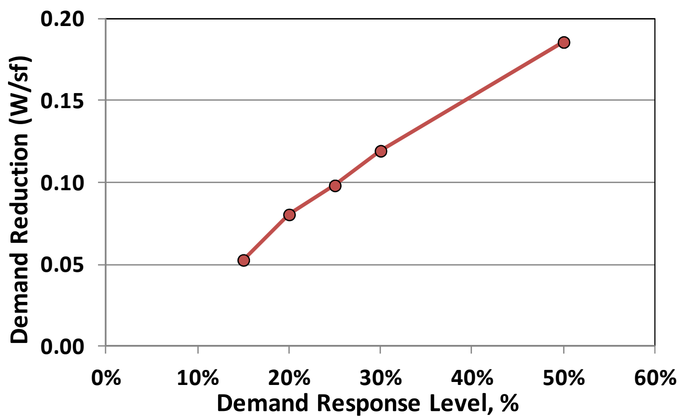

FIGURE 1. AVERAGE MANUAL DR DEMAND REDUCTION NORMALIZED TO W/S F AT VARIOUS DR LEVELS

In contrast to the manual DR process, testing of the AutoDR signal was only successful with two controllers: WattStopper and Daintree Networks. These two products showed very similar reduction levels. At the high mode, AutoDR event resulted in a demand reduction of 0.09 W/sf each for these two controllers.

The installed costs for the ALCS at the five test sites ranged from $6,500 to $9,100. The average installation cost was approximately $7,500. It is likely that these costs will come down in the future and integration of the DR capabilities with the energy savings that the ALCS provides would make these systems more attractive to customers.

Further studies of existing systems should be conducted in order to determine whether it is possible for all five of these ALCSs to reliably provide AutoDR.

ABBREVIATIONS

AutoDR	Automated Demand Response
ALCS	Advanced Lighting Control System
CT	Current Transducer
DR	Demand Response
DRAS	Demand Response Automated Server
kW	kilowatt
kWh	Kilowatt-hour
LED	Light Emitting Diode
SCE	Southern California Edison
W	Watts
W/sf	Watts per square foot

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INTRODUCTION

This study evaluated the Demand Response (DR) capability of Advanced Lighting Control Systems (ALCSs) developed by Daintree, Enlighted, nLight, and WattStopper. These ALCSs were installed in five fast food restaurants. Two sites used the Enlighted product. The study involves in-situ testing of the products to measure the demand reduction from manual DR and automated DR (AutoDR). These real-world settings also allow testing the compatibility of systems produced by separate manufacturers.

Southern California Edison (SCE) is studying such concepts to advance the implementation of demand reduction technologies and increase the customer participation in DR program offerings.

BACKGROUND

Demand reduction is needed when the electrical grid is constrained, when demand exceeds supply or when electricity costs are high. These conditions tend to occur during hot summer afternoons.

Peak electricity demand has been managed by Southern California Edison (SCE) customers participating in DR program offerings such as:

- Demand Bidding
- Capacity Bidding
- Critical Peak Pricing
- Real-Time Pricing
- Summer Discount Plan

SCE continues to investigate the DR potential of several new technologies in order to reduce the peak demand on its electric grid. SCE customers will benefit from these new technologies as they have the potential to achieve large demand reductions either by substantially reducing loads at a few major facilities or by performing smaller demand reductions at a large number of facilities, which should increase customer participation in DR programs.

OBJECTIVES

The project focuses in evaluating the DR capabilities and performance of different ALCSs in five fast food restaurants, representing 2,250 to 3,110 square feet of space. The ALCSs control the level of light output associated with Light Emitting Diode (LED) lighting systems that were installed in 2012 as part of an Emerging Technologies project.

The main objectives of the project are to:

- Determine whether the ALCSs can be scheduled for reliable control of lighting loads as part of a Manual DR test events
- Determine whether the ALCSs can be scheduled for reliable control of lighting loads as part of an Automated Demand Response (AutoDR) test events

To achieve the project objectives, electric load monitoring was conducted for the interior lighting in each participating restaurant. Manual DR and AutoDR testing events were conducted and results analyzed to quantify the demand reduction at each restaurant.

TECHNOLOGY EVALUATION

This is a field project of four different ALCSs used to provide dimming, daylight harvesting, and demand response control of interior lighting. Five fast food restaurants, in the Inland Empire region in southern California, were selected to test the ALCSs and to monitor the demand reduction associated with these technologies.

The project was designed to limit facility selection to one fast food chain for all sites because this more effectively preserves uniformity in conditions and minimizes the number of variables affecting results.

The lighting control products evaluated in this study are listed in Table 1. These products provide signals to the lighting system installed at these sites, allowing the lighting to be dimmed to various levels. DR test periods can be scheduled in advance as part of the lighting level control. One of the most effective ways utilities can promote DR for large number of commercial sites with small loads is by using the Open Automated Demand Response (OpenADR) communication standards. OpenADR was developed by Lawrence Berkeley National Laboratory to promote a common communication standard for DR programs and technology manufacturers. The WattStopper, Enlighted, and Daintree controllers are compatible with the OpenADR standards.

TABLE 1. SUMMARY OF LIGHTING CONTROL PRODUCTS BY LOCATION

LOCATION (CITY – STREET)	CONTROLLER MANUFACTURER	SITE SQUARE FEET
Corona – Magnolia Avenue	WattStopper	2,967
Corona – Temescal Canyon	Enlighted, Inc.	3,111
Upland	Enlighted, Inc.	2,555
Rancho Cucamonga	Daintree Networks	2,251
Montclair	Acuity nLight	2,651

One page from the controller brochure or specification sheet for each of the four controllers can be found in Appendix A. Most of the controllers are installed in locations where they are out of sight from the customer.

CONTROLLED LIGHTING

The five restaurants were retrofitted with commercially available dimmable LED fixtures as summarized in Table 2. All of the listed fixtures are controllable by the ALCSs. The total controlled LED wattage for each restaurant is presented in Table 3. The LED lighting was commissioned to 80% of full light output.

TABLE 2. SUMMARY OF LED LIGHTING DIMMABLE BY CONTROLLERS FOR EACH LOCATION

SITE LOCATION	FIXTURE TYPE	MANUFACTURER, MODEL	NUMBER OF FIXTURES	WATTS/ FIXTURE
Corona – Magnolia Avenue	2’ x 2’ recessed	Finelite, HPR 2x2	32	34
	6” recessed downlights	Philips Omega, RV11-19	9	27
	4’ x 1’ surface mounted	Finelite, HPR 1x4	4	37
	2’ x 2’ surface mounted	Finelite, HPR 2x2	5	34
	60-watt A-lamp replacement	LSG, Definity A19	4	13.5
Corona – Temescal Canyon	2’ x 2’ Recessed	Philps Daybrite, DuaLED 2x2	29	31
	6” recessed downlights	Philips Omega, RV11-19	8	27
	2’ x 2’ surface mounted	Philips Daybrite, Attune 2x2	7	31
	60-watt A-lamp replacement	LSG, Definity A19	11	13.5
Upland	Recessed	Lunera, 22G3	29	40
	6” recessed downlights	Philips Omega, RV11-19	10	27
	4’ x 1’ Surface mounted	Acuity, STL4	6	26
	60-watt A-lamp replacement	LSG, Definity A-19	12	13.5
Rancho Cucamonga	Recessed	Cree, CR22	4	35
	6” recessed downlights	Philips Omega, RV11-19	5	27
	Surface mounted	Cree, CR22	20	35
	60-watt A-lamp replacement	LSG, Definity A19	7	13.5
Montclair	Recessed	Acuity, VTLED	27	36
	6” recessed downlights	Philips Omega, RV11-19	9	27
	4’ x 1’ Surface mounted	Acuity, STL4	5	26
	60-watt A-lamp replacement	LSG, Definity A19	9	13.5

TABLE 3. RATED AND COMMISSIONED BASELINE LED LIGHTING kW BY RESTAURANT

	CORONA - MAGNOLIA	CORONA - TEMESCAL	UPLAND	RANCHO CUCAMONGA	MONTCLAIR
Rated LED Baseline (kW)	1.703	1.481	1.748	1.070	1.467
Commissioned Baseline at 80% (kW)	1.362	1.185	1.398	0.856	1.174

OPERATING HOURS

The operating hours for the five locations are relatively similar but not identical, as shown in Table 4. The long operating hours allow the lighting loads to be available for DR over a wide range of times.

TABLE 4. RESTAURANT OPERATING HOURS BY DAY OF WEEK

RESTAURANT LOCATION	MON-THU	FRI	SAT	SUN
Corona – Magnolia Avenue	6AM-11PM	6AM-Midnight	6AM-Midnight	7AM-10PM
Corona – Temescal Canyon	6AM-11PM	6AM-Midnight	6AM-Midnight	6AM-11PM
Upland	6AM-Midnight	6AM-Midnight	24 hours	24 hours
Rancho Cucamonga	6AM-Midnight	6AM-Midnight	24 hours	24 hours
Montclair	6AM-Midnight	6AM-Midnight	24 hours	24 hours

TECHNICAL APPROACH

The project evaluates four different control systems in five fast food restaurants. One unique ALCS solution is installed at each of three restaurants, and two other restaurants have another ALCS. The sites were chosen because of similarities among their lighting systems and operating conditions. All five sites were from the same chain of fast food restaurants, which are owned and operated by two independent franchises, and are located within 30 miles of each other. All controlled lighting systems had new LED fixtures. Some characteristics, however, varied including the number and type of fixtures.

The project monitored the baseline demand of the interior lighting and tested both manual DR and AutoDR of the interior lighting. The ALCSs have recently been installed and commissioned by contractors representing the respective ALCS manufacturers. A schedule of DR test events was developed to show that the lighting systems are able to respond to demand reduction requests and quantify the achievable demand reduction. Although each of the lighting and control systems has a dimming capability that can be used for energy savings, this study focuses only on the demand reduction resulting from DR testing.

DATA ACQUISITION EQUIPMENT

Multi-channel data loggers were used to monitor power consumption of the lighting systems. These loggers recorder electric energy, analog signals, and digital pulses. For this project, the loggers were used to monitor true root mean square (RMS) power (kW) of the circuits feeding the interior lights. From five to seven interior lighting circuits were monitored at each of the sites. The logger accuracy for power measurements is ±0.5% from 1 to 100% of full scale. The split-core current transducer (CT) used have an accuracy of ±1% from 10% to 100% of full scale, ±3% at 5% of full scale, and ±5% at 2% of full scale. CTs with appropriately rated primary current were used for the lighting circuits ensuring ±1% accuracy (see Table 2). Multiple channels on each logger were used to measure kW. The logger samples the full 60 Hertz waveform once every 5 seconds, and the data samples are averaged and recorded in 1-minute intervals. One-time power measurements were made using an AEMC 3910 true RMS power meter to confirm calibration of the data logger and to assure proper installation of the CTs. Data were collected remotely via telephone land lines at each site and modems in each of the loggers. A central computer retrieved data daily.

FIGURE 2. CURRENT TRANSDUCERS MOUNTED INSIDE ELECTRIC PANEL

Prior to installing monitoring equipment, the lighting power for all the interior lighting was traced. One CT was installed to monitor the power of each individual circuit. In a few cases there were non-controlled lighting loads connected to the same circuits as the controlled lighting. Examples include incandescent lamps inside of walk-in coolers and freezers and exhaust hood lamps. The data analysis accounts for these few cases.

TEST PROCEDURES

Two general DR test approaches were taken. One approach used manual DR testing, which was implemented by the lighting controller manufacturer's representatives. The other approach used AutoDR testing implemented by SCE personnel. All computers, equipment, and loggers were synchronized to clocks on Pacific Time, as obtained from the National Institute of Standards and Testing website.[1]

Manual DR testing was scheduled to be conducted on the same business hours over three separate days at each of the five restaurants. Power recording intervals were set at 1 minute during the DR test periods. The testing procedure included changing the lighting level to five different settings. Each test was scheduled to last for one hour, after which the setting was returned to the baseline DR level of 0%. Table 5 shows the schedule of the DR lighting tests.

TABLE 5. LIGHTING MANUAL DEMAND RESPONSE TEST SCHEDULE

DR LEVEL, %	CONTROL SYSTEM TIMING
15	9:30 a.m. – 10:30 a.m.
0	10:30 a.m. – 11:00 a.m.
20	11:00 a.m. – 12:00 p.m.
0	12:00 p.m. – 1:00 p.m.
25	1:00 p.m. – 2:00 p.m.
0	2:00 p.m. – 2:30 p.m.
30	2:30 p.m. – 3:30 p.m.
0	3:30 p.m. – 4:00 p.m.
50	4:00 p.m. – 5:00 p.m.

Exceptions to the planned schedule occurred. For example, at the Magnolia Avenue location, the controller was not set back to the baseline level (0% reduction) between each DR level setting. Additionally, the ALCS at the Montclair location did not have compatible level setting flexibility and was only able to be set in 10% increments. The DR levels settings for Montclair were actually 90%, 80%, 70%, 60%, and 50%. Attempts to rerun them at 10%, 20%, 30%, 40%, and 50% were not successful as of the time this report was drafted.

AutoDR testing was scheduled to occur on only two days. The schedule was planned as shown in Table 6. The 25 and 50% levels were to simply the testing.

TABLE 6. LIGHTING AUTOMATED DEMAND RESPONSE TEST SCHEDULE

DR LEVEL (%)	DR EVENT-MODE LEVEL	CONTROL SYSTEM TIMING
15	Low	9:30 a.m. – 10:30 a.m.
0		10:30 a.m. – 11:00 a.m.
20	Medium	11:00 a.m. – 12:00 p.m.
0		12:00 p.m. – 2:30 p.m.
30	High	2:30 p.m. – 3:30 p.m.

Two strategies were employed to conduct the AutoDR testing to ensure that the signal was sent to the ALCSs. Leveraging the DR Automated Server (DRAS), DR events were sent using the OpenADR specification. Two different scheduling methodologies were used to schedule an event that would test the full set of capabilities provided by each ALCS.

A simpler method followed the traditional means of scheduling an AutoDR event in the DRAS, but it did not allow for the event-mode level to be set. The default event-mode level was set to “high” in the test DRAS. In order to test the controllers’ abilities to respond to different event-mode levels, an alternative scheduling method was used. For this alternative method, the client was switched to a “manual” mode in the test DRAS, and a two-step process was followed. The first step identified the event-mode level, denoted “low”, “medium” or “high”, and the second step scheduled the DR event to signal the client to enter the desired event-mode at the appropriate time. For both scheduling methods, a signal is sent from the test DRAS to the ALCSs at the specified time, and includes both the duration and event-mode level. This information is received from the server by the lighting controller, which then translates the event-mode level into a pre-determined lighting reduction and maintains this reduction until either the event is completed or the signal is over-ridden.

Table 7 provides the dates by site for the manual and AutoDR test days. Testing was conducted at each site after the control system was completely functional for DR testing. It should be noted that the second AutoDR test day of November 26 included only the high level DR request from 2:30 p.m. to 3:30 p.m.

TABLE 7. MANUAL AND AUTOMATED DEMAND RESPONSE TEST DATES BY RESTAURANT

RESTAURANT LOCATION	MANUAL DR TEST DATE 1	MANUAL DR TEST DATE 2	MANUAL DR TEST DATE 3	AUTOMATED DR TEST DATE 1	AUTOMATED DR TEST DATE 2
Corona – Magnolia Avenue	11/8/12	11/9/12	11/10/12	11/21/12	11/26/12
Corona – Temescal Canyon	10/31/12	11/1/12	11/5/12	11/21/12	Not online
Upland	11/12/12	11/13/12	11/14/12	11/21/12	11/26/12
Rancho Cucamonga	10/15/12	10/17/12	10/19/12	11/21/12	11/26/12
Montclair	10/25/12*	10/26/12*	10/27/12	N/A	N/A

* The manual DR test with lower DR percentage was rescheduled for 11/23/12 and 11/24/12 but was not successful.

A non-test day was also recorded by the data loggers as a comparison to demand during the test days.

RESULTS

Data from each of the sites were collected and processed separately to determine demand levels for the baseline and DR event periods. An analysis of the data determined demand reduction for the restaurants.

DATA ANALYSIS

The data were initially processed site by site. Multiple channels of lighting circuit loads were recorded for each site, and all interior lighting circuit channels were summed to obtain the total interior lighting load for each site. On some monitored circuits, there were constant loads outside of the study, which were subtracted out of the data analysis. Data were recorded as average demand over 1-minute intervals. Three days of manual DR test data were available to analyze for each of the five sites. The demand reduction calculated for each DR level was averaged across all three days for a given restaurant. Charts showing daily profiles for each of the test days and a non-test day are presented in Appendix B through Appendix F.

To calculate the average demand reduction for a given DR level period, the average demand during the period was calculated and subtracted from the average demand for the proceeding baseline period. Close examination of the data was conducted to ensure that the 1-minute periods during the transition were not included in the average, and that blocks of time during other transitions such as daylight harvesting were properly accounted for in the averaged time series. The data from the Rancho Cucamonga site contained substantial noise. This was addressed by looking at the demand change of the 1-minute data at the transition times.

The Corona-Magnolia and Montclair locations were unique cases in the analysis. There was only one baseline period for Corona-Magnolia prior to 9:30 a.m. At this site, the ALCS did not reset to baseline between DR level tests. The Montclair location was only analyzed and presented for the 50% DR level, as DR levels below 50% were not conducted.

The analysis for the AutoDR testing was conducted similarly to the manual DR testing.

MANUAL DR RESULTS

Table 8 provides a summary of the average demand reduction for the manual DR tests. The table shows the kW demand reduction for each DR percentage level for each ALCS/restaurant combination. All ALCSs showed a demand reduction for the interior lights, ranging from 0.35 kW to 0.63 kW at the 50% DR level. The average demand reduction for the sites was 0.50 kW at the 50% DR level.

TABLE 8. DEMAND REDUCTION IN KW AT VARIOUS DR LEVELS BY RESTAURANT

DR LEVEL (%)	WATTSTOPPER /CORONA – MAGNOLIA (KW)	ENLIGHTED/ CORONA – TEMESCAL (KW)	ENLIGHTED/ UPLAND (KW)	DAINTREE/ RANCHO CUCAMONGA (KW)	NLIGHT/ MONTCLAIR (KW)	AVERAGE DEMAND REDUCTION (KW)
15	0.155	0.199	0.156	0.076		0.147
20	0.213	0.281	0.260	0.131		0.221
25	0.267	0.371	0.283	0.164		0.271
30	0.300	0.446	0.358	0.209		0.328
50	0.443	0.627	0.579	0.353	0.515	0.503

The normalized demand reduction in watts per square foot (W/sf) for each DR level at each restaurant is presented in Table 9. All ALCSs showed a demand reduction for the interior lights, ranging from 0.15 W/sf to 0.23 W/sf at the 50% DR level. The average demand reduction for the five restaurants was 0.19 W/sf at the 50% DR level. The results of Table 9 are graphed in Figure 3.

TABLE 9. DEMAND REDUCTION NORMALIZED TO W/SF AT VARIOUS DR LEVELS BY RESTAURANT

DR LEVEL (%)	WATTSTOPPER/ CORONA – MAGNOLIA (W/SF)	ENLIGHTED (A)/ CORONA –TEMESCAL (W/SF)	ENLIGHTED (B)/ UPLAND (W/SF)	DAINTREE/ RANCHO CUCAMONGA (W/SF)	NLIGHT/ MONTCLAIR (W/SF)	AVERAGE DEMAND REDUCTION (W/SF)
15	0.052	0.064	0.061	0.034		0.053
20	0.072	0.090	0.102	0.058		0.081
25	0.090	0.119	0.111	0.073		0.098
30	0.101	0.143	0.140	0.093		0.119
50	0.149	0.201	0.227	0.157	0.194	0.186

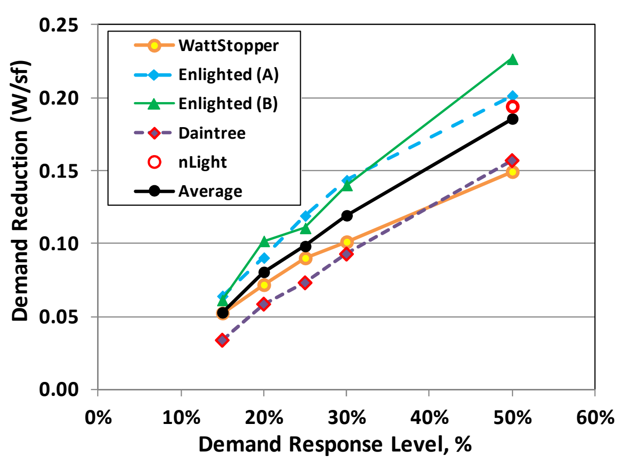


FIGURE 3. LIGHTING DEMAND REDUCTION NORMALIZED TO W/S F AT VARIOUS DR LEVELS BY ALCS

Table 10 presents the percentage demand reduction for each of the controllers and DR level scenarios. The percentage reduction was calculated by dividing the demand reductions from Table 8 by the commissioned LED kW displayed in Table 3. At the 50% DR level, the measured demand reduction percentage ranged from 31% to 53% with an average of 42%. The results of Table 10 are graphed in Figure 4.

TABLE 10. PERCENT DEMAND REDUCTION AT VARIOUS DR LEVELS BY RESTAURANT

DR Level (%)	WattStopper/ Corona – Magnolia (%)	Enlighted (A)/ Corona –Temescal (%)	Enlighted (B)/ Upland (%)	Daintree/ Rancho Cucamonga (%)	nLight/ Montclair (%)	Average Demand Reduction (%)
15	11.0	16.8	11.2	8.8		12.0
20	15.1	23.7	18.6	15.3		18.2
25	19.0	31.3	20.2	19.2		22.4
30	21.3	37.7	25.6	24.4		27.2
50	31.4	52.9	41.4	41.2	43.9	42.2

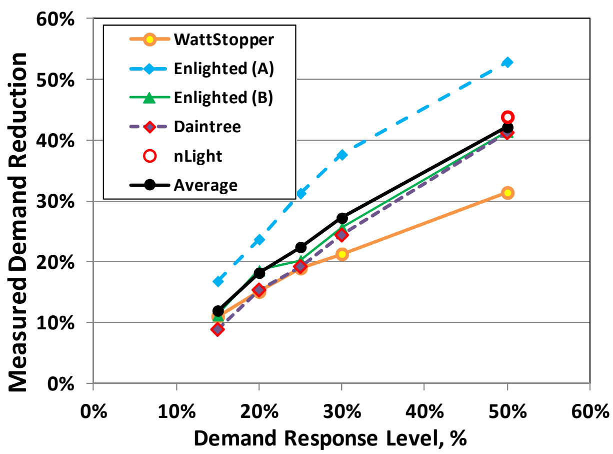


FIGURE 4. LIGHTING DEMAND REDUCTION PERCENT AT VARIOUS DR LEVELS BY ALCS

AUTOMATED DR RESULTS

The only two systems that responded to the AutoDR testing were the WattStopper (Corona – Magnolia Avenue) and the Daintree Networks (Rancho Cucamonga).

Table 11 provides a summary of the average demand reduction for the AutoDR tests. The table shows the kW demand reduction for each DR percentage level for each ALCS/restaurant combination. The two sites showed similar demand reductions.

TABLE 11. AUTOMATED DEMAND REDUCTION IN KW AT VARIOUS DR LEVELS BY RESTAURANT

AUTODR LEVEL (%)	WATTSTOPPER/CORONA – MAGNOLIA (KW)	DAINTREE/ RANCHO CUCAMONGA (KW)	AVERAGE DEMAND REDUCTION (KW)
20 (Medium)	0.153	0.119	0.136
30 (High)	0.255	0.197	0.226

The normalized demand reduction in W/sf for each DR level at each restaurant is presented in Table 12. Both products showed very similar demand reductions. A high level AutoDR event sheds almost 0.09 W/sf. The results of Table 12 are graphed in Figure 5.

TABLE 12. AUTOMATED DEMAND REDUCTION NORMALIZED TO W/SF AT VARIOUS DR LEVELS BY RESTAURANT

AUTODR LEVEL (%)	WATTSTOPPER/CORONA – MAGNOLIA (W/SF)	DAINTREE/ RANCHO CUCAMONGA (W/SF)	AVERAGE DEMAND REDUCTION (W/SF)
20 (Medium)	0.052	0.053	0.052
30 (High)	0.086	0.088	0.087

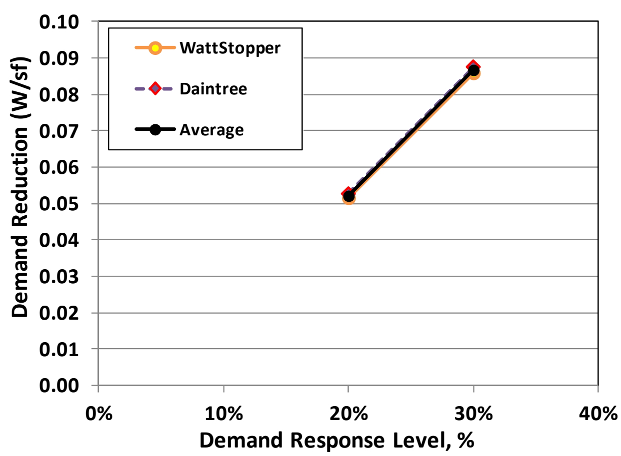


FIGURE 5. LIGHTING AUTOMATED DEMAND REDUCTION NORMALIZED TO W/SF AT VARIOUS DR LEVELS BY ALCS

ECONOMICS

The installed costs for the ALCS at the five test sites ranged from $6,500 to $9,100. The average installation cost was approximately $7,500. It is likely that these costs will come down in the future and integration of the DR capabilities with the energy savings that the ALCS provides would make these systems more attractive to customers.

DISCUSSIONS

This project evaluated new ALCSs with DR capabilities in fast food restaurants. Fast food restaurants typically have many windows, primarily to provide daylight in areas frequented by patrons. Although some of the interior lighting fixtures are reduced by daylight harvesting and offer minimal demand reduction opportunities, many of the interior fixtures can be dimmed in order to obtain demand reductions.

All ALCSs showed a demand reduction for the interior lights. The demand reduction ranged from 0.15 W/sf to 0.23 W/sf at the 50% DR level, while the average demand reduction for the five restaurants was 0.19 W/sf at the 50% DR level.

The manually-initiated AutoDR at a low DR level did not appear to register and did not change any lighting levels. The most consistent response of the AutoDR was in a prescheduled high mode of reduction. The average effective AutoDR level for the two sites in this test was 0.09 W/sf at the high (30%) DR mode.

The demand reductions are similar among the various ALCSs tested. The DR results are dependent on how much the lights are operated during a DR event. The daily lighting profiles provided in Appendix B through Appendix F show that the lighting load profiles are not the same for all sites. These differences can influence how various systems compare to each other.

The data from the DR testing showed that the WattStopper controls did not return the lighting levels to the original levels at the end of the testing period. The data from the DR testing showed the Acuity nLight controls were not set up with the same dimming settings as the other controllers. The nLight controls did overlap with the other controllers at the 50% DR level and showed that the nLight lighting was reduced very near the average of the other systems. Therefore, it is likely that the nLight system, if setup correctly, would provide similar reductions as the other ALCSs in each DR level. Although the nLight controller is only able to dim in 10% increments.

This project did not attempt to compare light output of the various ALCSs, and does not conclude whether the demand reduction levels for each ALCS represent uniform illumination conditions. Setting the initial dimming to a commissioned level of 80% reduces available lighting load that can be dimmed during a DR event.

The ALCSs evaluated in this project can also be used to control lighting in other business types. Examples include sit-down restaurants, hotels, fitness centers, retail stores, etc.

CONCLUSIONS

The main objectives and conclusions of the project are:

- Determine whether the advanced lighting controls systems can be scheduled for reliable control of lighting loads as part of a Manual DR test events.

  All controllers were able to reliably reduce lighting loads by means of a manually initiated test.

- Determine whether the ALCSs can be scheduled for reliable control of lighting loads as part of an AutoDR test.

  The Daintree Networks controller performed reliably and provided the expected demand response result. The WattStopper also provided the expected demand response but was not initially setup to reset after the DR period ended. The two Enlighted controllers received the signal but could not properly implement the response. This problem is being addressed and is expected to be resolved. The Acuity nLight controller was not able to respond to the AutoDR signal.

The most successful AutoDR occurred when the event was scheduled, and the AutoDR signal requested a high mode of demand reduction.

RECOMMENDATIONS

The results of this field evaluation show that demand reductions can be achieved by dimming lighting in response to a DR request. As with some new technologies, there are compatibility issues that need to be addressed during specification of equipment prior to installation.

Because many of these lighting control solutions are new, installers should learn how to properly install them in order to provide an effective product to the market place.

Further studies should be conducted to determine whether it is possible for all five of these ALCSs to reliably provide AutoDR strategies. Additionally, future studies should include the customer/employee response during the DR events, and to the new systems in general.

REFERENCES

1. NIST web link: http://nist.time.gov/timezone.cgi?Pacific/d/-8/java

APPENDIX A – CONTROLLER LITERATURE

The WattStopper control system installed at Corona Magnolia Ave.

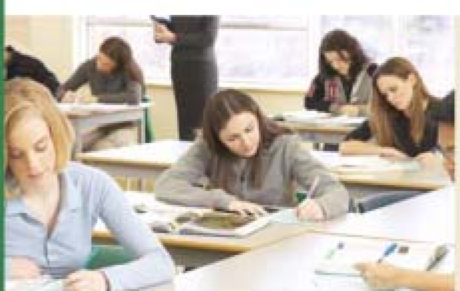
DIGITAL LIGHTING MANAGEMENT

DLM: for a room, a building or an entire campus

Digital Lighting Management (DLM) is an intelligent, distributed control system that automatically maximizes lighting energy efficiency. Its powerful features provide a higher return on investment (ROI) than any other lighting control solution.

DLM is designed to scale from stand-alone control of individual rooms to centralized control of a floor, a building, or an entire campus. With DLM, you layer your choice of control strategies to meet project goals, from energy code compliance to building aesthetics, simplified maintenance and enhanced energy performance.

Control options include: room controllers for switched or dimmed lighting loads, or for plug loads; digital occupancy sensors; sleek switches and handheld remotes; versatile daylighting sensors; lighting control panels; tools for remote configuration, scheduling and system management; and interfaces providing connectivity to third party devices.

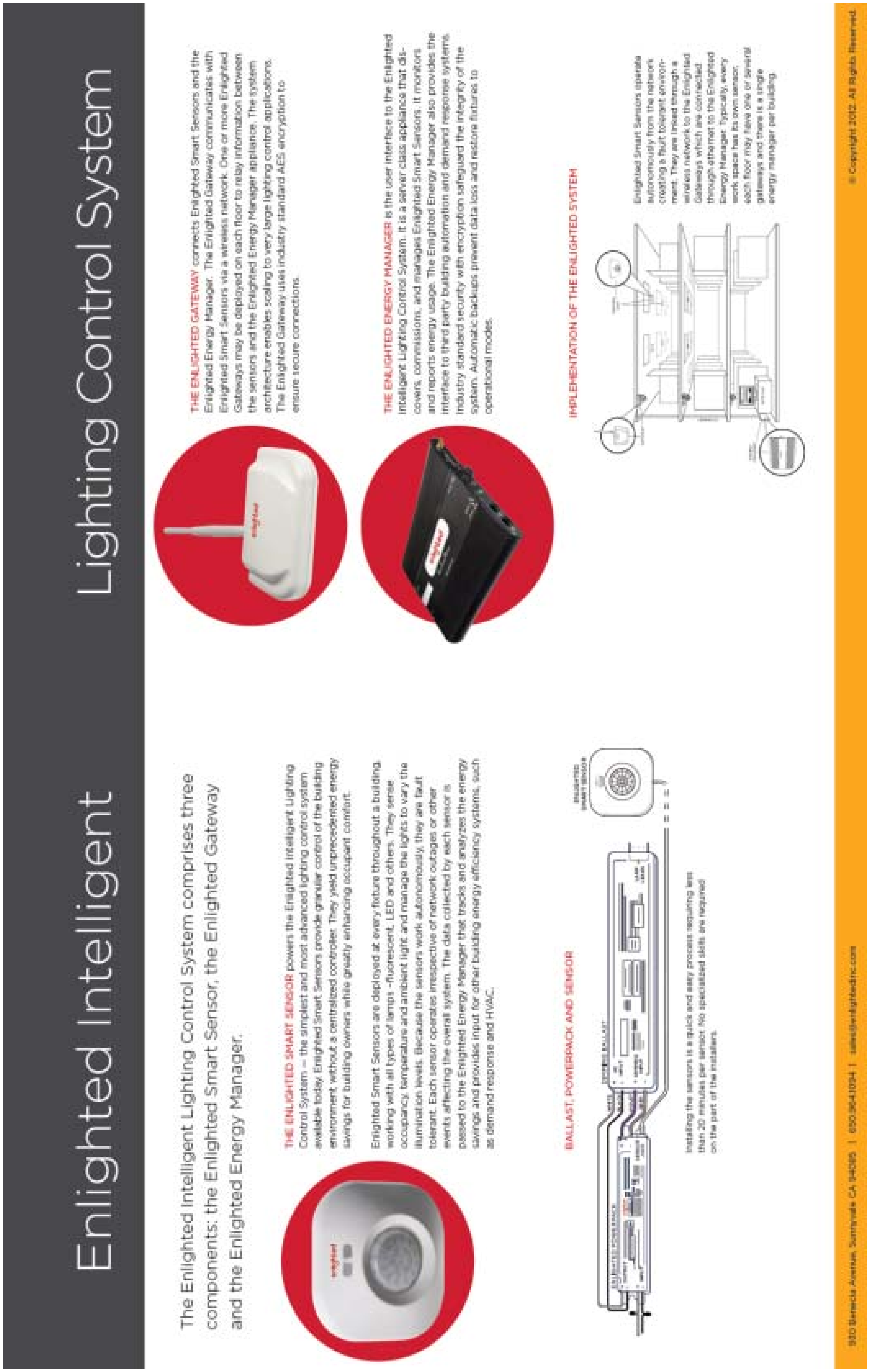


Digital occupancy sensors include **pushbuttons** and **LCD screens** for changing settings. A handheld remote allows ladder-free configuration.

A3

www.wattstopper.com
800.879.8585

The Enlighted control system installed at Corona Temescal Canyon and Upland.



Enlighted Intelligent Lighting Control System

The Enlighted Intelligent Lighting Control System comprises three components: the Enlighted Smart Sensor, the Enlighted Gateway and the Enlighted Energy Manager.

THE ENLIGHTED SMART SENSOR powers the Enlighted Intelligent Lighting Control System — the simplest and most advanced lighting control system available today. Enlighted Smart Sensors provide granular control of the building environment without a centralized controller. They yield unprecedented energy savings for building owners while greatly enhancing occupant comfort.

Enlighted Smart Sensors are deployed at every fixture throughout a building, working with all types of lamps –fluorescent, LED and others. They sense occupancy, temperature and ambient light and manage the lights to vary the illumination levels. Because the sensors work autonomously, they are fault tolerant. Each sensor operates irrespective of network outages or other events affecting the overall system. The data collected by each sensor is passed to the Enlighted Energy Manager that tracks and analyzes the energy savings and provides input for other building energy efficiency systems, such as demand response and HVAC.

BALLAST, POWERPACK AND SENSOR

Installing the sensors is a quick and easy process requiring less than 20 minutes per sensor. No specialized skills are required on the part of the installers.

THE ENLIGHTED GATEWAY connects Enlighted Smart Sensors and the Enlighted Energy Manager. The Enlighted Gateway communicates with Enlighted Smart Sensors via a wireless network. One or more Enlighted Gateways may be deployed on each floor to relay information between the sensors and the Enlighted Energy Manager appliance. The system architecture enables scaling to very large lighting control applications. The Enlighted Gateway uses industry standard AES encryption to ensure secure connections.

THE ENLIGHTED ENERGY MANAGER is the user interface to the Enlighted Intelligent Lighting Control System. It is a server class appliance that discovers, commissions, and manages Enlighted Smart Sensors. It monitors and reports energy usage. The Enlighted Energy Manager also provides the interface to third party building automation and demand response systems. Industry standard security with encryption safeguard the integrity of the system. Automatic backups prevent data loss and restore fixtures to operational modes.

IMPLEMENTATION OF THE ENLIGHTED SYSTEM

Enlighted Smart Sensors operate autonomously from the network creating a fault tolerant environment. They are linked through a wireless network to the Enlighted Gateways which are connected through ethernet to the Enlighted Energy Manager. Typically, every work space has its own sensor, each floor may have one or several gateways and there is a single energy manager per building.

930 Benecia Avenue, Sunnyvale CA 94085 | 650.964.1094 | sales@enlightedinc.com

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The Daintree Networks control system installed at Rancho Cucamonga.

DaintreeNetworks

Wireless Area Controller – WAC50

Product Overview

Daintree Networks' Wireless Area Controller (WAC) is the key hardware component of Daintree-based solutions that enable powerful, simple and low-cost access to energy saving control strategies such as daylighting, occupancy sensing and demand response. It is designed to deliver intelligent local control across a large area for many dozens of interoperable wireless control devices from Daintree partners.

Built on Daintree's ControlScope™ wireless platform, the WAC collapses complex control panels, gateways and miles of wires into a single powerful controller. Using open and interoperable ZigBee® standards-based technology, the WAC communicates with standards-compliant sensors, switches, ballasts and LED drivers to transform basic room controls into a complete wireless control solution. A WAC can independently control a single extended area, and multiple WACs can be connected together through an Ethernet network to scale the system to many hundreds or thousands of lights across a distributed enterprise.

Specifications	
Dimensions	9.4" H x 8" W x 1.2" D
Weight	1.06lb (480g)
Operating Environment	32°F to 104°F (0°C to 40°C) Indoor, dry location (Install in non-metallic waterproof enclosure for outdoor applications)
Status Indicator	Green (Normal Operation) Orange (Attention Required) Red (Error Condition)
I/O	2 10/100 Mbps Ethernet 2 USB Type-A (host) 1 USB Mini-B (device) 1 microSD memory card 1 2.1mm barrel (power) 2 Button (configuration)
RF	2.4GHz ISM Band 100mW (+20dBm)
Power	5V DC 1.5A
Power Consumption	2.8W (network joined)
Warranty	5 Years Annual Support Plan

Specification Data	
Job Name	
Job #	
Catalog #	
Comments	

Product Number	Product Description
WAC50-N25	Wireless Area Controller (25 wireless node license)
WAC50-N50	Wireless Area Controller (50 wireless node license)
WAC50-N100	Wireless Area Controller (100 wireless node license)

Daintree Networks, Inc.
1503 Grant Road, Suite 202
Mountain View, CA 94040 U.S.A.

Phone: +1 (650) 965-3454
email: sales@daintree.net
www.daintree.net

The Acuity nLight control system installed at Montclair.

LIGHTING CONTROL : EVOLVED

What is *nLIGHT*?

nLIGHT is a revolutionary digital architecture and networking technology that cost-effectively integrates time-based, daylight-based, sensor-based, and manual lighting controls. Designed to function standalone in an individual zone or networked together across an entire facility or campus, ***nLIGHT*** is an easy-to-use, easy-to-install system that can cut energy consumption and enhance occupant convenience.

DISTRIBUTED INTELLIGENCE

nLIGHT offers "distributed intelligence," meaning that every device in every zone or network is digitally addressable. However, unlike other digital lighting control systems, every ***nLIGHT*** device is empowered to make its own switching and dimming decisions. So, instead of just room controllers, network servers, or centralized panels having intelligence, every ***nLIGHT*** device with a relay or dimming component has the intelligence to make its own control decisions. This enables designs where relays and dimming outputs can be located within sensors, photocells, and wall stations – not just in relay-only devices, such as room controllers or panels. This unmatched design flexibility allows for more elegant and cost-effective designs that minimize device count and wiring.

How *nLIGHT* Works...

nLIGHT connects together intelligent digital devices, including occupancy sensors, photocells, power/relay packs, wall switches, dimmers, panels, and now even luminaires. Combined, this creates a system with "distributed intelligence" that can be configured in limitless ways to meet lighting needs and codes.

2

APPENDIX B – WATTSTOPPER, MAGNOLIA

In this section, the interior lighting profiles at the restaurant in Corona on Magnolia Avenue are displayed in daily charts. A non-DR test day, which is representative of typical lighting power use, is presented in Figure 6. The electrical use data series illustrates the minute-to-minute electrical usage from the sum of all the monitored lighting breakers. The shaded vertical portions of the graph show the scheduled periods when power is reduced on test days.

Figure 7 through Figure 9 illustrate the three days of manual DR testing, with the DR level percentages labeled above the shaded areas. The figures show drops in demand when the power level settings were reduced as per the DR testing schedule. Note that at this site, the lighting did not return to baseline (0%) between each test level. Figure 10 illustrates the first AutoDR test day. There is a drop in power use at 11:03, which is approximately four minutes after the actual signal was sent. The control system was not setup to reset at the end of a DR period. Figure 11 illustrates the second AutoDR test day. There is a drop in power use at 14:34, which is again approximately four minutes after the actual signal was sent.

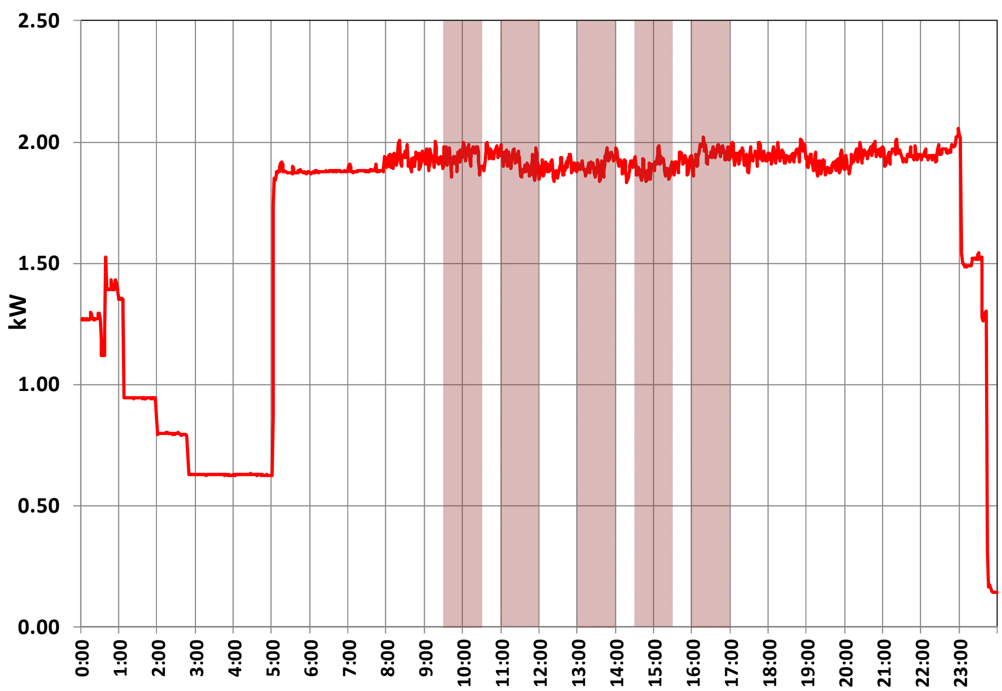

FIGURE 6. LIGHTING DURING A NON-TEST DAY - WEDNESDAY NOVEMBER 7TH

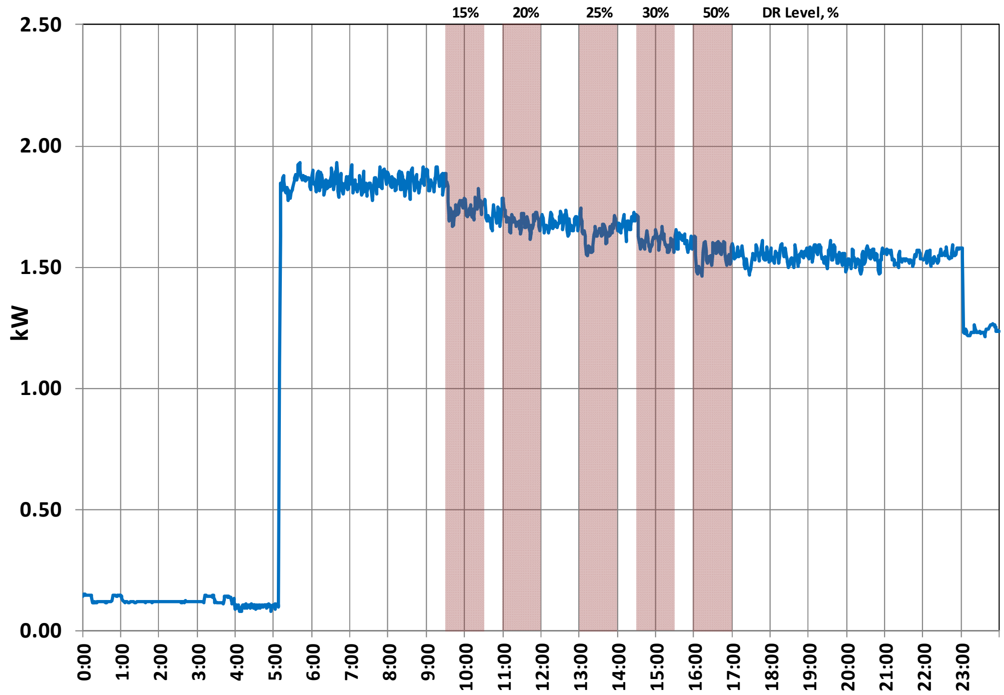

FIGURE 7. LIGHTING DURING A MANUAL DR TEST DAY - THURSDAY NOVEMBER 8TH

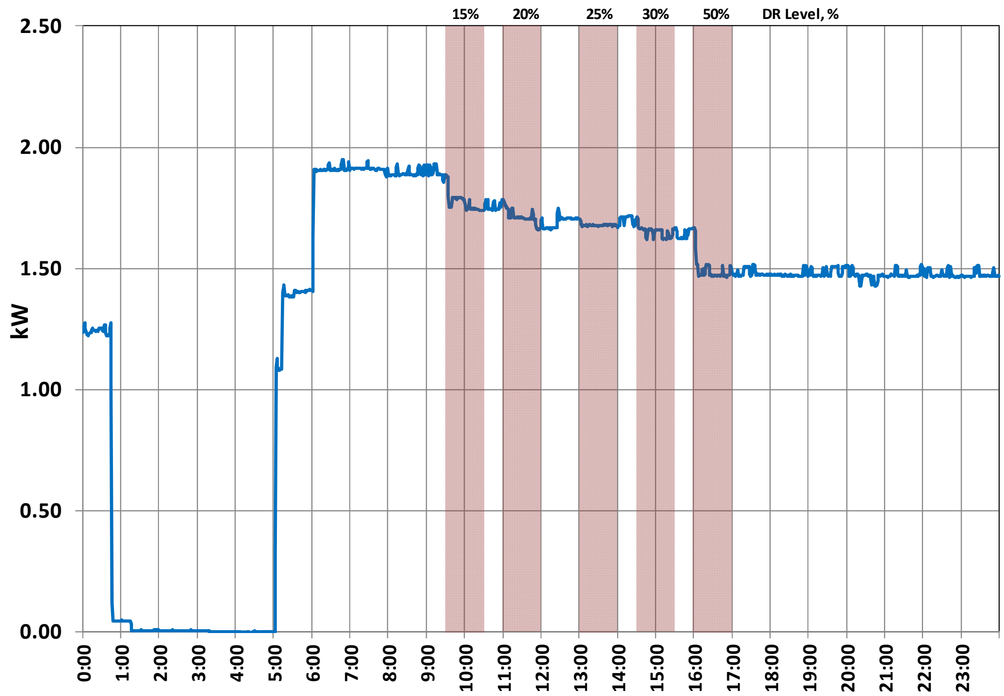

FIGURE 8. LIGHTING DURING A MANUAL DR TEST DAY - FRIDAY NOVEMBER 9TH

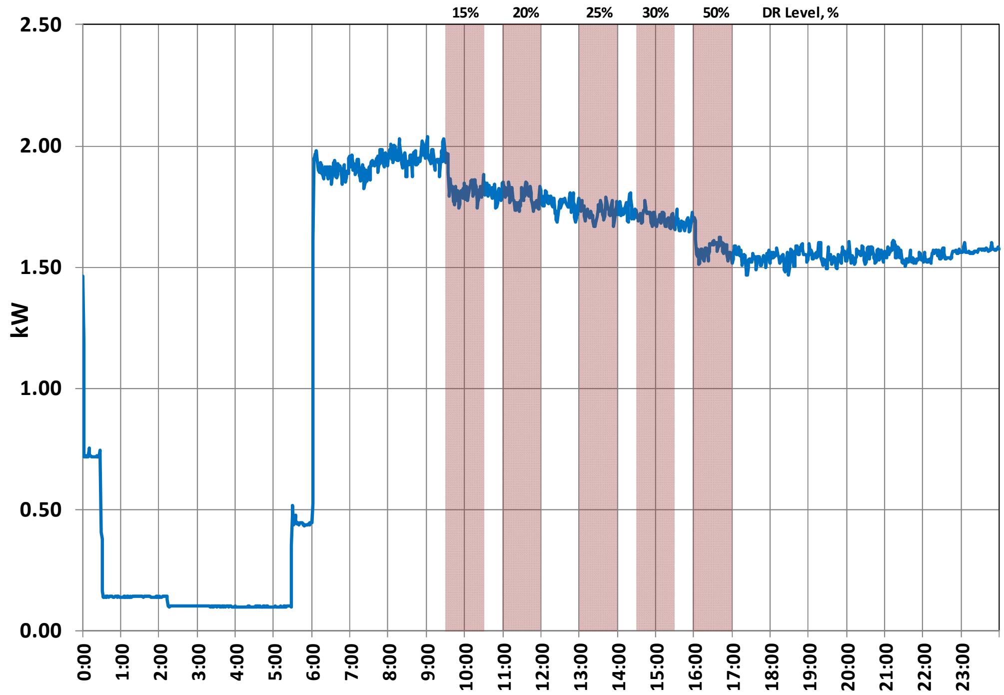

FIGURE 9. LIGHTING DURING A MANUAL DR TEST DAY - SATURDAY NOVEMBER 10TH

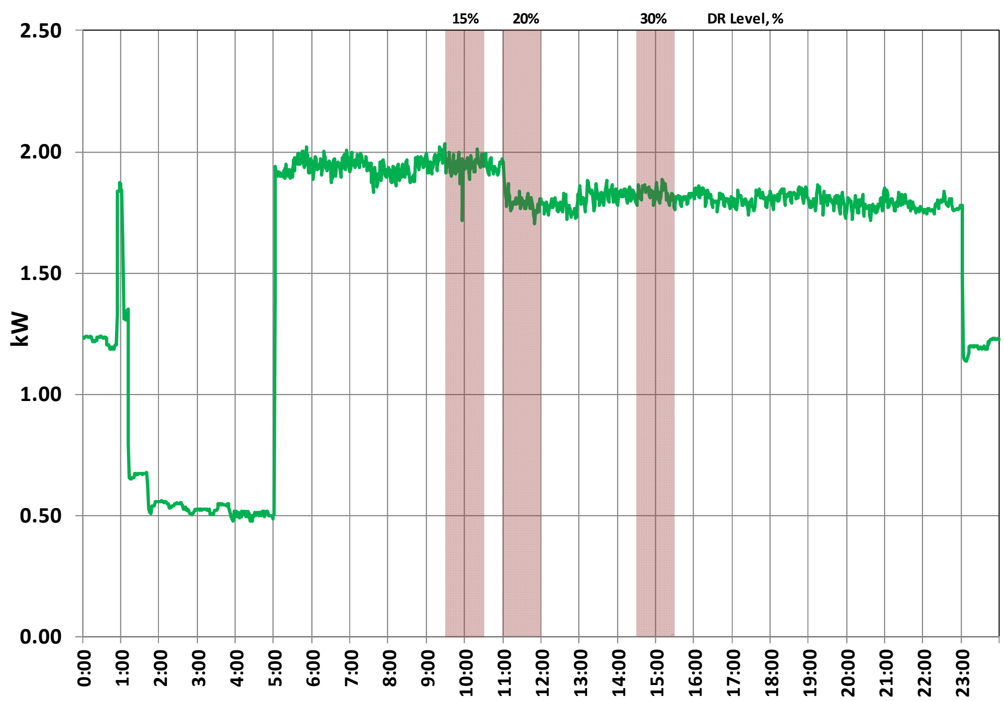

FIGURE 10. LIGHTING DURING AN AUTOMATED DR TEST DAY - WEDNESDAY NOVEMBER 21ST

FIGURE 11. LIGHTING DURING AN AUTOMATED DR TEST DAY - MONDAY NOVEMBER 26TH

APPENDIX C – ENLIGHTED, TEMESCAL CANYON

In this section, the interior lighting profiles at the restaurant in Corona on Temescal Canyon Rd. are displayed in daily charts. A non-DR test day, which is representative of typical lighting power use, is presented in Figure 12. The electrical use data series illustrates the minute-to-minute electrical usage from the sum of all the monitored lighting breakers. The shaded vertical portions of the graph show the scheduled periods when power is reduced on test days.

Figure 13 through Figure 15 illustrate the three days of manual DR testing, with the DR level percentages labeled above the shaded areas. The figures show distinctive drops in demand when the power level settings were reduced as per the DR testing schedule. There are minor start and stop time differences associated with the manual initiation of the DR periods. Figure 16 illustrates the first AutoDR test day. There are no detectable impacts from the AutoDR testing.

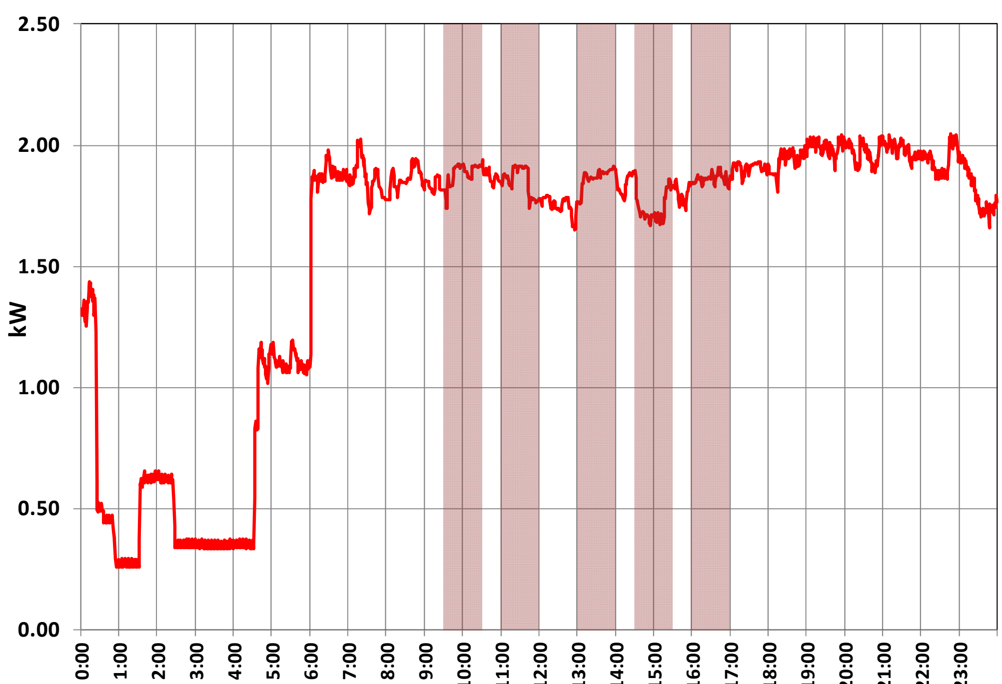

FIGURE 12. LIGHTING DURING A NON-TEST DAY - FRIDAY NOVEMBER 2ND

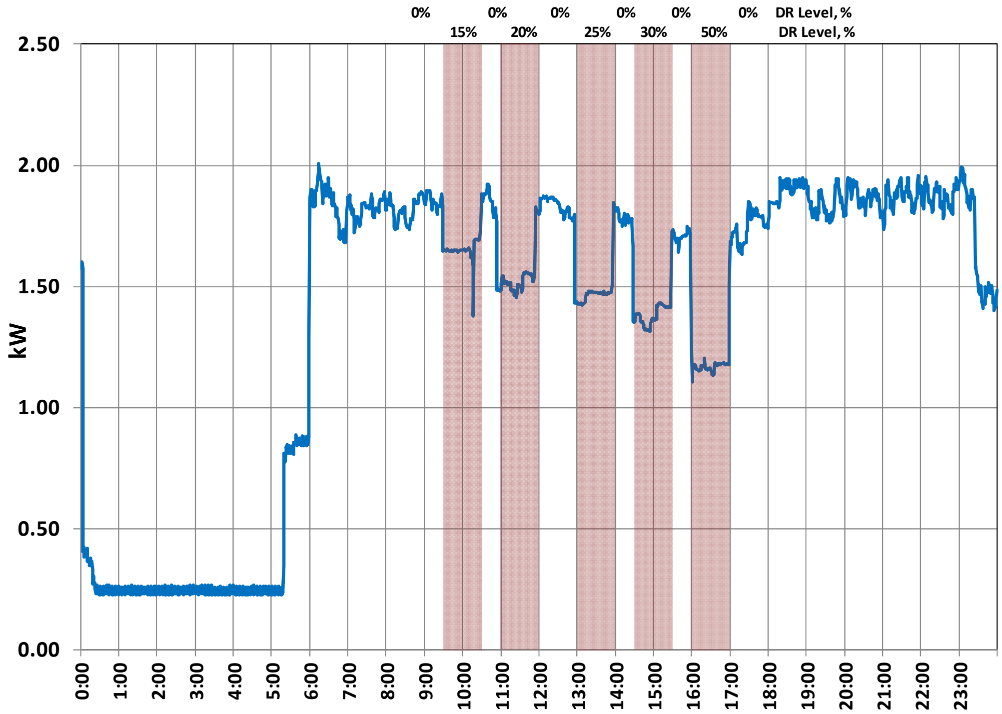

FIGURE 13. LIGHTING DURING A MANUAL DR TEST DAY - WEDNESDAY OCTOBER 31ST

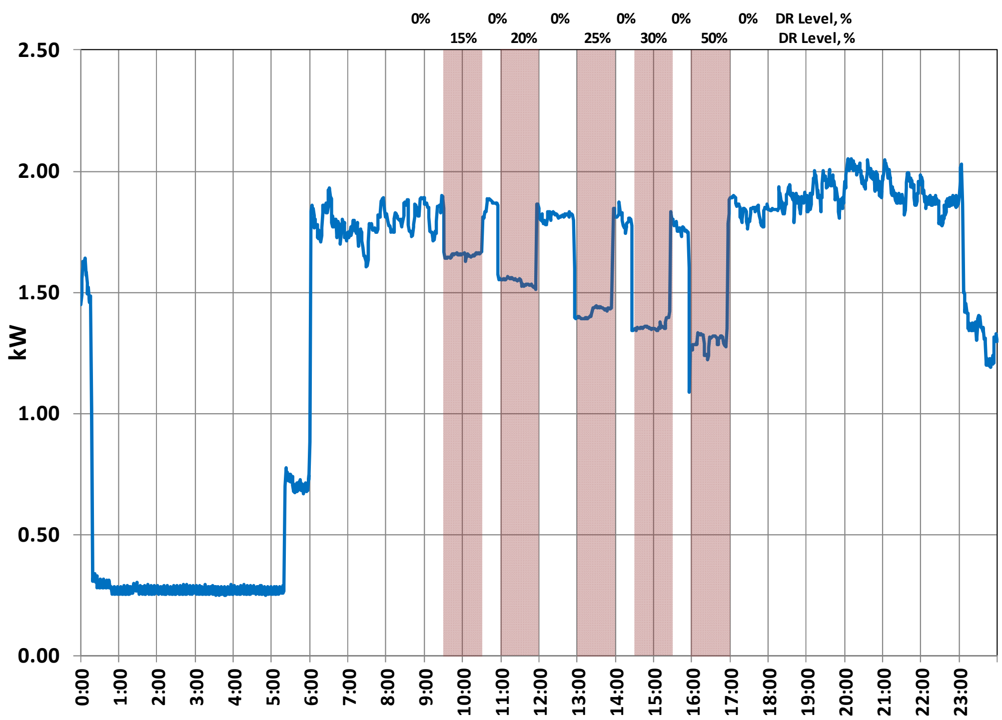

FIGURE 14. LIGHTING DURING A MANUAL DR TEST DAY - THURSDAY NOVEMBER 1ST

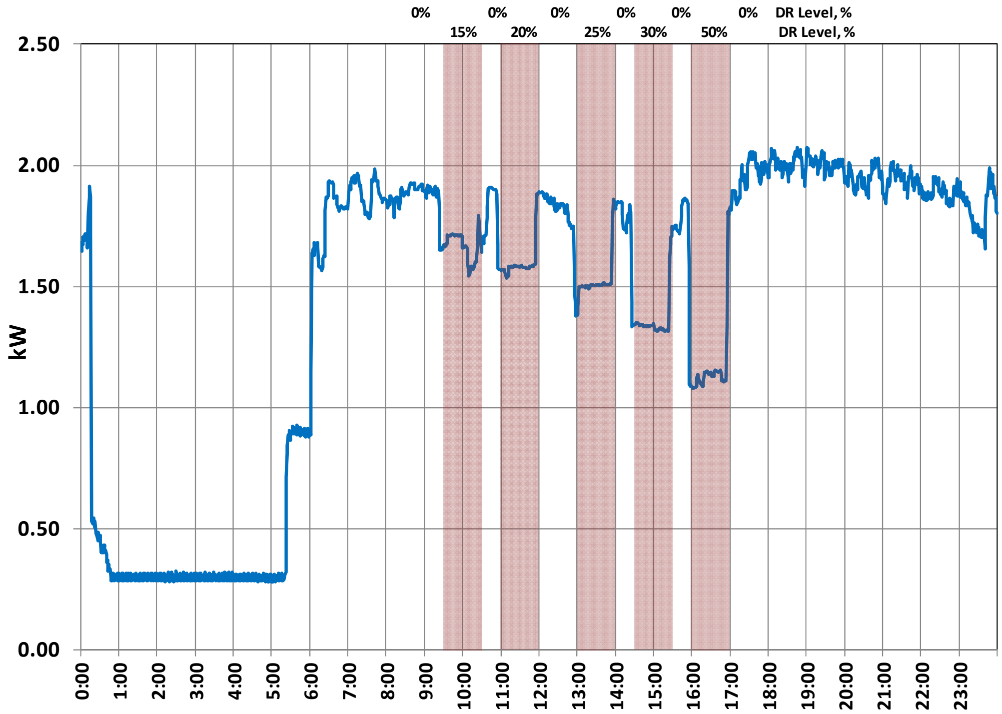

FIGURE 15. LIGHTING DURING A MANUAL DR TEST DAY - MONDAY NOVEMBER 5TH

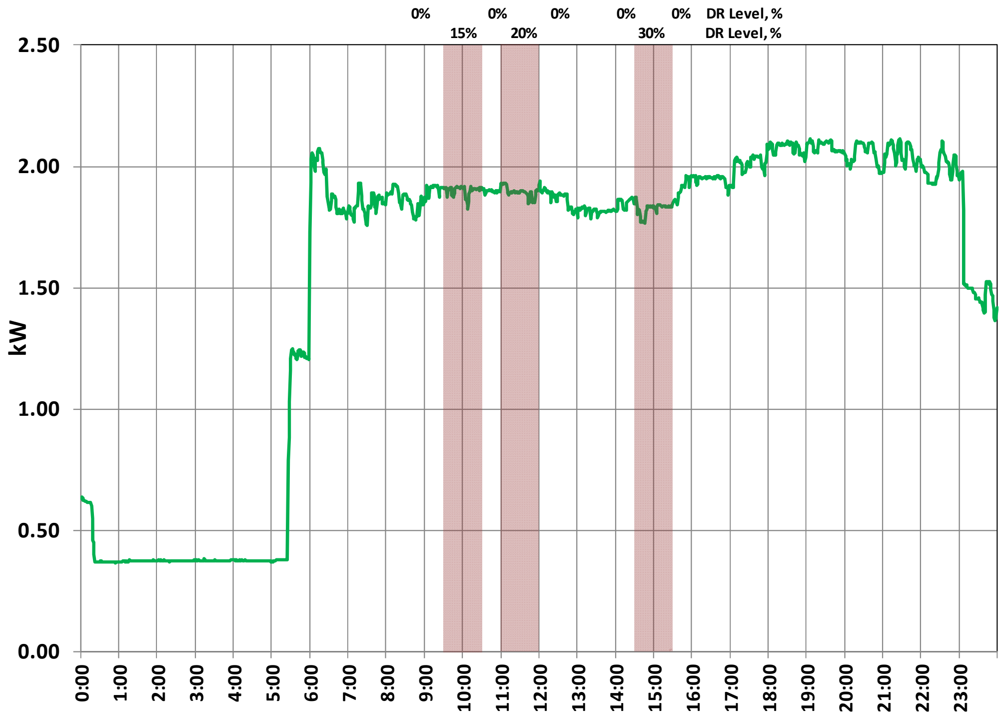

FIGURE 16. LIGHTING DURING AN AUTOMATED DR TEST DAY - WEDNESDAY NOVEMBER 21ST

APPENDIX D – ENLIGHTED, UPLAND

In this section, the interior lighting profiles at the restaurant in Upland are displayed in daily charts. A non-DR test day, which is representative of typical lighting power use, is presented in Figure 17. The electrical use data series illustrates the minute-to-minute electrical usage from the sum of all the monitored lighting breakers. The shaded vertical portions of the graph show the scheduled periods when power is reduced on test days.

Figure 18 through Figure 20 illustrate the three days of manual DR testing, with the DR level percentages labeled above the shaded areas. The figures show drops in demand when the power level settings were reduced as per the DR testing schedule. There are minor start and stop time differences associated with the manual initiation of the DR periods. Figure 21 illustrates the first AutoDR test day. There are no detectable impacts from the AutoDR testing.

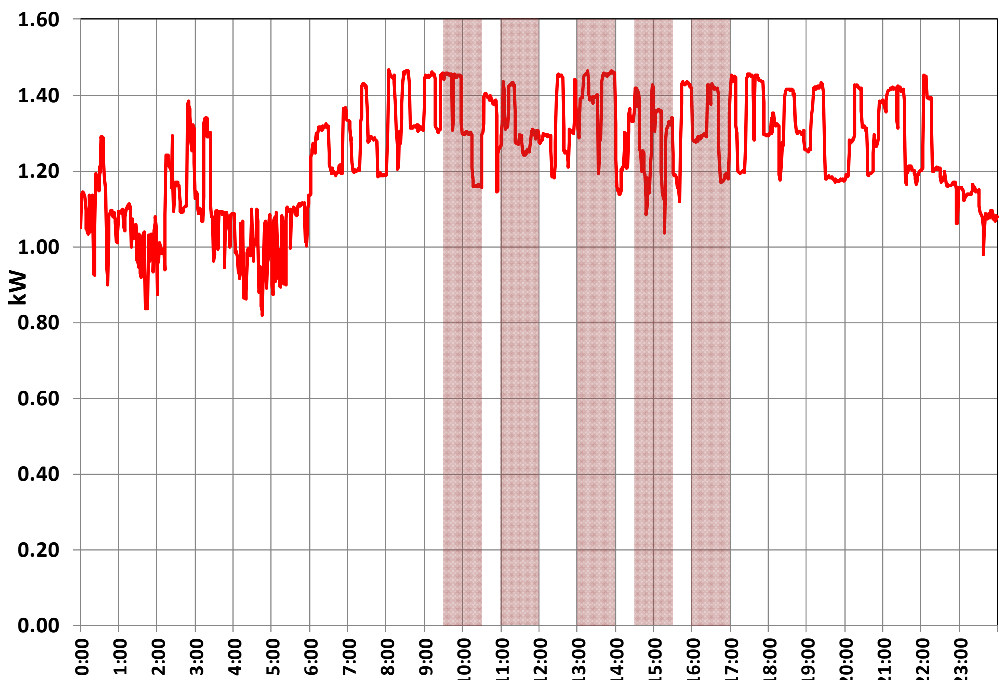

FIGURE 17. LIGHTING DURING A NON-TEST DAY - THURSDAY NOVEMBER 15TH

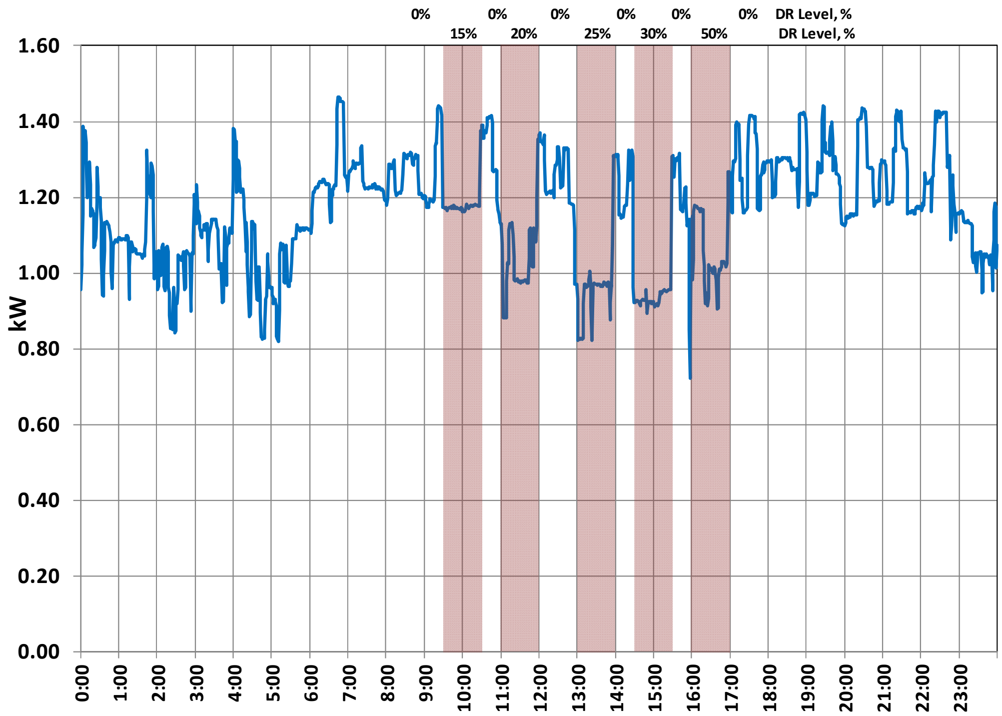

FIGURE 18. LIGHTING DURING A MANUAL DR TEST DAY -MONDAY NOVEMBER 12TH

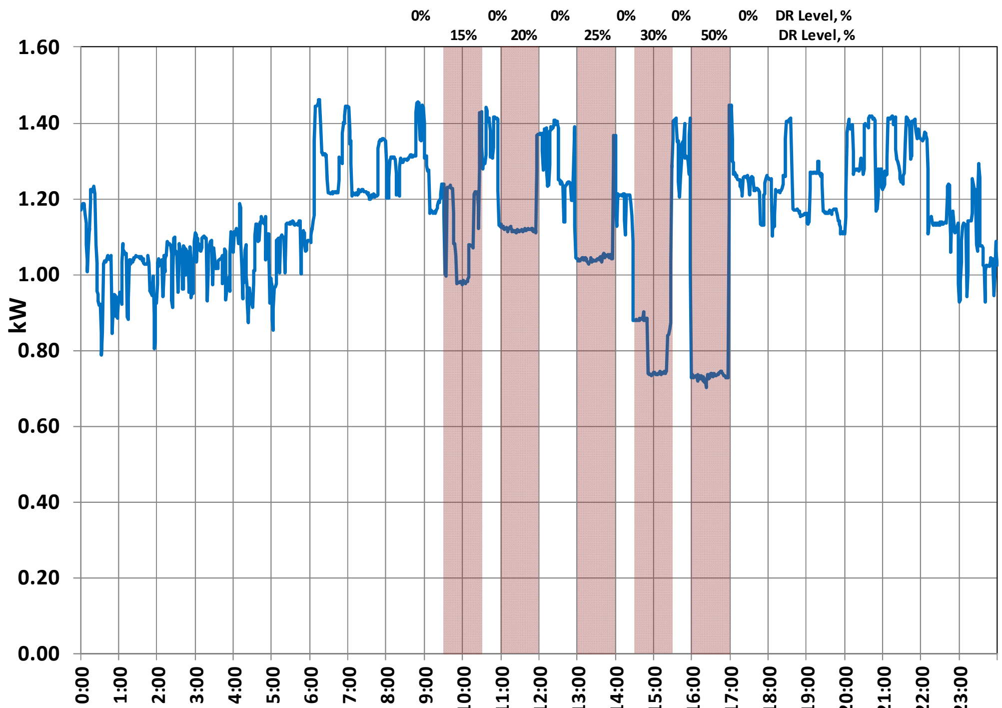

FIGURE 19. LIGHTING DURING A MANUAL DR TEST DAY - TUESDAY NOVEMBER 13TH

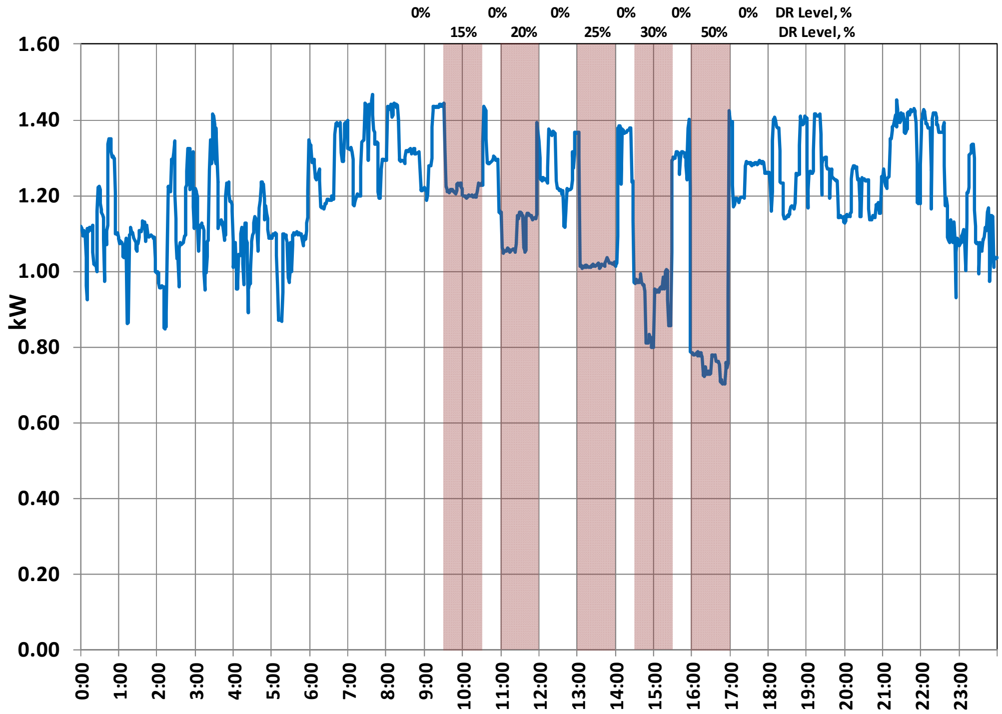

FIGURE 20. LIGHTING DURING A MANUAL DR TEST DAY - WEDNESDAY NOVEMBER 14TH

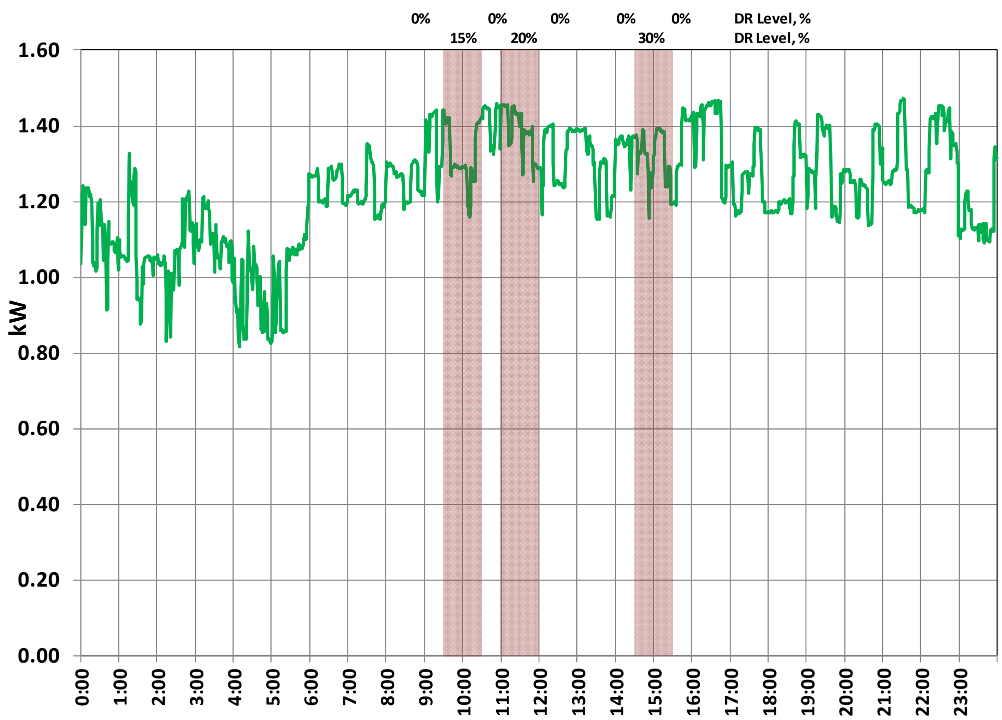

FIGURE 21. LIGHTING DURING AN AUTOMATED DR TEST DAY - WEDNESDAY NOVEMBER 21ST

APPENDIX E – DAINTREE, RANCHO CUCAMONGA

In this section, the interior lighting profiles at the restaurant in Rancho Cucamonga are displayed in daily charts. A non-DR test day, which is representative of typical lighting power use, is presented in Figure 22. The electrical use data series illustrates the minute-to-minute electrical usage from the sum of all the monitored lighting breakers. The shaded vertical portions of the graph show the scheduled periods when power is reduced on test days.

Figure 23 through Figure 25 illustrate the three days of manual DR testing, with the DR level percentages labeled above the shaded areas. The figures show drops in demand when the power level settings were reduced as per the DR testing schedule, even though the lighting load is not stable. Figure 26 illustrates the first AutoDR test day. Only one event (from 2:30 p.m. to 3:30 p.m.) registered, and it is barely discernible from the noise. Figure 26 illustrates the second AutoDR test day. Only one event was conducted (from 2:30 p.m. to 3:30 p.m.) and is clearly visible in the chart despite the noise.

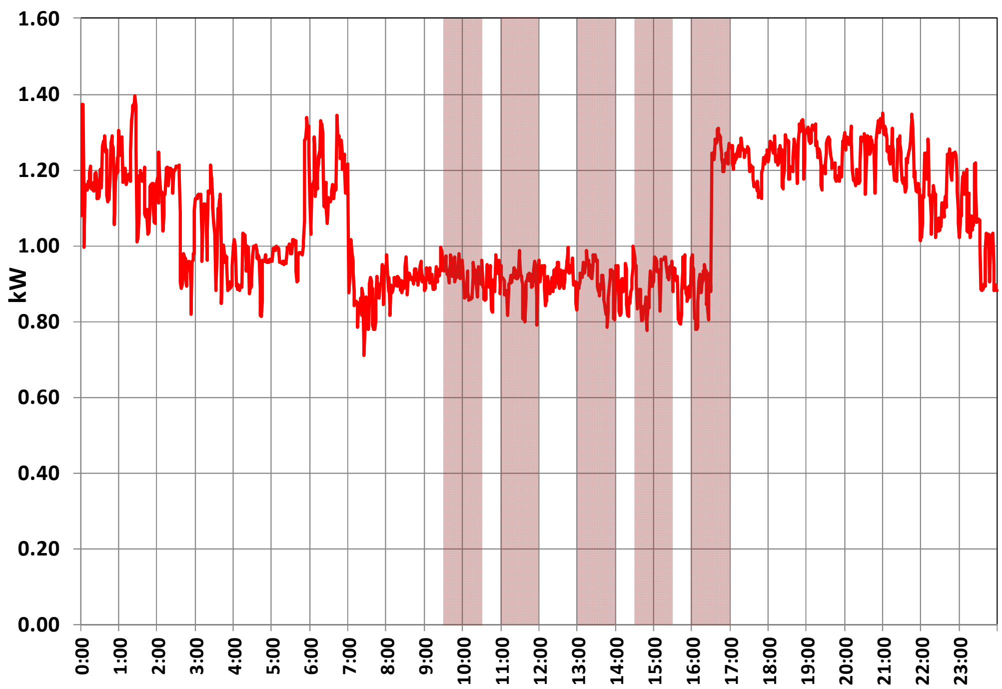

FIGURE 22. LIGHTING DURING A NON-TEST DAY - THURSDAY OCTOBER 18TH

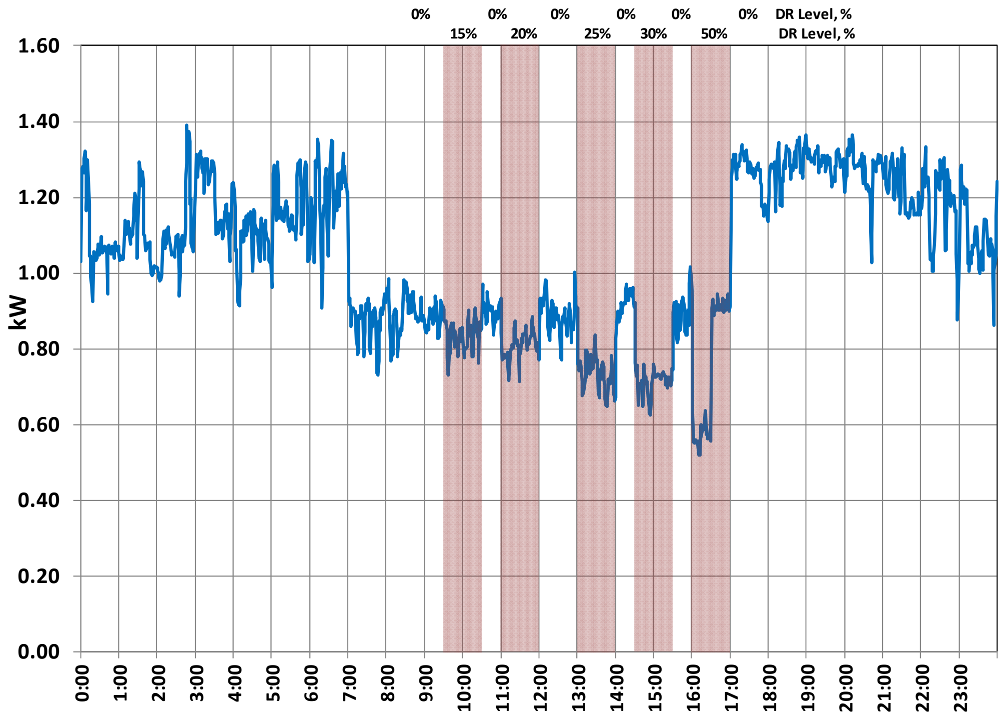

FIGURE 23. LIGHTING DURING A MANUAL DR TEST DAY - MONDAY OCTOBER 15TH

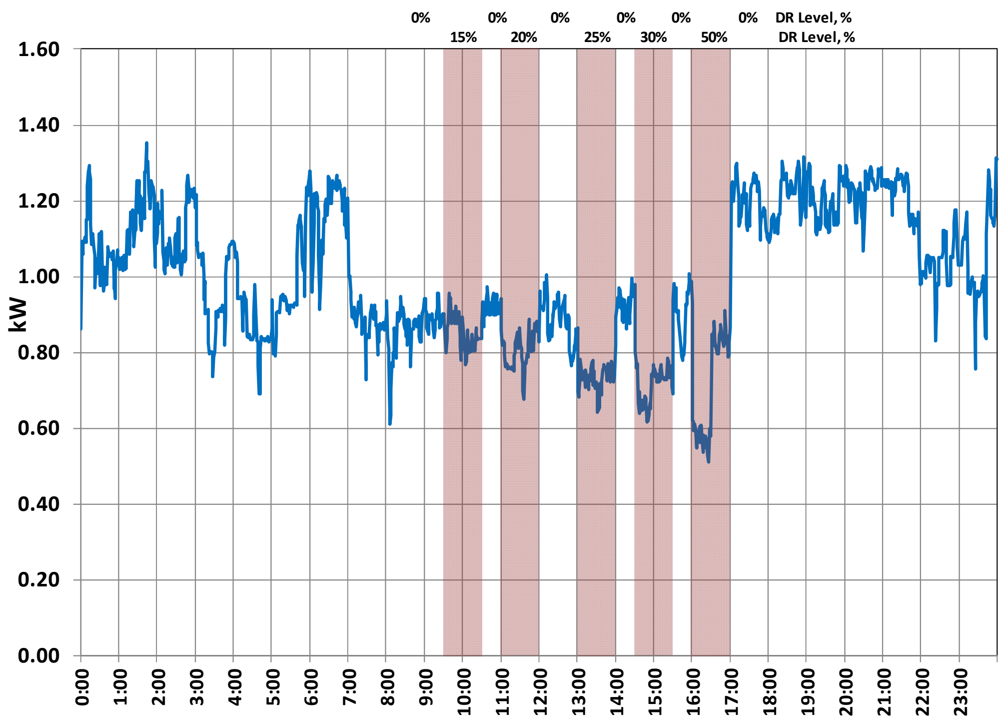

FIGURE 24. LIGHTING DURING A MANUAL DR TEST DAY - WEDNESDAY OCTOBER 17TH

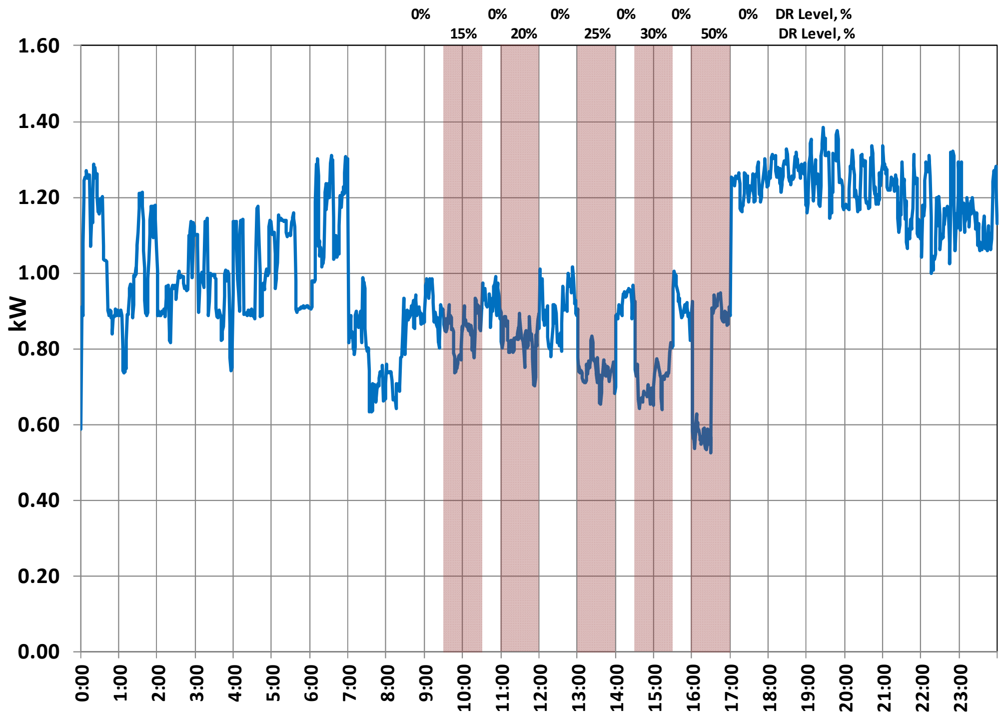

FIGURE 25. LIGHTING DURING A MANUAL DR TEST DAY - FRIDAY OCTOBER 19TH

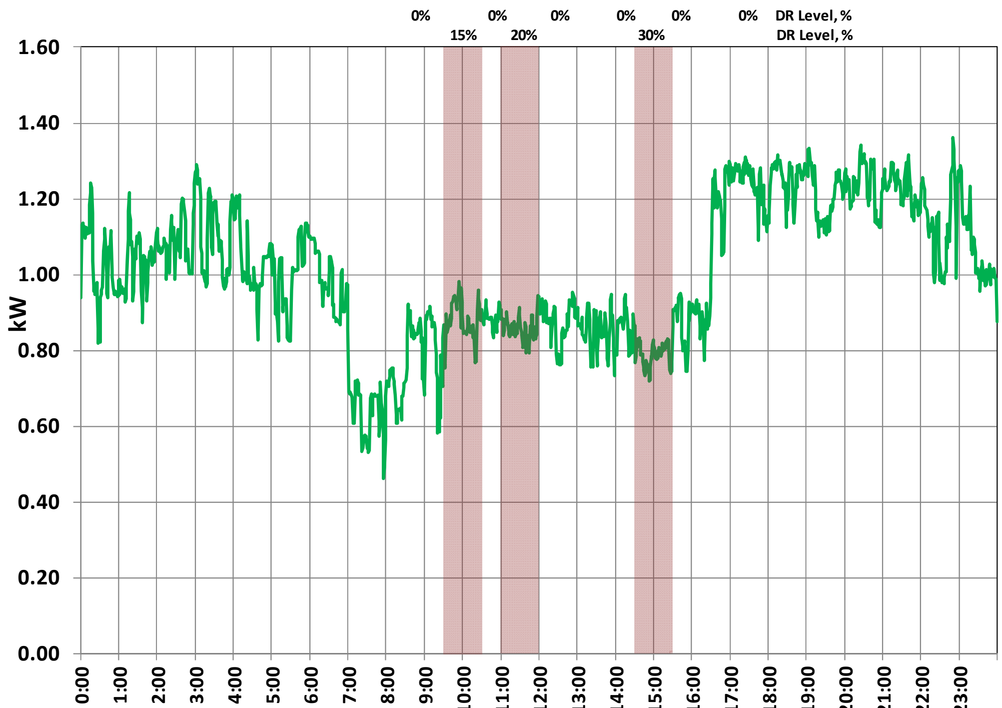

FIGURE 26. LIGHTING DURING AN AUTOMATED DR TEST DAY - WEDNESDAY NOVEMBER 21ST

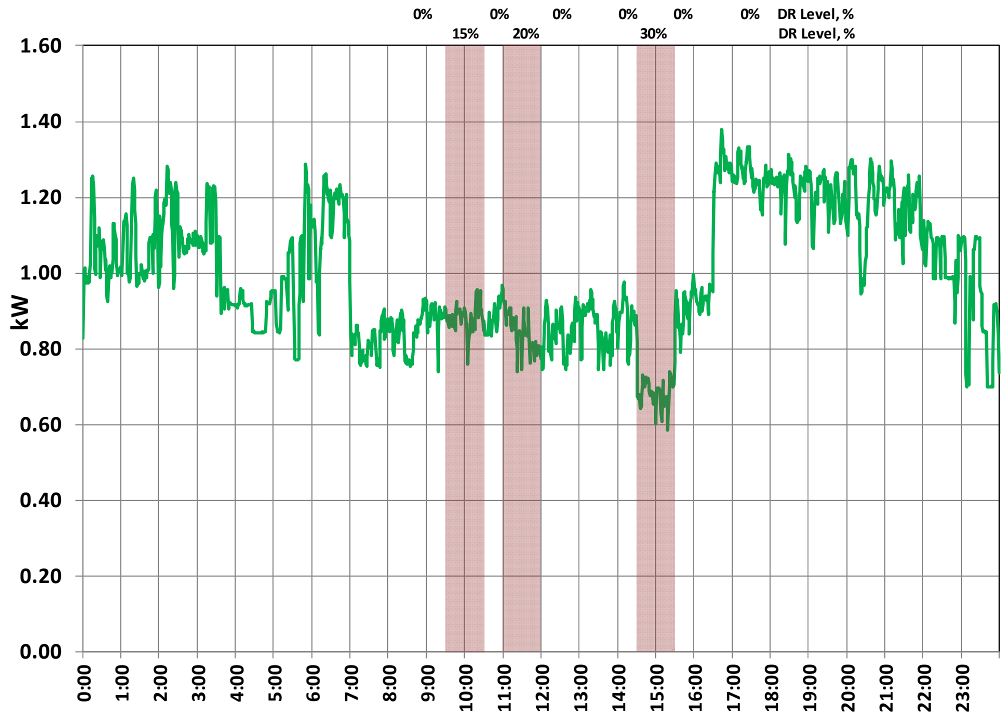

FIGURE 27. LIGHTING DURING AN AUTOMATED DR TEST DAY - MONDAY NOVEMBER 26TH

APPENDIX F – NLIGHT, MONTCLAIR

In this section, the interior lighting profiles at the restaurant in Montclair are displayed in daily charts. A non-DR test day, which is representative of typical lighting power use, is presented in Figure 28. The electrical use data series illustrates the minute-to-minute electrical usage from the sum of all the monitored lighting breakers. The shaded vertical portions of the graph show the scheduled periods when power is reduced on test days.

Figure 29 through Figure 31 illustrate the three days of manual DR testing, with the DR level percentages labeled above the shaded areas. The figures show distinctive drops in demand when the power level settings were reduced. This site used a different set of DR levels than the other sites, starting at 90% and reducing from there. This site was unable to participate in the AutoDR test.

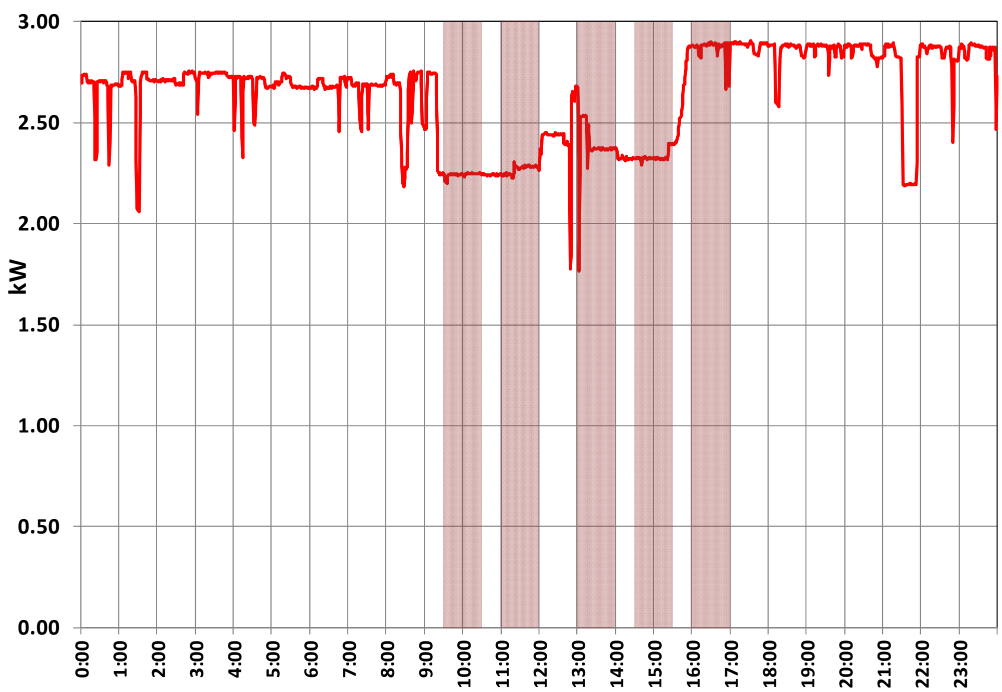

FIGURE 28. LIGHTING DURING A NON-TEST DAY - WEDNESDAY OCTOBER 24TH

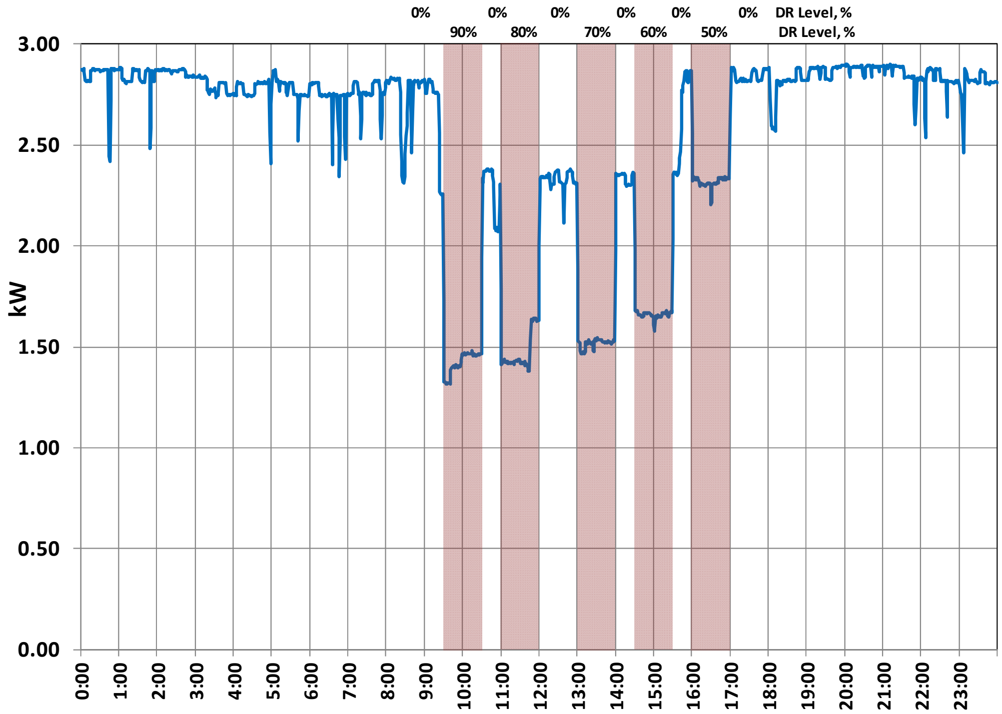

FIGURE 29. LIGHTING DURING A MANUAL DR TEST DAY - THURSDAY OCTOBER 25TH

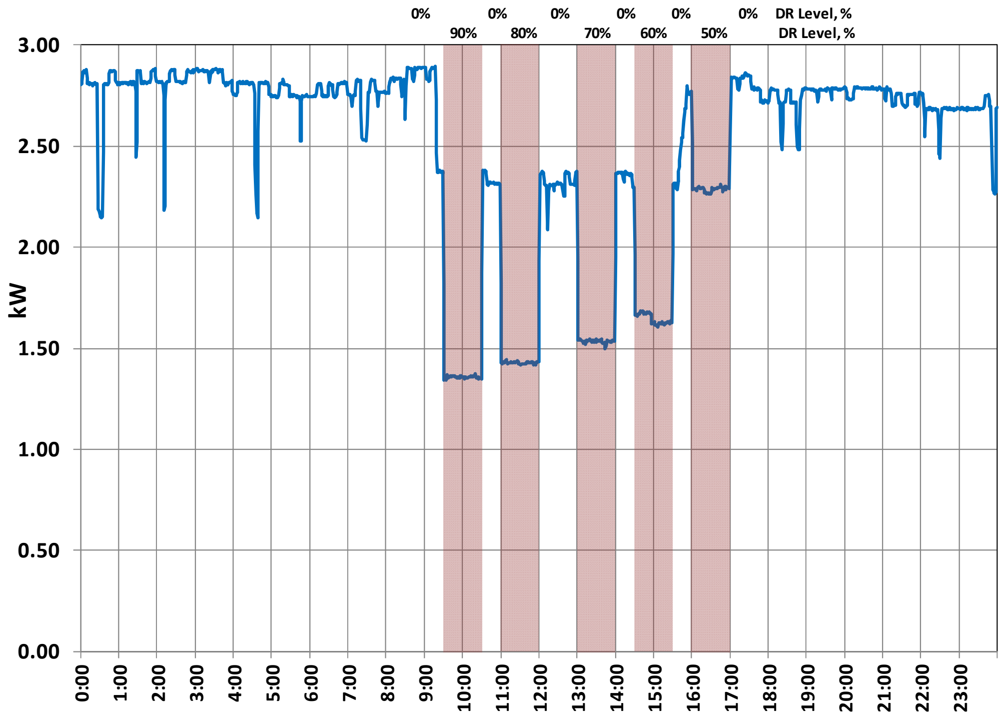

FIGURE 30. LIGHTING DURING A MANUAL DR TEST DAY - FRIDAY OCTOBER 26TH

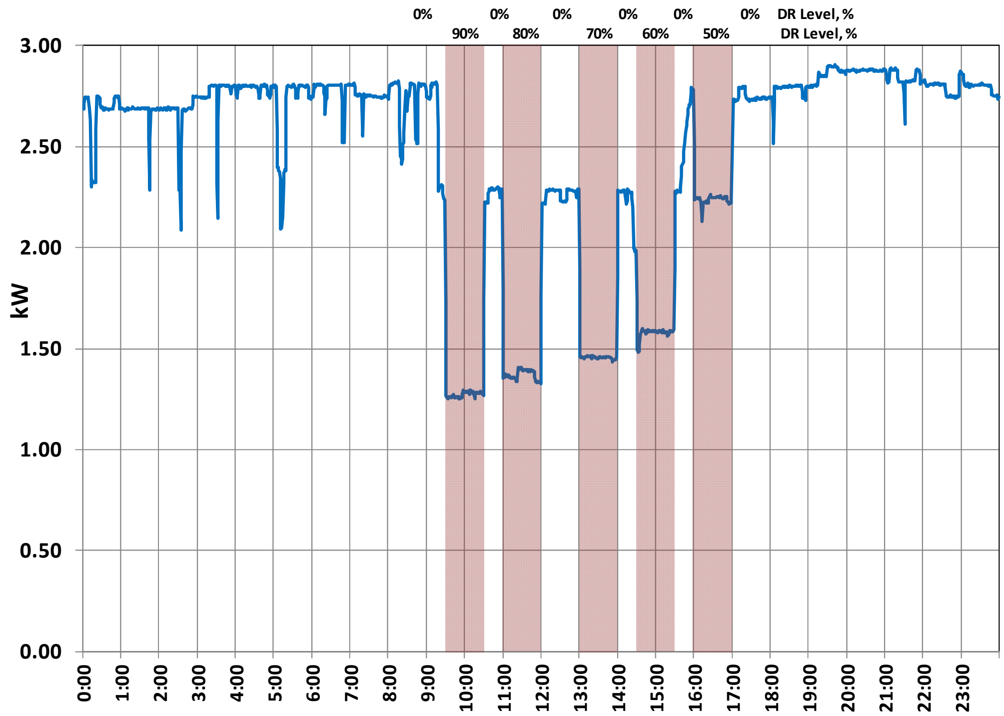

FIGURE 31. LIGHTING DURING A MANUAL DR TEST DAY - SATURDAY OCTOBER 27TH

APPENDIX G – EMBEDDED DATA FILES

Raw and processed data collected for the evaluation of this project can be found in the embedded Excel files. There is one file for each of the five lighting control sites tested. Additionally, there is one file that summarizes and compares the data among the products. The files contain the charts used in this report in the event that they need to be reformatted.

CJ DR Test Summary.xlsx

CJMC DR Test Appx.xlsx

CJMG DR Test Appx.xlsx

CJRC DR Test Appx.xlsx

CJTC DR Test Appx.xlsx

CJUP DR Test Appx.xlsx