

# ComEd

## Midstream Incentives Program Evaluation Report

**FINAL**  
**Energy Efficiency / Demand Response Plan:**  
**Plan Year 8 (PY8)**  
**(6/1/2015-5/31/2016)**

**Presented to**  
**Commonwealth Edison Company**

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**Prepared by:**  
Luke Scheidler  
Itron, Consulting and Analysis

George Jiang  
Itron, Consulting and Analysis



[www.navigant.com](http://www.navigant.com)

**Submitted to:**

ComEd  
Three Lincoln Centre  
Oakbrook Terrace, IL 60181

**Submitted by:**

Navigant Consulting, Inc.  
30 S. Wacker Drive, Suite 3100  
Chicago, IL 60606

**Contact:**

Randy Gunn, Managing Director  
312.583.5714  
Randy.Gunn@Navigant.com

Jeff Erickson, Director  
608.497.2322  
Jeff.Erickson@Navigant.com

Robert Neumann Associate Director  
312.583.2176  
Rob.Neumann@Navigant.com

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## E. EXECUTIVE SUMMARY

This report presents a summary of the findings and results from the impact and process evaluations of the Program Year 8 (PY8)<sup>1</sup> Midstream Incentives program. The primary component of Midstream Incentives focuses on lighting products and is branded the Business Instant Lighting Discounts (BILD) program. The BILD program provides incentives to increase the market share of energy efficient LED lamps, LED fixtures, LED exit signs, and linear fluorescent lamps (LF). Compact fluorescent lamps, LF ballasts, and high intensity discharge (HID) lamps were included in the program in prior years, but have been removed from BILD in PY8. Additionally, as in PY7, midstream incentives for commercial battery chargers were offered as part of the Business Products Discounts (BPD) program. The program was designed to provide an expedited, simple solution to business customers interested in purchasing efficient lighting by providing instant discounts at the point of sale.

### E.1. Program Savings

Table E-1 summarizes the total electricity savings from the PY8 Midstream Incentives program. Table E-1 also includes verified PY8 net carryover savings. All savings from the Midstream Incentives program are attributable to the EEPs portfolio. The verified gross savings estimate of 282,451 MWh represents a gross realization rate of 97 percent (i.e., verified savings were 97 percent of the ex ante gross savings estimate). Verified savings were lower than ComEd ex ante savings primarily due to differences in hours of use parameters and because ex ante estimates do not include a residential / nonresidential split. Differences in ex ante and verified hours of use are attributed to the evaluation’s classification of end-user business types as specified in the IL TRM v4.0, compared to the default ex ante value of “Unknown.” The TRM also specifies a split of four percent residential and 96 percent non-residential for LED bulbs and fixtures, and one percent / 99 percent for linear fluorescent lamps. Commercial installations have higher deemed hours of use and interactive effects values than residential installations, so attributing savings to residential installations has a downward impact on savings.

**Table E-1. PY8 Total Program Electric Savings**

Savings Category	Energy Savings (MWh)	Demand Savings (MW)	Summer Peak Demand Savings (MW)	Winter Peak Demand Savings (MW)
Ex Ante Gross Savings	292,353	NR	NR	NR
Verified Gross Savings	282,451	61.6	57.4	49.6
Verified Net Savings	191,523	41.5	39.0	33.8
Verified Net Carryover Savings	19,687	4.6	4.0	3.4
Verified Total PY7 Net Savings	211,210	46.1	43.0	37.2

Source: ComEd tracking data and Navigant team analysis.

### E.2. Program Savings by Measure

Table E-2 and Table E-3 summarize the energy, demand, and peak demand savings from the ComEd PY8 BILD and BPD programs by measure type. As these tables show, LED lamps made up approximately 84 percent of the total program verified net MWh and 87 percent of net peak MW (summer and winter). LED fixtures and exit signs accounted for approximately eight percent of verified net MWh

<sup>1</sup> The PY8 program year began June 1, 2015 and ended May 31, 2016.

and six percent of net peak MW impacts, and linear fluorescent lamps made up approximately four percent of verified net MWh and three percent of peak MW savings.

Table E-2 and Table E-3 also include line items for PY8 carryover<sup>2</sup> and Small Business Energy Savings (SBES) program overlap. The SBES overlap is a negative adjustment because some products incentivized through the BILD program are also incentivized through the SBES program. Because both programs cannot claim full savings for these measures, adjustments are made to properly attribute savings between the two programs. Additional detail on PY8 carryover savings can be found in Sections 3.2 and 3.4. Additional detail on SBES overlap methods and savings adjustments can be found in Section 3.4.

**Table E-2. PY8 Program Energy and Demand Results by Measure**

Research Category	Ex Ante Gross Savings (MWh)	Verified Gross Savings (MWh)	Verified Gross Realization Rate	Verified Gross Demand Reduction (MW)	NTGR	Verified Net Savings (MWh)	Verified Net Demand Reduction (MW)
LED Lamps	244,030	230,169	94%	51.8	0.77	177,230	39.9
LED Fixtures	12,731	16,039	126%	2.7	0.77	12,350	2.1
LED Exit Signs	5,754	5,734	100%	0.5	0.77	4,415	0.4
Linear Fluorescents	13,346	13,080	98%	2.2	0.61	7,979	1.3
Battery Chargers	201	201	100%	0.1	0.77	155	0.1
Carryover	31,002	31,002	100%	7.3	0.64	19,687	4.6
SBES Overlap	-14,710	-13,773	94%	-3.0	0.77	-10,605	-2.3
<b>Total</b>	<b>292,353</b>	<b>282,451</b>	<b>97%</b>	<b>61.6</b>	<b>0.75</b>	<b>211,210</b>	<b>46.1</b>

Source: ComEd tracking data and Navigant team analysis.

† An overall savings-weighted ratio based on deemed values - the actual weighted NTGR is 0.748.

Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

**Table E-3. PY8 Program Summer and Winter Peak Demand Results by Measure**

Research Category	Verified Gross Summer Peak Savings (MW)	Verified Gross Winter Peak Savings (MW)	NTGR	Verified Net Summer Peak Savings (MW)	Verified Net Winter Peak Savings (MW)
LED Lamps	48.6	41.9	0.77	37.4	32.3
LED Fixtures	2.6	2.2	0.77	2.0	1.7
LED Exit Signs	0.8	0.8	0.77	0.6	0.6
Linear Fluorescents	2.1	1.8	0.61	1.3	1.1
Battery Chargers	0.03	-	0.77	0.02	-
Carryover	6.3	5.3	0.64	4.0	3.4
SBES Overlap	-3.1	-2.4	0.77	-2.4	-1.8
<b>Total</b>	<b>57.4</b>	<b>49.6</b>	<b>0.75</b>	<b>43.0</b>	<b>37.2</b>

Source: ComEd tracking data and Navigant team analysis.

† An overall savings-weighted ratio based on deemed values. Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

## E.3. Impact Estimate Parameters for Future Use

The PY8 Midstream Incentives program evaluation did not conduct evaluation research on deemed parameters, and, thus, there are no parameter updates to report.

<sup>2</sup> PY8 carryover savings result from products purchased in prior program years but not installed until subsequent program years. PY8 carryover savings are from products purchased through the BILD program in PY6 and PY7.

### E.4. Program Volumetric Detail

The PY8 BILD and BPD programs incentivized more than one and a half million lamps, fixtures, and battery chargers as shown in the table below. Reductions in total unit sales volume in PY8 compared to PY7 are primarily due to the removal of CFLs and LF ballasts from the program in PY8.

**Table E-4. PY8 Volumetric Findings Detail**

Program Year	Standard CFLs	Specialty CFLs	LEDs	Linear FLs	HIDs	LF Ballasts	Battery Chargers	Total
PY8	N/A	N/A	1,131,992	503,948	N/A	N/A	76	1,636,016
PY7	279,320	261,262	1,109,148	791,443	2,025	67,331	160	2,510,689
PY6	343,577	362,332	804,299	840,903	2,607	67,391	N/A	2,421,109
PY5	249,799	347,639	211,955	503,627	2,799	N/A	N/A	1,315,819
PY4	194,180	381,072	N/A	N/A	N/A	N/A	N/A	575,252
PY3	4,173	929	N/A	N/A	N/A	N/A	N/A	5,102

Source: ComEd tracking data and Navigant team analysis.

Table E-5 displays the number of enrolled and participating distributors and end-users.

**Table E-5. PY8 Enrolled and Participating Distributors and End Users**

Program Participants	Enrolled	Participating
Distributors	103	88
End Users	NA	~6,500 – 7,500 <sup>3</sup>

Source: ComEd tracking data and Navigant team analysis.

<sup>3</sup> The exact number of unique end users is unknown due to multiple various name and address combinations for the same end-user in the tracking data.

## E.5. Results Summary

The following table summarizes the key metrics from PY8.

**Table E-6. PY8 Results Summary**

Participation	Units	PY8
Net Savings	MWh	211,210
Net Summer Peak Demand Reduction	MW	43.0
Net Winter Peak Demand Reduction	MW	37.2
Gross Savings	MWh	282,451
Gross Summer Peak Demand Reduction	MW	57.4
Gross Winter Peak Demand Reduction	MW	49.6
Carryover Net Savings	MWh	19,687
Carryover Net Summer Peak Demand Reduction	MW	4.0
Carryover Net Winter Peak Demand Reduction	MW	3.4
Carryover Gross Savings	MWh	31,002
Carryover Gross Summer Peak Demand Reduction	MW	6.3
Carryover Gross Winter Peak Demand Reduction	MW	5.3
SBES Overlap Net Savings Reduction	MWh	-10,605
SBES Overlap Net Summer Peak Demand Reduction	MW	-2.4
SBES Overlap Net Winter Peak Demand Reduction	MW	-1.8
SBES Overlap Gross Savings Reduction	MWh	-13,773
SBES Overlap Gross Summer Peak Demand Reduction	MW	-3.1
SBES Overlap Gross Winter Peak Demand Reduction	MW	-2.4
Program Realization rate	%	97%
Program NTG Ratio <sup>†</sup>	%	75%
LEDs Sold	#'s	1,106,695
LED Exit Signs Sold	#'s	25,297
LFs Sold	#'s	503,948
Non-Lighting Products Sold	#'s	76
Non-Lighting Products Net Savings	MWh	155
Customers touched	#'s	-6,500 to 7,500

Source: ComEd tracking data and Navigant team analysis.

<sup>†</sup> An overall savings-weighted ratio for all measure types based on deemed values - the actual weighted NTGR is 0.748.

Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>



## E.6. Findings and Recommendations

The following provides insight into some of the key program findings and recommendations.<sup>4</sup>

### Verified Gross Impacts and Realization Rate

**Finding 2.** The PY8 gross verified energy savings were estimated to be 282,451 MWh. LEDs comprised 89 percent of program energy savings. The gross realization rate on this savings estimate is 97 percent. Verified savings were lower than ComEd ex ante savings primarily due to differences in hours of use by business type as specified in the IL TRM v4.0, and because ex ante estimates do not include a residential / nonresidential split. The IL TRM specifies a split of 4 percent residential and 96 percent commercial for LED lamps and one percent / 99 percent for linear fluorescent lamps. Commercial installations have higher deemed hours of use and interactive effects values than residential installations, so attributing savings to residential installs has a downward impact on savings.

**Recommendation 2.** ComEd could improve their ex ante savings estimates by establishing preliminary business types for end-users where possible and applying the associated parameters from the TRM. Estimates could also be improved by applying the deemed residential and nonresidential splits and the other appropriate deemed residential parameters (hours of use, interactive effects, etc.).

**Finding 3.** The PY8 gross verified summer peak demand reduction was 57.4 MW and winter peak demand savings were 49.6 MW. The net verified summer and winter peak demand reductions were 43.0 MW and 37.2 MW, respectively. As in PY7, the largest portion of these savings are due to LED sales, which comprised 93 percent of verified net peak demand savings.

### Verified Net Impacts

**Finding 4.** The overall unit sales-weighted net-to-gross ratio (NTGR) found in this evaluation was 0.75 based on deemed values.<sup>5</sup> The BILD and BPD programs accomplished 211,210 MWh of net energy savings, 43.0 MW of summer peak demand reduction, and 37.2 MW of winter peak demand reductions. Over 91 percent of these energy savings were from LED lamps, fixtures, and exit signs while only four percent were from linear fluorescents. Verified summer and winter peak demand savings were also dominated by LEDs (approximately 93 percent).

### Process Evaluation

**Finding 6.** In November of PY8, ComEd instituted the requirement that BILD distributors provide customer contact information and the business name and address where the lamps were to be installed. After this requirement was instituted, almost two-thirds (62.7 percent) of distributors were able to collect information for all BILD transactions. The primary reasons why distributors were not able to capture all BILD transactions were that the customer did not want to provide it (61 percent) or the customer was a contractor that did not know where the lamps would be installed (21 percent).

**Recommendation 4.** The evaluation team has recommended that ComEd collect the purchaser contact information rather than the end-user contact information, which should alleviate the issue surrounding contractor purchases. Tying the distributor bonus to the successful collection of customer contact information could potentially encourage extra effort to be made for the remaining transactions.

**Finding 9.** In November 2015, the BILD program instituted a new minimum customer co-pay of 50 percent of each lamp type's incentive amount for all program transactions. The vast

<sup>4</sup> This is a subset of our findings and recommendations. Numbered findings and recommendations in this section are the same as those found in the Findings and Recommendations section of the evaluation report for ease of reference between each section.

<sup>5</sup> Deemed values. Source: ComEd\_NTG\_History\_and\_PY7\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

majority claimed that a minimal amount of sales in each category (0-5 percent) triggered the minimum copays, but there were several distributors who claimed that 100 percent of their BILD transactions for a given lamp category triggered the minimum copay. Most of the participants thought that the minimum copay was beneficial to the program, stating that it balances the playing field for distributors and increases customer interest in the bulbs, by legitimizing the investment in energy efficiency.

**Recommendation 7.** ComEd should maintain a close eye on this metric. A large percentage of lamp sales triggering the minimum customer co-pay would indicate that market prices have dropped and that incentive levels need to be revisited or certain low-quality products should be removed from the approved products list (APL).

**Finding 10.** In PY8, there were 30-day funding periods instituted between July and November, and 45-day to 60-day funding periods defined for the remainder of the program year. To help inform the design of additional funding cycles, distributors were asked over what time period they could accurately forecast (within 10%) their need for BILD funds. Over 80% of distributors estimate that they can forecast their need for BILD funding for one to three months into the future.

**Recommendation 8.** The evaluation recommends that ComEd require program distributors to forecast their need for incentives 90 days in advance, which captures the time period over which the majority of distributors feel they can accurately forecast their need for funding.

## 1. INTRODUCTION

### 1.1 Program Description

The Non-Residential Business Instant Lighting Discounts (BILD) program and Business Products Discounts (BPD) program provide incentives to increase the market share of energy efficient products commonly sold to business customers. The BILD Program was launched as a pilot in PY3 (originally called the Midstream Incentives program) and was a full scale program in PY4. The program was designed to provide an expedited, simple solution to business customers interested in purchasing efficient lighting by providing instant discounts at the point of sale. The BPD program offers commercial, industrial and contractor customers discounts, at the time of sale, on high-efficiency battery chargers.

At this time the BILD Program provides incentives on a mix of standard and specialty LEDs (lamps and fixtures), LED exit signs, and linear fluorescent (LF) lamps. The BPD program only offers incentives on battery chargers (transformers were previously included in the program but have been removed in PY8). The PY8 rebate values vary by technology, as follows:

- LED lamps (screw based and pin based) \$2 to \$12.
- LED trim kits \$5 to \$10
- LED exit signs \$5 to \$15
- Linear fluorescent lamps \$1
- Industrial battery chargers \$184 per unit.

In PY8, BILD program sales came from a total of 88 unique distributors (this is a decrease from 95 unique distributors in PY7). BILD products were sold to approximately 6,500 to 7,500 unique end-users.<sup>6</sup> All BILD program unit sales were delivered via the “distributor program.” In prior program years, a small fraction of products were sold through a “retail program,” which sells bulbs directly to contractors through the pro desk of major Do-it-Yourself retailers, but this delivery channel was not included in the PY8 program.

### 1.2 Evaluation Objectives

The Evaluation Team identified the following key researchable questions for PY8.

#### 1.2.1 Impact Questions

1. What is the level of gross annual energy (kWh) and gross peak demand (kW) savings induced by the program?
2. What is the level of net annual energy (kWh) and net peak demand (kW) savings induced by the program?
3. Did the program meet its energy and demand goals? If not, why not?

#### 1.2.2 Process Questions

1. How burdensome is the rebate application and submission process for distributors? Specifically, what is the level of effort required by distributors to gather the end-user information required by the evaluation team and what are best practices that would reduce this burden?
2. What other aspects of the program can be improved from the program distributors' perspective?

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<sup>6</sup> The exact number of unique end-users is unknown due to multiple various name and address combinations for the same end-user in the tracking data.

## 2. EVALUATION APPROACH

The PY8 BILD and BPD program evaluation primarily consists of a verification analysis. That is, ex ante energy and demand savings calculations in the program tracking data were verified by the evaluation team using the deemed values and methods described in the Illinois Statewide Technical Reference Manual (TRM), Version 4.0.<sup>7</sup> The BILD evaluation typically includes additional “evaluation research,” which is aimed at collecting data to support and refine future updates to the TRM for relevant parameters such as installation rate, residential / non-residential split, and net-to-gross ratio. The evaluation team postponed additional evaluation research on these parameters until PY9. Beyond the verification analysis, the PY8 evaluation also included process research with program distributors to identify opportunities for streamlining and improving the BILD program.

Finally, in many of the tables throughout this report, there is a line item for Small Business Energy Savings (SBES) program overlap. Subsequent to the beginning of the PY7 evaluation year, an overlap was identified between the ComEd BILD program and the ComEd Small Business Energy Savings program. The SBES program offers free energy audits, contractor quotes and incentives for upgrades, as well as direct installation services for little to no customer cost. Part of the SBES program includes lighting retrofits with BILD qualified products. SBES trade allies receive a combined materials and labor incentive for installing energy efficient lighting for small businesses, which also includes the BILD discount through a BILD distributor trade ally. In PY7, it was not possible to determine record level overlap between the two programs. Due to this, savings from any BILD qualified product installed through the SBES program was subtracted from SBES program savings, regardless of whether that product actually received a BILD discount. In PY8, ComEd decided to attribute the savings between the two programs rather than subtracting all savings from SBES. The tracking data still does not allow for a record level accounting, but ComEd and the evaluation team developed a methodology to attribute savings to the two programs based on the relative incentive amounts paid by each program weighted by the total savings for each product category.

### 2.1 Overview of Data Collection Activities

The core data collection activities for the evaluation of the PY8 Midstream programs included in-depth analysis of the program tracking data and a web survey of program distributors. Other primary data sources used to complete the evaluation included tracking spreadsheets from the program implementers and the Illinois TRM v4.0.<sup>8</sup> The full set of data collection activities is shown in Table 2-1 and Table 2-2.

**Table 2-1. Primary Data Collection Activities**

What	Who	Target Completes	Completes Achieved	When	Comments
Program Tracking Database	Participants	N/A	N/A	July – September. 2016	Data supporting Gross and Net impact assessment
In Depth Interviews	Program Manager/Implementer Staff	2	2	July – September. 2016	Data to inform the overall evaluation approach
Web Survey <sup>9</sup>	BILD Distributors	Census	75	May – June. 2016	Data supporting process evaluation

<sup>7</sup> Source: [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

<sup>8</sup> Source: [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

<sup>9</sup> The survey instrument can be found in Appendix 7.3.

Table 2-2. Additional Resources

Reference Source	Author	Application	Gross Impacts
Illinois Technical Reference Manual	VEIC	Verified Savings Ex Ante Assumptions	X
Workpaper on Battery Chargers <sup>10</sup>	DNV GL / PG&E	Verified Savings Ex Ante Assumptions	X
SBES Program Tracking Data	ComEd	Gross and Net Impact Assessment	X

## 2.2 Verified Savings Parameters

Verified gross and net savings (energy and coincident peak demand) resulting from the PY8 program were calculated using the following algorithms as defined by the Illinois TRM version 4.0:<sup>11</sup>

**Verified Gross Annual kWh Savings** = Program bulbs \* Delta Watts/1000 \* HOU \* IEe\* ISR

**Verified Gross Annual kW Savings** = Program bulbs \* Delta Watts/1000 \* ISR

**Verified Gross Annual Summer Peak kW Savings** = Gross Annual kW Savings \* Summer Peak Load CF \* IEd

**Verified Gross Annual Winter Peak kW Savings** = Gross Annual kW Savings x Winter Peak CF<sup>12</sup>

### Where:

- Delta Watts = Difference between the Baseline Wattage and Energy Efficient Wattage
- HOU = Annual Hours of Use
- ISR = Installation Rate
- Summer Peak Load CF = Peak Load Coincidence factor is calculated as the percentage of program bulbs turned on during peak hours (weekdays from 1 to 5 p.m.) throughout the summer.
- Winter Peak CF = Peak load coincidence factor, the percentage of Program Bulbs turned on during the PJM Winter Peak hours<sup>13</sup>
- IEe = Energy Interactive Effects
- IEd = Demand Interactive Effects

The following table presents the parameters that were used in the verified gross and net savings calculations and indicates which were examined through evaluation activities and which were deemed. Deemed parameters from the TRM were used directly for all BILD products. Battery chargers are not included in the TRM and ComEd submitted a workpaper to the Illinois TRM administrator based on Pacific Gas and Electric Company research that presented verified savings parameters.

<sup>10</sup> Based on Pacific Gas and Electric Company research and a DNV GL workpaper. See Section 7.3.

<sup>11</sup> Source: [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

<sup>12</sup> Because ComEd is an electric utility and the majority of ComEd's customer have gas heating, no heating penalties have been included in the winter peak savings estimate.

<sup>13</sup> The Winter Peak Period is defined by PJM as the period from 6-8 am and 5-7 pm, Central Time Zone, between January 1 and February 28.

**Table 2-3. Verified Savings Parameter Data Sources**

Gross Savings Input Parameters	Data Source	Deemed † or Evaluated?
Program Bulbs	PY8 Program Tracking Data	Evaluated
Delta Watts	TRM v4.0	Deemed
Res / Non-Res Split	TRM v4.0	Deemed
Hours of Use (HOU)	TRM v4.0	Deemed
Peak Coincidence Factor (CF)	TRM v4.0	Deemed
Energy Interactive Effects	TRM v4.0	Deemed
Demand Interactive Effects	TRM v4.0	Deemed
Installation Rate	TRM v4.0	Deemed
All Battery Charger parameters	ComEd Workpaper	Evaluated
NTGR	Statewide Advisory Group process (EEPS)†	Deemed

† Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

### 2.2.1 Verified Gross Program Savings Analysis Approach

The evaluation team calculated verified savings by measure based upon available data. The data used to estimate the verified gross program savings came from the PY8 program tracking data and the IL TRM v4.0.<sup>14</sup> Tracking data was used to weight the deemed parameters found in the TRM.

### 2.2.2 Verified Net Program Savings Analysis Approach

Verified net energy and demand (coincident peak and overall) savings were calculated by multiplying the verified gross savings estimates by a net-to-gross ratio (NTGR). In PY8, the NTGR estimates used to calculate the net verified savings were based on past evaluation research and defined through a negotiation process through SAG; the NTG SAG discussions occur between early January of each year and are completed by March 1<sup>st</sup>. BILD PY8 NTG values were based upon NTG evaluation research in PY5 and PY6.<sup>15</sup> There was no evaluation research conducted in PY8 to support future updates to the SAG recommended values.

## 2.3 Process Evaluation

Midstream incentive delivery mechanisms are beneficial because they reduce the administrative burden of processing thousands of downstream rebate applications. Similarly, because rebates are submitted by the distributor, all burden is removed from the end-user. However, due to this approach, a lack of end-user information has been a consistent challenge for evaluation of this program. Beginning in November 2015, ComEd asked distributors to capture additional end-user information in the rebate submissions. The PY8 process evaluation primarily explores how distributors are collecting, organizing, and submitting the required information and determine if this process is too burdensome for some distributors and identify best practices for streamlining this activity in future program years. The evaluation team utilized a brief web survey sent to all program distributors to provide insight into these process-related issues.

<sup>14</sup> Source: [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

<sup>15</sup> Source: ComEd PY5-PY6 Proposal Comparisons with SAG.xls, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

### 3. GROSS IMPACT EVALUATION

This section presents the results of the verified gross impact findings.

#### 3.1 Tracking System Review

The tracking system review in the PY8 BILD program was an iterative process. ComEd provided a comprehensive dataset that only included current program year records based on collaboration with the evaluation team from the previous year. Initial checks ensured that the current program year records were complementary and non-overlapping with bulb sales attributed to previous program years. Records were also checked to verify that the bulbs were bought and installed in ComEd territory in the PY8 date range.

The evaluation also strived to assign business types to each transaction, as specified in the IL TRM. The evaluation team used the purchaser business name (or end-user business name where available) to assign a more accurate business type to each end-user where possible. An algorithm using keywords found in the purchasers' business names was used to automatically assign business types. However, due to the fact that the collection of end-user data began partway through the program year and given the large scale of transactions, the automated classification of end-users may not be completely accurate for all transactions. Thus, a manual QC process was employed for the top 50% of purchasers by sales volume. During this process, approximately 25% of the assignments were updated. Due to this relatively high error rate, the evaluation team assigned the ex-ante business type of "Unknown" for all records that were not reviewed (the bottom 50% of purchasers by sales volume). Additionally, where the evaluation team identified the purchaser as a contractor, the business type was also assigned as "Unknown" because contractors may install lamps at a variety of business types. At the conclusion of this process, the evaluation team was able to establish business type for 4 percent of BILD transactions (22 percent of total sales volume). Table 3-1 shows the distribution of the assigned business types used in the analysis – this is a new table that has not been included in prior BILD evaluation reports. The evaluation analysis was only able to confidently establish business type for a small fraction of overall sales volume. However, the distribution of business types within the program can have a potentially large effect (upward or downward) on program energy and coincident peak demand savings, and the evaluators recommend that ComEd and the implementation team continue to work collaboratively with evaluation efforts to improve business type assignments.

The evaluation team also reviewed the bulb information by manufacturer and model number. The wattage and lumens were verified for measures with over 1 GWh in gross savings, accounting for approximately 60 percent of the entire program savings. For directional LEDs, center beam candlepower (CBCP), beam angle, and lamp diameter were also verified. This resulted in a handful of minor changes to these fields to increase the accuracy of impact calculations. The evaluation team also looked up reflector types (e.g., PAR38, BR20, etc.) for each of the directional LEDs. These are necessary to use the lumen mappings in the IL TRM v4.0 to determine delta watts of these bulbs.

Overall, the tracking data was very accurate in terms of bulb information and application of the IL TRM. After each of the validation steps above, there were only 18 model numbers with discrepancies between reported and TRM-based savings calculations. About half of these discrepancies were a result of updates to lamp specifications based on lookups. The remainder was due to incorrect assignment of lamp type (e.g., candelabra classified as an A-lamp).



**Table 3-1. Distribution of End-User Business Types**

End-User Business Type	Transactions	Percent	Total Units Sold	Percent
Assisted Living	2	0.0%	7,420	0.5%
College	108	0.5%	66,683	4.1%
Garage	1	0.0%	6,000	0.4%
Grocery	12	0.1%	8,619	0.5%
Hospital - FCU	79	0.4%	37,709	2.3%
Hotel/Motel - Common	81	0.4%	19,661	1.2%
Hotel/Motel - Guest	108	0.5%	52,178	3.2%
MF - High Rise - Common	8	0.0%	2,556	0.2%
MF - Mid Rise	42	0.2%	21,390	1.3%
Office - Mid Rise	269	1.2%	95,773	5.9%
Religious Building	17	0.1%	5,434	0.3%
Restaurant	2	0.0%	34	0.0%
Retail - Department Store	49	0.2%	4,190	0.3%
Retail - Strip Mall	124	0.6%	15,963	1.0%
Unknown	16,757	77.4%	804,877	49.2%
Warehouse	14	0.1%	24,404	1.5%
Contractor (Unknown)	3,967	18.3%	463,049	28.3%

Source: ComEd tracking data and Navigant team analysis.

## 3.2 Program Volumetric Findings

As shown in Table 3-2, the total number of units sold during the PY8 BILD and BPD programs was 1,636,016, which is a 35 percent decrease from the total units sold in PY7. The decrease between program years was largely due to the removal of CFLs, LF ballasts, and HIDs from the program in PY8. LEDs<sup>16</sup> comprised 69 percent of PY8 BILD sales. Linear fluorescent lamps made up 31 percent of sales. Product sales are represented graphically in Figure 3-1. Compared to PY7, the total sales of LEDs increased by two percent and total sales of linear fluorescent lamps decreased by 36 percent. It is unknown what caused the large drop in reduced wattage LFs in PY8. However, as part of the distributor survey, over 70 percent of respondents said that they sold high-efficiency lamps in PY8 that did not receive BILD discounts. Approximately 47 percent of these high-efficiency, non-discounted lamps were reduced wattage linear fluorescents. This may indicate that additional LF products could be added to the Approved Products List (APL).

Key findings include:

1. Overall unit sales decreased 35 percent compared to PY7, largely due to removal of CFLs and LF ballasts from the program.
2. LED unit sales were almost stagnant, increasing by two percent over PY7.
3. Linear fluorescent lamp sales decreased 36 percent from PY7, compared to a 6 percent decrease between PY6 and PY7.

<sup>16</sup> Including LED Fixtures and exit signs.



**Table 3-2. PY8 Volumetric Findings Detail**

Program Year	Standard CFLs	Specialty CFLs	LEDs	Linear FLs	HIDs	LF Ballasts	Battery Chargers	Total
PY8	N/A	N/A	1,131,992	503,948	N/A	N/A	76	1,636,016
PY7	279,320	261,262	1,109,148	791,443	2,025	67,331	160	2,510,689
PY6	343,577	362,332	804,299	840,903	2,607	67,391	N/A	2,421,109
PY5	249,799	347,639	211,955	503,627	2,799	N/A	N/A	1,315,819
PY4	194,180	381,072	N/A	N/A	N/A	N/A	N/A	575,252
PY3	4,173	929	N/A	N/A	N/A	N/A	N/A	5,102

Source: ComEd tracking data and Navigant team analysis.

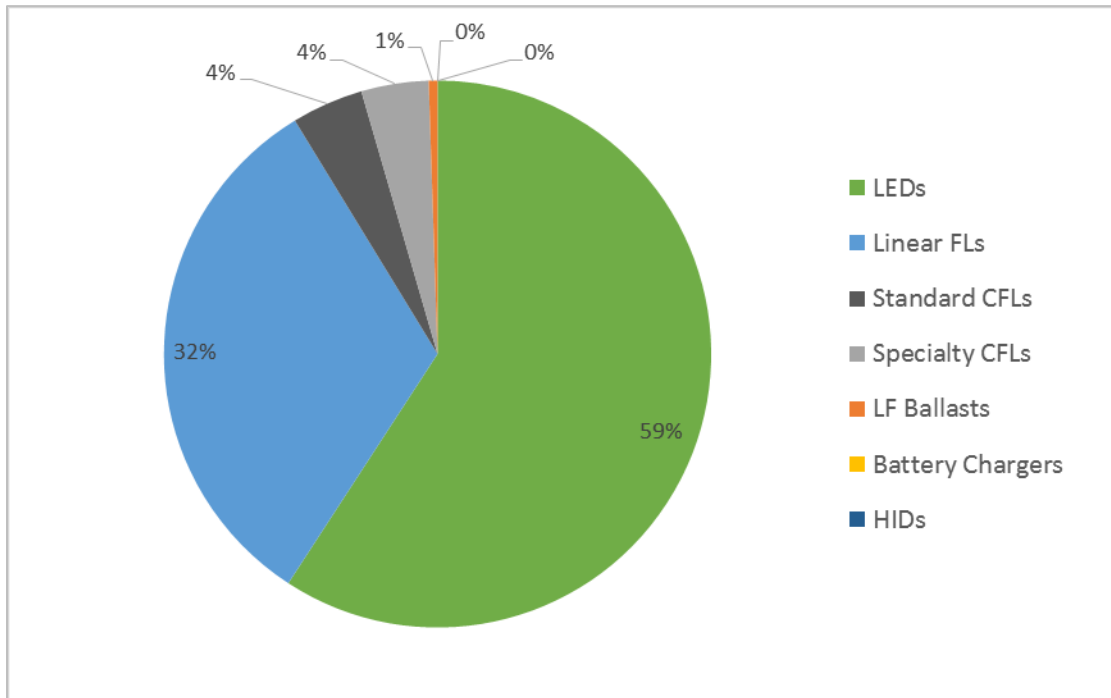
Table 3-3 provides the volume of bulbs incentivized through the BILD Program estimated to have been installed during the PY8 program year. This includes bulbs sold in prior program years and installed in PY8.

**Table 3-3. PY8 Installed Volumetric Findings Detail**

Program Year	Standard CFLs	Specialty CFLs	LEDs	Linear FLs	HIDs	LF Ballasts	Battery Chargers	Total
PY8 Incentivized Units	N/A	N/A	1,131,992	503,948	N/A	N/A	76	1,636,016
PY8 1st Year Installed Units	N/A	N/A	1,072,590	483,790	N/A	N/A	76	1,556,456
PY6 Carryover Units – installed in PY8	45,009	44,632	1,914	110,158	0	8,828	N/A	210,541
PY7 Carryover Units – installed in PY8	34,624	30,040	37,090	8,706	71	741	N/A	111,272
Total Installed Units in PY8	79,633	74,672	1,111,594	602,654	71	9,569	76	1,878,269

Source: ComEd tracking data and Navigant team analysis.

Figure 3-1. Number of Measures Installed by Type (Including Carryover)



Source: ComEd tracking data and Navigant team analysis.

Table 3-4 displays the number of enrolled and participating distributors and end-users.

Table 3-4. PY8 Enrolled and Participating Distributors and End Users

Program Participants	Enrolled	Participating
Distributors	103	88
End Users	NA	-6,500 – 7,500 <sup>17</sup>

Source: ComEd tracking data and Navigant team analysis.

### 3.3 Gross Program Impact Parameter Estimates

The EM&V team conducted research to validate and supplement parameters that were not fully specified in the tracking system. Evaluation research verified specialty bulb type classifications (globe, candelabra, PAR30, etc.) and ensured that TRM parameters that vary by bulb type were applied correctly. The evaluation team also applied the residential and non-residential splits for each product type (detailed in Table 3-5). Finally, where possible, the evaluation team assigned building type based on business name and address and applied the building type specific parameters from the TRM. The resulting verified savings parameters used in PY8 that are independent of installation location (residential versus non-residential) are included in Table 3-5 and those parameters that may vary are included in Table 3-6.<sup>18</sup> These tables include both ex ante and verified savings parameter estimates. The differences are explained in the section after the tables.

<sup>17</sup> The exact number of unique end users is unknown due to multiple various name and address combinations for the same end-user in the tracking data.

<sup>18</sup> Values in Table 3-6 reflect the weighted average parameters for all business types.

**Table 3-5. Verified Gross Savings Parameters**

Gross Savings Input Parameters	Product Type	PY8 Ex Ante Value	PY8 Verified Savings Value	Deemed ‡ or Evaluated?
Program Unit Sales	LED Bulbs	1,045,905	1,045,905	Evaluated
	LED Fixtures	60,790	60,790	Evaluated
	LED Exit Signs	25,297	25,297	Evaluated
	Linear FL	503,948	503,948	Evaluated
	Battery Chargers	76	76	Evaluated
	Carryover Bulbs	321,813	321,813	Evaluated
	<b>Total</b>		<b>1,957,829</b>	<b>1,957,829</b>
Delta Watts	LED Bulbs	51.5	51.8	Deemed
	LED Fixtures	46.2	46.3	Deemed
	LED Exit Signs	19.8	19.8	Deemed
	Linear FL	4.4	4.4	Deemed
	Battery Chargers	309.1	309.1	Deemed
Res/NonRes Split	LED Bulbs, LED Fixtures	0%/100%	4%/96%	Deemed
	Linear FL	0%/100%	1%/99%	Deemed
	LED Exit Signs, Battery Chargers	0%/100%	0%/100%	Deemed

‡ State of Illinois Technical Reference Manual version 4.0 from [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

**Table 3-6. Verified Gross Savings Parameters – Residential vs. Non-Residential**

Gross Savings Input Parameters	Product Type	PY8 Ex Ante Value	PY8 Verified Savings Values Res	PY8 Verified Savings Values Non-Res	Deemed ‡ or Evaluated?
Installation Rate	LED Bulbs	95.7%	95.0%	95.7%	Deemed
	LED Fixtures	95.7%	95.0%	95.7%	Deemed
	LED Exit Signs	100.0%	100.0%	100.0%	Deemed
	Linear FL	98.0%	95.0%	98.0%	Deemed
	Battery Chargers	100.0%	100.0%	100.0%	Deemed
Hours of Use	LED Bulbs	3,612	847	3,503	Both*
	LED Fixtures	3,612	891	4,760	Both
	LED Exit Signs	8,766	8,766	8,766	Both
	Linear FL	4,683	891	4,606	Both
	Battery Chargers	8,371	8,371	8,371	Both
Summer Peak CF	LED Bulbs	NR	0.08	0.64	Both
	LED Fixtures	NR	0.09	0.66	Both
	LED Exit Signs	NR	1.00	1.00	Both
	Linear FL	NR	0.09	0.66	Both
	Battery Chargers	NR	0.39	0.39	Both
Winter Peak CF	LED Bulbs	NR	0.12	0.55	Evaluated
	LED Fixtures	NR	0.12	0.55	Evaluated
	LED Exit Signs	NR	1.00	1.00	Evaluated
	Linear FL	NR	0.12	0.54	Evaluated
	Battery Chargers	NR	-	-	Evaluated
Interactive Effects	LED Bulbs	1.31	1.06	1.30	Both
	LED Fixtures	1.31	1.06	1.30	Both
	LED Exit Signs	1.31	1.04	1.31	Both
	Linear FL	1.31	1.06	1.31	Both
	Battery Chargers	NR	NR	NR	Both

‡ State of Illinois Technical Reference Manual version 4.0 from [http://www.ilsag.info/il\\_trm\\_version\\_4.html](http://www.ilsag.info/il_trm_version_4.html)

\* A value of "Both" indicates that business-type specific parameters from the TRM were used, but that evaluation activities were necessary to identify business types.

### 3.3.1 Unit Sales

There were no misclassifications of lamp categories in the tracking system; therefore, there were no differences in unit sales in any lamp category between ex ante and ex post.

### 3.3.2 Delta Watts

The differences in delta watts between ex ante and ex post were marginal for each of the measure groups. ComEd accurately defined ex ante assignments of baseline and measure wattages, with only small discrepancies for a handful of line items. Average delta watts for each lighting measure group differed by no more than 0.1W between ex ante and ex post. These small differences were due to the

updates of lamp specifications based on the evaluation team's bulb information lookups and a small number of misclassified lamp types.

### 3.3.3 Installation Rates

ComEd does not define a residential / non-residential split in their ex ante estimates as defined by the IL TRM. Instead, ex ante estimates use only the non-residential installation rates from the IL TRM v4.0. Due to the applied residential / non-residential split, a small portion of the LED bulbs, LED fixtures, and linear fluorescents were subject to a slightly lower residential installation rate for the verification analysis.

### 3.3.4 Residential/Non-residential Installation Location Split

There were no residential installations for BILD products assumed by ComEd in their tracking system (100 percent non-residential). Evaluators used the IL TRM v4.0 for the ex post verified savings residential / non-residential split values. For LED bulbs and fixtures, the split was 4 percent residential and 96 percent non-residential. For LED exit signs, the split was 100 percent non-residential. For linear fluorescents, the split was 1 percent residential and 99 percent non-residential.

### 3.3.5 Hours of Use and Interactive Effects

In ComEd's tracking system, there were no residential installations assumed and all end user business types were classified as "Unknown." As mentioned above, the evaluation team used the business name to assign a more accurate business type where possible. This resulted in varying values for hours of use and interactive effects. For energy and demand interactive effects, there were only small differences between ex ante and non-residential ex post values. Residential interactive effects values, which are lower, were applied to a small portion of sales in accordance with the residential / non-residential split. The primary drivers of the realization rates for the lighting measures were the differences in hours of use. For LED bulbs, this resulted in an average non-residential HOU that was three percent lower than ex ante values. For LED fixtures, the ex post non-residential HOU was 31 percent higher than ex ante. For linear fluorescents, the ex post non-residential HOU was two percent lower than ex ante. For battery chargers, three different hours of use values were used based on a Pacific Gas and Electric Company (PG&E) study on this technology and information provided by the end-user. The evaluation team reviewed and accepted these methods and ComEd's workpaper based on the PG&E study.<sup>19</sup> In addition, while residential installations make up a small portion of sales, the residential HOU values for the lighting measures were much lower than their non-residential counterparts.

## 3.4 Verified Gross Program Impact Results Including Carryover

The resulting total program verified gross savings is 282,451 MWh, 57.4 peak summer MW, and 49.6 peak winter MW as shown in the following table (Table 3-7, all savings contribute to the EEPS portfolio). These saving estimates are based on deemed parameter estimates from the TRM v4.0. The verified gross realization rates shown in the table below are calculated as the proportion of ex ante savings found within the verified savings analysis. ComEd did not provide ex ante savings estimates for gross summer and winter peak MW savings, so no ex ante values or realization rates are presented for those metrics.

The table presents savings for each product type as well as carryover from previous program years and overlap with the SBES program. Additional detail on the carryover savings can be found in Table 3-8.

For the SBES overlap savings, ex post savings values are slightly higher (less negative) than ex ante estimates. Similar to the remainder of the ex post analysis, this difference is due to the assignment of business types for these records. Because SBES is a prescriptive and direct installation program, the installation location is known for these overlap records and those building type specific parameters were used in the ex post calculation. The ex ante calculation for BILD reductions due to SBES overlap used the

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<sup>19</sup> See Section 7.3.

same method as the overall BILD program, which was to use the “Unknown” business type parameter values from the TRM.

**Table 3-7. PY8 Verified Gross Impact Savings Estimates by Measure Type**

	Ex ante Gross MWh Savings	Verified Gross Realization Rate	Verified Gross MWh Savings	Verified Gross Summer Peak MW Savings	Verified Gross Winter Peak MW Savings
<b>Lighting Measures</b>					
LED Lamps	244,030	94%	230,169	48.6	41.9
LED Fixtures	12,731	126%	16,039	2.6	2.2
LED Exit Signs	5,754	100%	5,734	0.8	0.8
Linear Fluorescent Lamps	13,346	98%	13,080	2.1	1.8
<b>Non-Lighting Measures</b>					
Battery Chargers	201	100%	201	0.03	-
Carryover	31,002	100%	31,002	6.3	5.3
SBES Overlap	-14,710	94%	-13,773	-3.1	-2.4
<b>Total</b>	<b>292,353</b>	<b>97%</b>	<b>282,451</b>	<b>57.4</b>	<b>49.6</b>

Source: ComEd tracking data and Navigant team analysis.

The BILD program is also able to claim energy and demand savings from program bulbs purchased during PY6 and PY7, but not installed (i.e., used by the end user) until the current program year. Table 3-8 provides additional details of estimates of the verified gross savings resulting from these carryover bulbs.

**Table 3-8. PY8 Verified Gross Impact Savings from PY6 and PY7 Carryover Bulbs**

	PY6 Program	PY7 Program	Total
Verified Gross MWh Savings	15,416	15,586	31,002
Verified Gross Summer Peak MW Savings	3.1	3.3	6.3
Verified Gross Winter Peak MW Savings	2.6	2.7	5.3

Source: ComEd tracking data and Navigant team analysis.

## 4. NET IMPACT EVALUATION

SAG determined<sup>20</sup> that the NTG values for this program should be deemed prospectively and used to calculate verified net savings. Table 4-1 and Table 4-2 below show the deemed NTG values and the PY8 verified net energy and demand (summer and winter coincident peak) savings were calculated by multiplying the verified gross savings estimates by a net-to-gross ratio (NTGR). The NTGR estimates applied to calculate verified net savings were 0.77 for LEDs, 0.61 for linear fluorescents, and 0.77 for all other products, as specified by SAG. The tables below show the deemed NTG values and the PY8 verified net savings (all savings attributed to the EEPS portfolio). The overall NTG ratio was calculated as the overall ratio of verified net savings to verified gross savings and represents the savings weighted average NTG across all measures. As with gross impacts, line items for carryover savings and SBES overlap deductions are included. Additional detail on carryover impacts can be found in Table 4-3.

**Table 4-1. PY8 Verified Net MWh Impact Savings Estimates by Measure Type**

	Ex ante Gross MWh Savings	Verified Gross Realization Rate	Verified Gross MWh Savings	NTG Ratio	Verified Net MWh Savings
<b>Lighting Measures</b>					
LED Lamps	244,030	94%	230,169	0.77	177,230
LED Fixtures	12,731	126%	16,039	0.77	12,350
LED Exit Signs	5,754	100%	5,734	0.77	4,415
Linear Fluorescent Lamps	13,346	98%	13,080	0.61	7,979
<b>Non-Lighting Measures</b>					
Battery Chargers	201	100%	201	0.77	155
Carryover	31,002	100%	31,002	0.64	19,687
SBES Overlap	-14,710	94%	-13,773	0.77	-10,605
<b>Total</b>	<b>292,353</b>	<b>97%</b>	<b>282,451</b>	<b>0.75<sup>†</sup></b>	<b>211,210</b>

Source: ComEd tracking data and Navigant team analysis.

† An overall savings-weighted ratio for all measure types based on deemed values - the actual weighted NTGR is 0.747776.

Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

<sup>20</sup> Source: ComEd PY5-PY6 Proposal Comparisons with SAG.xls, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

**Table 4-2. PY8 Verified Net Peak MW Impact Savings Estimates by Measure Type**

	Verified Gross Summer Peak MW Savings	Verified Gross Winter Peak MW Savings	NTG Ratio	Verified Net Summer Peak MW Savings	Verified Net Winter Peak MW Savings
<b>Lighting Measures</b>					
LED Lamps	48.6	41.9	0.77	37.4	32.3
LED Fixtures	2.6	2.2	0.77	2.0	1.7
LED Exit Signs	0.8	0.8	0.77	0.6	0.6
Linear Fluorescent Lamps	2.1	1.8	0.61	1.3	1.1
<b>Non-Lighting Measures</b>					
Battery Chargers	0.03	-	0.77	0.02	-
Carryover	6.3	5.3	0.64	4.0	3.4
SBES Overlap	-3.1	-2.4	0.77	-2.4	-1.8
<b>Total</b>	<b>57.4</b>	<b>49.6</b>	<b>0.75<sup>†</sup></b>	<b>43.0</b>	<b>37.2</b>

Source: ComEd tracking data and Navigant team analysis.

† An overall savings-weighted ratio for all measure types based on deemed values - the actual weighted NTGR is 0.747776.

Source: ComEd\_NTG\_History\_and\_PY8\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

The BILD program is able to claim energy and demand savings from program bulbs purchased during PY6 and PY7 but not installed (i.e., used by the consumer) until the current program year. Table 4-3 provides additional details of estimates of the Verified Net savings resulting from these carryover bulbs.

**Table 4-3. PY8 Verified Net Impact Savings from PY6 and PY7 Carryover Bulbs**

	PY6 Program	PY7 Program	Total
Verified Net MWh Savings	9,712	9,975	19,687
Verified Net Summer Peak MW Savings	1.9	2.1	4.0
Verified Net Winter Peak MW Savings	1.6	1.8	3.4

Source: ComEd tracking data and Navigant team analysis.

## 4.1 PY9 Carryover Savings Estimate

Calculation of the PY9 carryover estimate relies upon the IL TRM v4.0 and the PY7 and PY8 reports. At this time all of these data sources are available and thus it is possible to estimate the gross and net carryover energy savings that the evaluation team recommends for PY8. The energy and demand savings from these PY7 and PY8 late installed bulbs are calculated based on the following parameters:

- Delta Watts – Verified savings estimate from the year of installation (source: IL TRM v5.0).
- Res/Non-Res Split - Verified savings estimate from the year of purchase (source: IL TRM v3.0 and IL TRM v4.0).
- HOU and Peak CF – Verified savings estimate from the year of installation (source: IL TRM v5.0).
- Energy and Demand IE – Verified savings estimate from the year of installation (source: IL TRM v5.0).
- Installation Rate - Verified savings estimate from the year of purchase (source: IL TRM v3.0 and IL TRM v4.0).
- NTGR – Evaluation research from the year of purchase (source: PY7 and PY8 Reports).



Table 4-4 shows that in PY9 124,748 bulbs, purchased during either PY7 or PY8, are expected to be installed within ComEd service territory. The table provides both the gross and net energy and demand savings from these bulbs. The total net energy savings is estimated to be 11,007 MWh, 2.2 summer peak MW, and 2.1 winter peak MW, which will be counted in PY9 as BILD lighting program carryover savings.

**Table 4-4. PY9 Verified Savings Carryover Estimate**

PY9 Verified Savings Carryover Estimate	PY7 Bulbs	PY8 Bulbs	PY9 Carryover
Carryover Bulbs Installed in PY9	99,282	25,466	124,748
Average Delta Watts	31.6	40.8	n/a
Average Daily Hours of Use	8.8	9.5	n/a
Summer Peak Load Coincidence Factor	0.51	0.57	n/a
Winter Peak Load Coincidence Factor	0.49	0.54	n/a
Gross kWh Impact per unit	99.4	142.7	n/a
Gross kW Impact per unit	0.03	0.04	n/a
Installation Rate	100%	100%	n/a
Energy Interactive Effects	1.22	1.09	n/a
Demand Interactive Effects	1.34	1.35	n/a
Carryover Gross MWh Savings	12,039	3,959	15,998
Carryover Gross MW Savings	3.5	1.0	4.5
Carryover Gross Summer Peak MW Savings	2.4	0.8	3.2
Carryover Gross Winter Peak MW Savings	2.3	0.8	3.0
Net-to-Gross Ratio	0.66	0.74	0.69
Carryover Net MWh Savings	7,973	3,034	11,007
Carryover Net MW Savings	2.3	0.8	3.1
Carryover Net Summer Peak MW Savings	1.6	0.6	2.2
Carryover Net Winter Peak MW Savings	1.5	0.6	2.1

Source: ComEd tracking data and Navigant team analysis.

## 5. PROCESS EVALUATION

Midstream incentive delivery mechanisms are beneficial in part because they reduce the administrative burden of processing thousands of downstream rebate applications. Similarly, because rebates are submitted by the distributor, all burden is removed from the end-user. However, a lack of end-user information has been a consistent challenge for evaluation of this program and is the main focus of this process evaluation. Beginning in November 2015, ComEd asked distributors to capture additional end-user information in the rebate submissions. The process evaluation included a web survey fielded to all program distributors and explores how distributors are collecting, organizing, and submitting the required information. The analysis seeks to determine if this process is too burdensome for some distributors and to identify best practices for streamlining this activity in future program years. Similarly, distributors have indicated that several other program aspects have been challenging, including changing incentive levels, copays, and funding periods. These issues are also explored to identify areas for program improvement. Additionally, several typical process topics such as motivations for program participation and overall program satisfaction were explored. Results for these topics can be found in the appendix.

### 5.1 Program Processes – Customer Information

Beginning in November 2015, ComEd has asked BILD distributors to provide customer contact information and the business name and address where the lamps were to be installed. After this requirement was instituted, almost two-thirds (62.7 percent) of distributors were able to collect information for all BILD transactions. Of the remaining third, the large majority of these distributors indicated that they were not able to collect contact information for 5 to 30 percent of transactions (though four distributors noted that they were unable to collect contact information for 90 to 100 percent of transactions). The primary reasons why distributors were not able to capture all BILD transactions were that the customer did not want to provide it (61 percent) or the customer was a contractor that did not know where the lamps would be installed (21 percent).

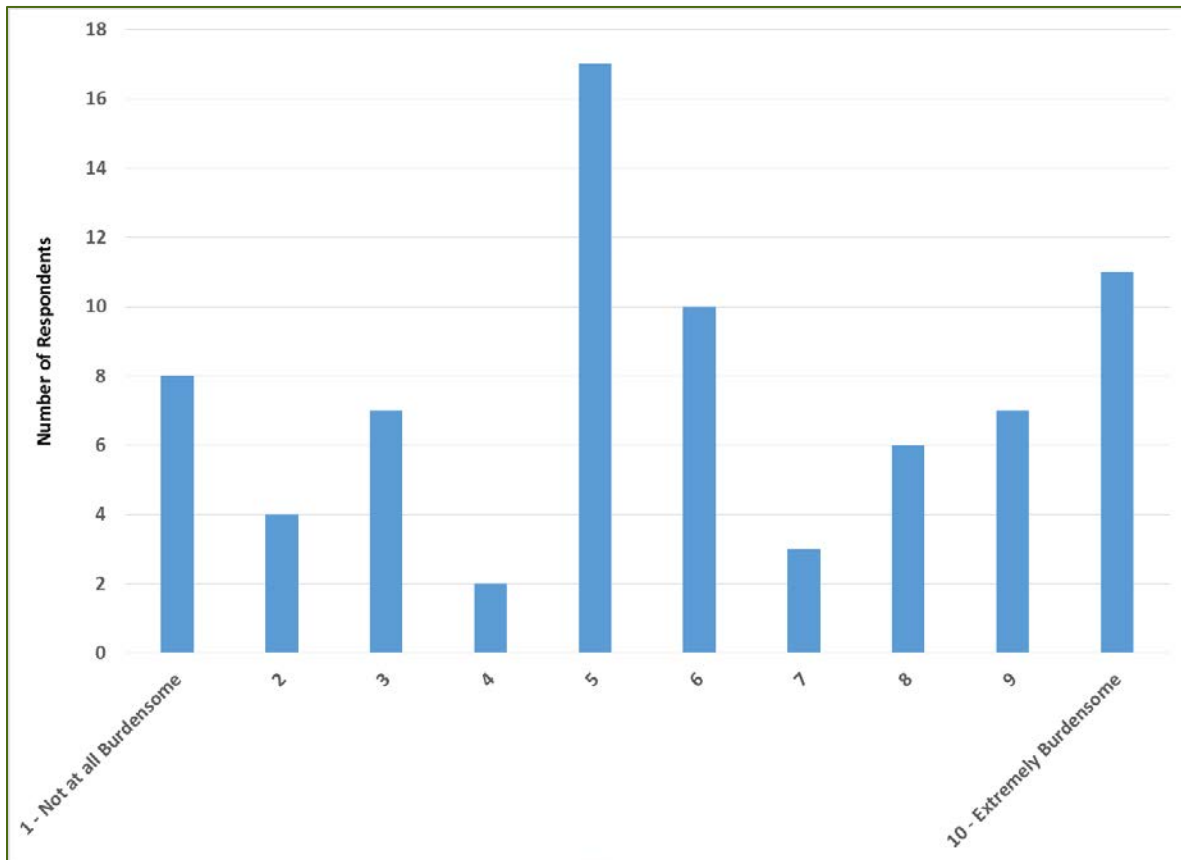
There was also a requirement in PY8 that distributors had to submit incentive requests and customer contact information within 15 days of the transaction. Over half of the respondents felt that this was a sufficient amount of time (55 percent) while those who did not overwhelmingly said that 30 days would be an adequate amount of time. Several distributors indicated that they would prefer monthly submissions over the 15-day window because it would ease their administrative burden.

Distributors were also asked to rate the difficulty of the BILD transaction reporting process from 1 to 10, with 10 being extremely burdensome. The responses were relatively evenly split between the ratings, with an overall average of 5.7. Those who claimed the difficulty as an 8, 9, or 10 tended to be medium or large distributors (defined as being in the top two terciles of program bulb sales). The primary difficulty was collecting the customer contact information, such as email addresses and zip codes. Tying the distributor bonus to the successful collection of customer contact information could potentially encourage extra effort to be made. Also cited were the manual process and the frequency of reporting. More than half of the respondents use Quickbooks, Excel, or both in their recording and reporting, while custom or in-house software was the third most popular choice. There does not appear to be a substantial correlation between a distributor's invoicing/CRM software and perceived burden of BILD transaction reporting. In other words, the evaluation revealed instances where two firms were using Quickbooks, for example, and one respondent indicated a high level of burden while the other indicated that it was very straightforward. Sharing of best practices, processes, and techniques between distributors, especially those with similar characteristics (e.g. sales volume, national account distributors vs. boutique firms), could be beneficial for alleviating the difficulties that may arise from BILD transaction reporting.

## 5.2 Changing Incentive Levels and Copays

In PY8 and previous program years, it has been necessary to adjust incentive amounts for certain products in the middle of the program year due to price shifts in the LED market and overall availability of BILD incentive funding. Distributors were asked to rate the difficulty in adapting to the changing incentive levels in the middle of the program year. Figure 5-1 shows the distribution of ratings. The average rating was 5.8, indicating that it was somewhat burdensome for distributors to update incentive levels. However, responses were relatively trimodal with ratings tending toward the extremes (1 or 10) or the middle (5). Those who say that the updates are relatively easy tend to be smaller distributors, citing the provided BILD Excel files that are easily linked through UPC codes. Those who say that the updates are burdensome tend to be larger distributors, citing the difficulty in changing marketing and price quotes to customers, and the manual process necessary to make the updates in their systems. Going forward, most distributors say that more forewarning and a longer grace period would be helpful in ameliorating the issues associated with changing incentives in the middle of a program year. As with the transaction reporting, sharing of information between similar distributors on how to effectively deal with changing incentive levels in their sales systems could be beneficial.

Figure 5-1. Distributor Difficulty Adapting to Changing Incentive Levels

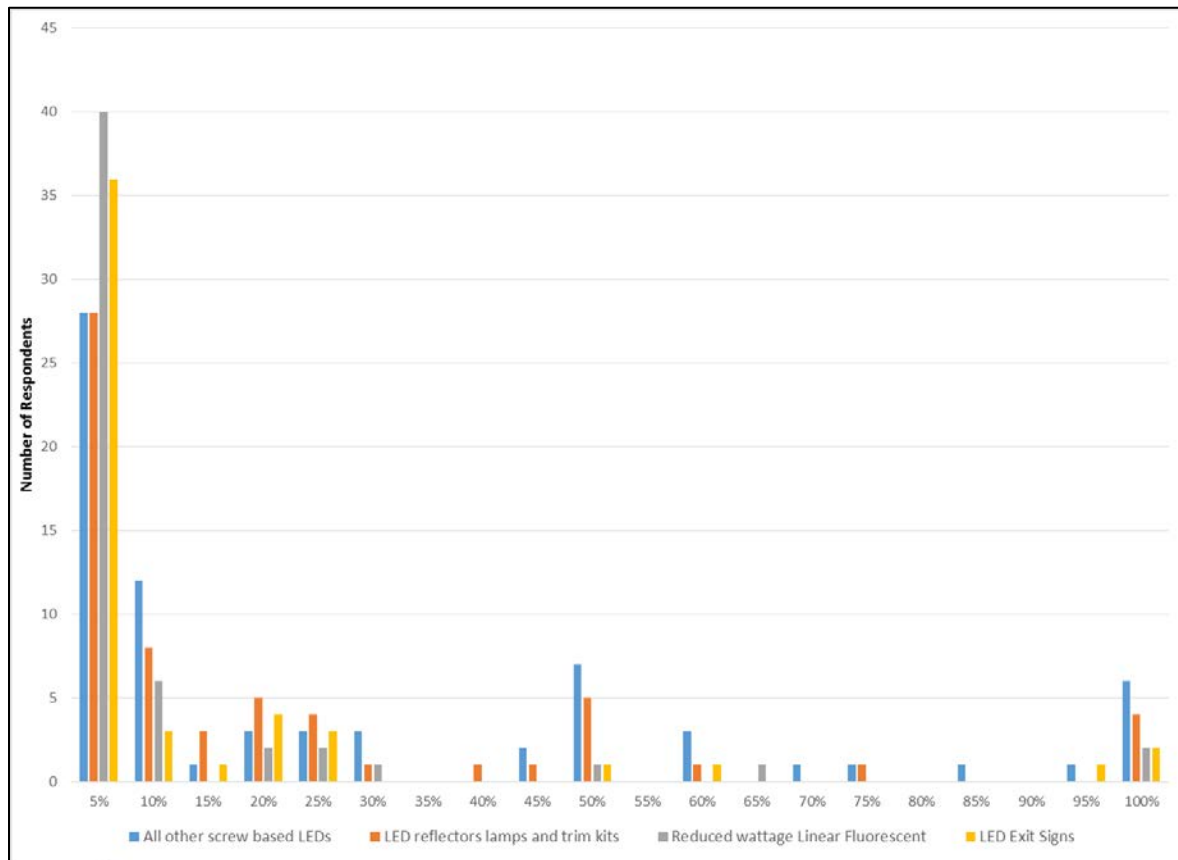


Source: Navigant Evaluation Team Analysis of Distributor Survey Data

In November 2015, the BILD program instituted a new minimum customer co-pay of 50% of each lamp type’s incentive amount for all program transactions. Distributors were asked to estimate the percentage of sales for each lamp type category that triggered the minimum copay [for example, for an LED reflector, how often was the final “sale” price less than \$12.00 (\$8.00 incentive + \$4.00 minimum co-pay)?]. Figure 5-2 shows the distribution of lamp sales that were subject to minimum copays. The vast majority of respondents claimed that a minimal amount of sales in each category (0-5%) triggered the minimum

copays. Reduced-wattage linear fluorescent lamps and LED exit signs were reported to be subject to minimum copays less frequently than the other LED lamp types (screw-based and reflectors). There were several distributors who claimed that 100% of their BILD transactions for a given lamp category triggered the minimum co-pay. These distributors had small/medium volumes of sales. Most of the participants thought that the minimum co-pay was beneficial to the program, stating that it evens the playing field for distributors and increases customer interest in the bulbs, by legitimizing the investment in energy efficiency. This is true to the extent that lower-quality and/or low-cost products exist on the BILD Approved Products List (APL). However, ComEd should maintain a close eye on this metric. A large percentage of lamp sales triggering the minimum customer co-pay would indicate that incentive levels need to be revisited or certain low-quality products should be removed from the APL. In fact, one distributor noted that, “(w)ith the rapid updates in technology, the costs are falling as well and sometimes the 50% co-pay to reach the full incentive creates a price that may not be market level.” Another distributor said that “(i)n my experience it’s not in the customers best interest. There are many bulbs I can sell for less than the 50% co-pay.” Several distributors also noted that the minimum co-pay put them at a disadvantage for some lamps because their customers could get the lamps cheaper at big box stores.

Figure 5-2. Percentage of Lamp Types Sold Triggering Minimum Copay



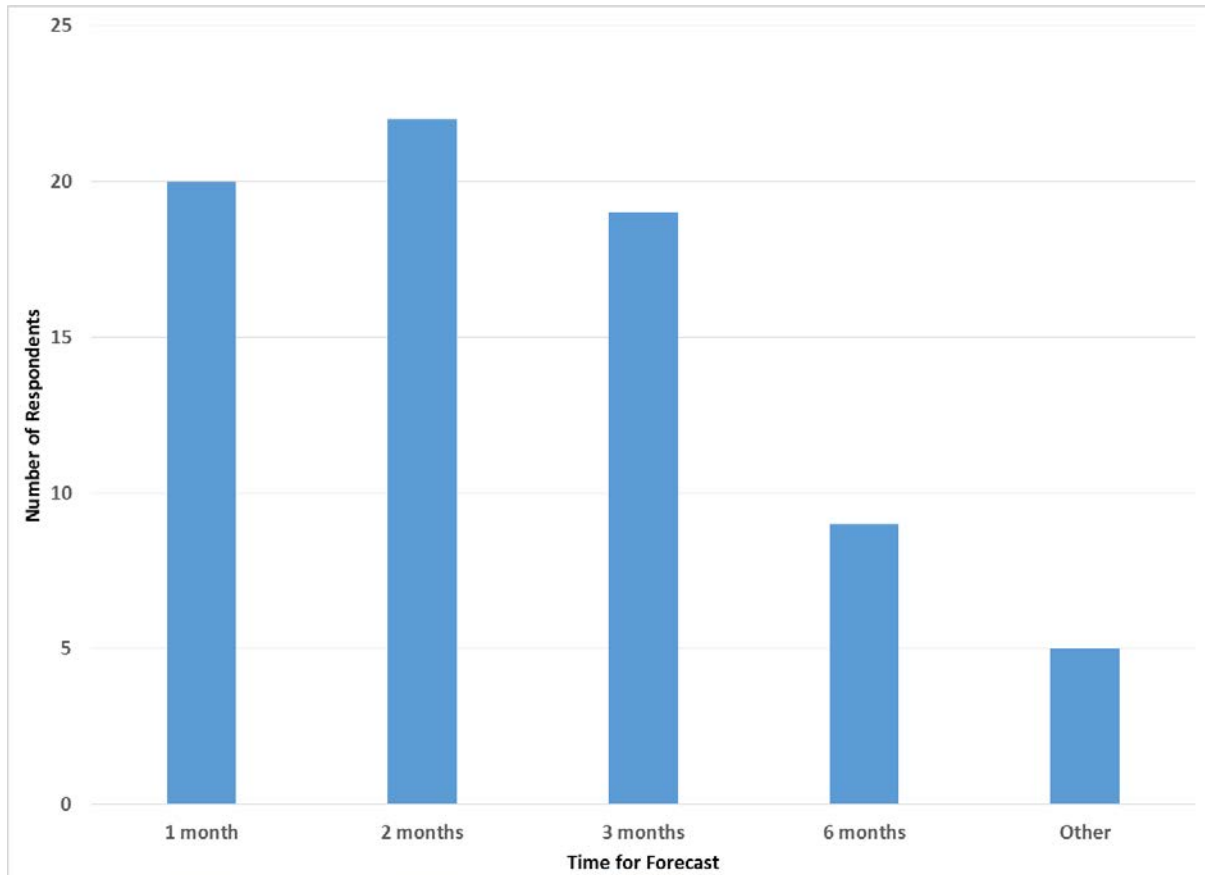
Source: Navigant Evaluation Team Analysis of Distributor Survey Data

### 5.3 Program Funding Periods

In PY8, there were 30-day funding periods instituted between July and November, and 45-day to 60-day funding periods defined for the remainder of the program year. To help inform the design of additional funding cycles, distributors were asked over what time period they could accurately forecast (within 10%) their need for BILD funds. Figure 5-3 presents the distribution of responses. Over 80% of distributors

estimate that they can forecast their need for BILD funding for one to three months into the future. Other distributors claim that it is difficult to provide forecasts within 10% for any given time frame.

Figure 5-3. Distributor Time Period Forecast for BILD Funds



Source: Navigant Evaluation Team Analysis of Distributor Survey Data

## 6. FINDINGS AND RECOMMENDATIONS

This section summarizes the full set of key impact and process findings and recommendations.

### Program Tracking Data Review

**Finding 1.** Overall, the tracking data was very accurate in terms of bulb information and application of the IL TRM v4.0. The bulb information provided (wattages, center beam candlepower (CBCP), beam angle, and lamp diameter) was complete.

**Recommendation 1.** To accurately determine delta watts for directional LEDs, the bulb information should include the specific specialty bulb type (PAR38, R20, etc.) used to determine ex ante savings values.

### Verified Gross Impacts and Realization Rate

**Finding 2.** The PY8 gross verified energy savings were estimated to be 282,451 MWh. LEDs comprised 89 percent of program energy savings. The gross realization rate on this savings estimate is 97 percent. Verified savings were lower than ComEd ex ante savings primarily due to differences in hours of use by business type as specified in the IL TRM v4.0, and because ex ante estimates do not include a residential / nonresidential split. The IL TRM specifies a split of 4 percent residential and 96 percent commercial for LED lamps and one percent / 99 percent for linear fluorescent lamps. Commercial installations have higher deemed hours of use and interactive effects values than residential installations, so attributing savings to residential installs has a downward impact on savings.

**Recommendation 2.** ComEd could improve their ex ante savings estimates by establishing preliminary business types for end-users where possible and applying the associated parameters from the TRM. Estimates could also be improved by applying the deemed residential and nonresidential splits and the other appropriate deemed residential parameters (hours of use, interactive effects, etc.).

**Finding 3.** The PY8 gross verified summer peak demand reduction was 57.4 MW and winter peak demand savings were 49.6 MW. The net verified summer and winter peak demand reductions were 43.0 MW and 37.2 MW, respectively. As in PY7, the largest portion of these savings are due to LED sales, which comprised 93 percent of verified net peak demand savings.

### Verified Net Impacts

**Finding 4.** The overall unit sales-weighted net-to-gross ratio (NTGR) found in this evaluation was 0.75 based on deemed values.<sup>21</sup> The BILD and BPD programs accomplished 211,210 MWh of net energy savings, 43.0 MW of summer peak demand reduction, and 37.2 MW of winter peak demand reductions. Over 91 percent of these energy savings were from LED lamps, fixtures, and exit signs while only four percent were from linear fluorescents. Verified summer and winter peak demand savings were also dominated by LEDs (approximately 93 percent).

### Program Volumetric Findings.

**Finding 5.** The total number of units sold during the PY8 BILD Program was 1,636,016, which is a 35 percent decrease from the total units sold in PY7. This decrease was largely due to the removal of CFLs, LF ballasts, and HIDs from the program. Sixty-nine percent of units sold were LEDs,<sup>22</sup> 31 percent were linear fluorescents, and the remaining fraction was battery chargers. Compared to PY7, the total sales of LEDs increased by two percent and total sales of linear fluorescent lamps decreased by 36 percent. The evaluation does not know what caused the large drop in reduced wattage LFs in PY8. However, as part of the distributor survey, over 70 percent of respondents said that they sold high-efficiency lamps in PY8 that

<sup>21</sup> Deemed values. Source: ComEd\_NTG\_History\_and\_PY7\_Recommendation\_2014-02-28\_Final\_EMV\_Recommendations.xlsx, which is to be found on the IL SAG web site here: <http://ilsag.info/net-to-gross-framework.html>

<sup>22</sup> Including LED Fixtures and exit signs.

did not receive BILD discounts. Approximately 47 percent of these high-efficiency, non-discounted lamps were reduced wattage linear fluorescents.

**Recommendation 3.** The evaluation recommends that ComEd check with BILD distributors to identify what types of RW-LFs are being sold without an incentive and potentially add those lamps to the Approved Product List.

#### Process Evaluation.

**Finding 6.** In November of PY8, ComEd instituted the requirement that BILD distributors provide customer contact information and the business name and address where the lamps were to be installed. After this requirement was instituted, almost two-thirds (62.7 percent) of distributors were able to collect information for all BILD transactions. The primary reasons why distributors were not able to capture all BILD transactions were that the customer did not want to provide it (61 percent) or the customer was a contractor that did not know where the lamps would be installed (21 percent).

**Recommendation 4.** The evaluation team has recommended that ComEd collect the purchaser contact information rather than the end-user contact information, which should alleviate the issue surrounding contractor purchases. Tying the distributor bonus to the successful collection of customer contact information could potentially encourage extra effort to be made for the remaining transactions.

**Finding 7.** The program had a requirement in PY8 that distributors had to submit incentive requests and customer contact information within 15 days of transaction. Over half of the respondents felt that this was a sufficient amount of time (55%) while those who did not overwhelmingly said that 30 days would be an adequate amount of time. Several distributors indicated that they would prefer monthly submissions over the 15-day window because it would ease their administrative burden. Additionally, many distributors reported that the transaction reporting process was labor intensive (manual process) and that transaction reports were required too frequently. There does not appear to be a substantial correlation between a distributor's invoicing/CRM software and perceived burden of BILD transaction reporting. In other words, the evaluation revealed instances where two firms were using Quickbooks, for example, and one respondent indicated a high level of burden while the other indicated that it was very straightforward. Several distributors indicated that moving the transaction reporting system to an online web portal may be beneficial.

**Recommendation 5.** The evaluation recommends that the reporting period be extended to 30 days. Additionally, to facilitate streamlined transaction reporting, the evaluation team recommends that ComEd hold a distributor workshop to share best practices, processes, and techniques for managing incentive reporting.

**Finding 8.** In PY8 and previous program years, the program has had to adjust incentive amounts for certain products in the middle of the program year due to price shifts in the LED market and overall availability of BILD incentive funding. Distributors were asked how burdensome the changing incentive levels were and responses ranged from not burdensome to very burdensome. Those who say that the updates are relatively easy tend to be smaller distributors, citing the provided BILD Excel files that are easily linked through UPC codes. Those who say that the updates are burdensome tend to be larger distributors, citing the difficulty in changing marketing and price quotes to customers, and the manual process necessary to make the updates in their systems. Going forward, most distributors say that more forewarning and a longer grace period would be helpful in ameliorating the issues associated with changing incentives in the middle of a program year.

**Recommendation 6.** The evaluation recommends that ComEd provide at least 30 days' notice prior to any incentive adjustments taking effect. This would allow for 60 days from the time incentive changes are announced to the time the first transaction report must be submitted where incentive updates are reflected.



**Finding 9.** In November 2015, the BILD program instituted a new minimum customer co-pay of 50% of each lamp type's incentive amount for all program transactions. The vast majority of distributors claimed that a minimal amount of sales in each category (0-5%) triggered the minimum copays, but there were several distributors who claimed that 100% of their BILD transactions for a given lamp category triggered the minimum copay. Most of the participants thought that the minimum copay was beneficial to the program, stating that it evens the playing field for distributors and increases customer interest in the bulbs, by legitimizing the investment in energy efficiency. However, due to rapidly declining costs for LEDs, the co-pay was higher than market costs for some lamps, which is not beneficial to the program.

**Recommendation 7.** ComEd should maintain a close eye on this metric. A large percentage of lamp sales triggering the minimum customer co-pay would indicate that market prices have dropped and that incentive levels need to be revisited or certain low-quality products should be removed from the APL.

**Finding 10.** In PY8, the program instituted 30-day funding periods between July and November, and 45-day to 60-day funding periods for the remainder of the program year. To help inform the design of additional funding cycles, the evaluation asked distributors over what time period they could accurately forecast (within 10%) their need for BILD funds. Over 80% of distributors estimate that they can forecast their need for BILD funding for 1 to 3 months into the future. Notably, smaller distributors have more difficulty with short "funding periods" because they do not have enough consistent volume to ensure that their forecasted incentive amounts will actually be used.

**Recommendation 8.** The evaluation recommends that ComEd require program distributors to forecast their need for incentives 90 days in advance, which captures the time period over which the majority of distributors feel they can accurately forecast their need for funding.



## 7. APPENDIX

### 7.1 Detailed Process Findings

The process evaluation of the PY8 BILD program focused primarily on resolving some of the inherent challenges encountered when evaluating a midstream program, such as collecting purchaser and end-user contact information. It also included an examination of other challenges consistently faced by program distributors including changing incentive levels, copays, and funding periods. The results relating to those topics are covered in Chapter 5. The content presented below includes additional information relating to the process evaluation, including data collection, lamp sales distributions, reasons for program participation, and overall program satisfaction.

#### 7.1.1 Distributor Web Survey Disposition

In PY8, web surveys were fielded to all active program distributors. A total of 75 participating distributors completed surveys, who collectively sold 81 percent of all LEDs, 96 percent of all LED Exit Signs, and 90 percent of all linear fluorescent lamps sold through the program in PY8. Table 7-1 shows the disposition of the distributor web survey.

Table 7-1. Distributor Web Survey Disposition

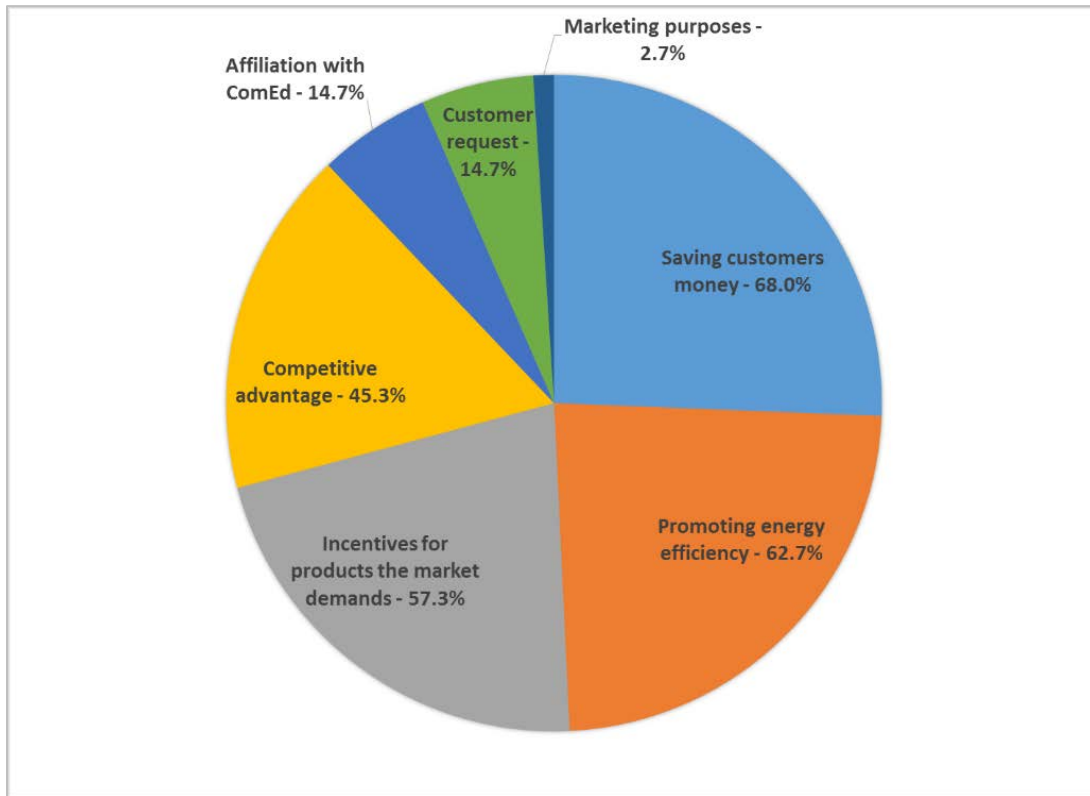
Web Survey Disposition	Distributor Survey	Percent
Sample Pulled	103	100%
Completed Surveys	75	73%
Invalid E-mail	2	2%
Opted Out	3	3%
Partial Completes	6	6%
No Response	17	17%

Source: Navigant team analysis of Distributor Survey Data.

#### 7.1.2 Program Participation

Of the distributors who completed the survey, the average tenure in the BILD program was 3.6 years. The distributors also provided their primary reasons for participating in the program. The most popular reasons were saving customers money and promoting energy efficiency. Figure 7-1 shows the distribution of reasons given.

Figure 7-1. Primary Reasons for Participating in BILD

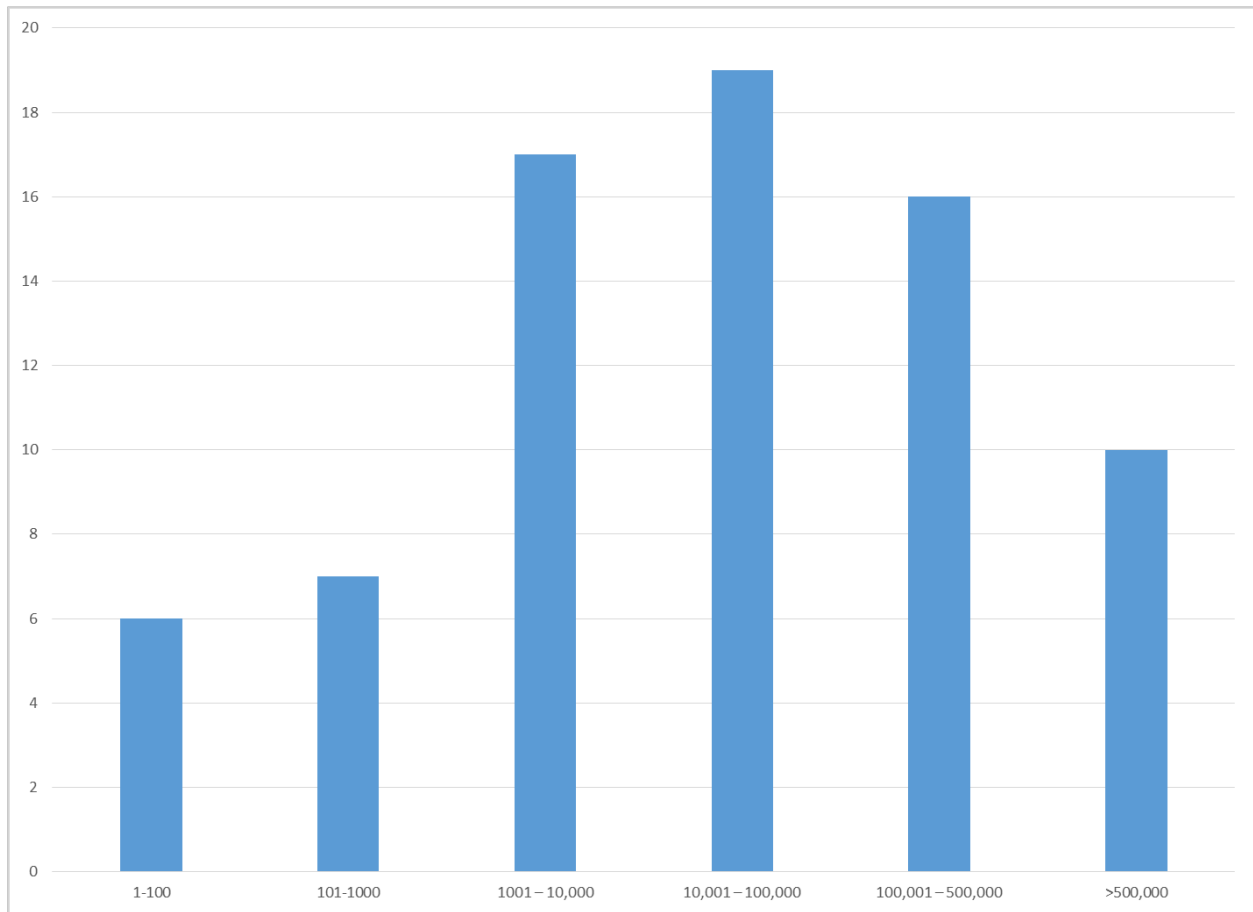


Source: Navigant Evaluation Team Analysis of Distributor Survey Data

### 7.1.3 Lamp Sales

Distributors self-reported an approximate sales volume of all lamps (program and non-program) sold in PY8. Over half of respondents indicated that they sold over 10,000 bulbs in the program year. Figure 2 shows the number of distributors reporting total lamp sales in each volumetric bucket.

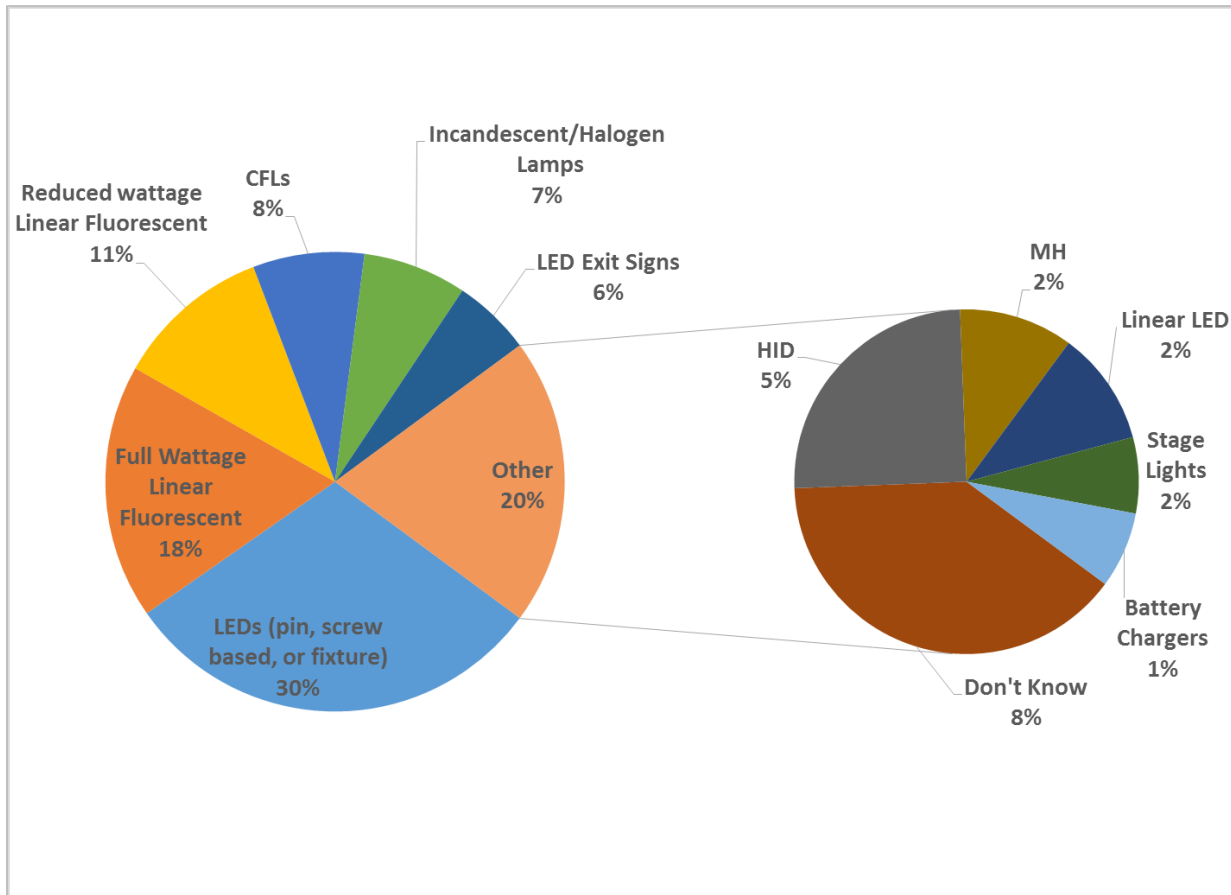
Figure 7-2. Distributor Total Lamp Sales Volumetric Distribution (Program and Non-program)



Source: Navigant Evaluation Team Analysis of Distributor Survey Data

The respondents also characterized the types of lamps sold in PY8 (all program and non-program). LEDs made up over 40 percent of each individual distributor’s sales on average. CFLs and incandescent lamps were approximately equal in distribution, comprising about 10 percent of distributors’ lamp sales on average. Figure 7-3 shows the relative proportions of each of the lamp types. The “Other” category is mainly comprised of HIDs. Linear LEDs do not make up a large portion of this category but are often requested as a technology to be added to the BILD products list.

Figure 7-3. Distributor Total Lamp Type Sales Distribution (Program and Non-Program)

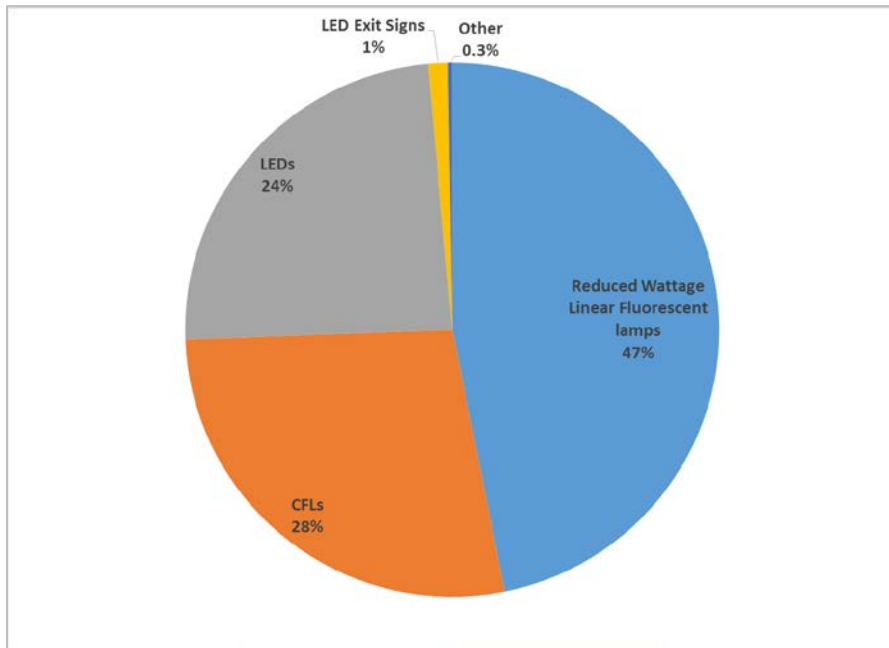


Source: Navigant Evaluation Team Analysis of Distributor Survey Data

Distributors seem to be very involved in helping customers determine which lamps to purchase. On a scale of 1 to 5, with 5 being very involved, respondents gave an average rating of 4.25. Eighty-seven percent of respondents said that they always or usually promoted high-efficiency lamps over the full wattage alternatives. The exceptions to this were usually specific to the architectural/engineering needs of specific projects. The primary sales tactics used to convince customers to switch to energy efficient lighting are emphasizing annual bill savings and energy reduction.

Over 70 percent of distributors said that they sold high-efficiency lamps in PY8 that did not receive BILD discounts. Figure 7-4 shows the distribution of these lamp types, almost half of which are comprised of reduced wattage linear fluorescents. The most common reasons that these lamps did not receive BILD discounts was that the end user was not eligible for participation in BILD or the lamps requested were not qualified. The average volume of non-qualified lamps sold per distributor was approximately 10,000. The majority of the distributors who sold non-discounted bulbs indicated that the BILD program had either minimal or no effect on their sales of any high-efficiency non-program bulbs, which indicates low program spillover.

Figure 7-4. PY8 Distribution of Efficient Lamps Sold Not Receiving a BILD Discount



Source: Navigant Evaluation Team Analysis of Distributor Survey Data

### 7.1.4 Program Satisfaction

Distributors were also given an opportunity to voice any additional challenges experienced in the program. There were challenges voiced that stemmed from aspects previously addressed in the survey, including the burden of inputting information, planning around incentive changes, and customers wanting additional products added to the APL. Several other interesting challenges were mentioned. One distributor claimed that there were several customers that purchased from them and proceeded to open branches of their own business to act as “distributors,” purchasing products through these branches and selling to themselves to take advantage of BILD discounts. Another distributor stated that it is difficult to be a smaller player and develop direct purchasing relationships with vendors. Also, smaller distributors have more difficulty with short “funding periods” because they do not have enough consistent volume to ensure that their forecasted incentive amounts will actually be used.

Lastly, distributors offered suggestions to improve the BILD program, including changing the distributor scope in terms of end-users, including more lamp types, improving the reporting timelines, and simplifying the transaction reporting process. As mentioned previously, several distributors had formatting and general usability issues surrounding the Excel transaction reports. They indicated that one potential solution could be an online portal where all transactions would be submitted. Key functionality for this web portal would include tracking features for all current program year transactions such as remaining budget and current status (in review, paid, discrepancy, etc.).

## 7.2 TRM Recommendations

There was no evaluation research done in PY8 to support updates to the TRM.

## 7.3 Attachments

### 7.3.1 Distributor Interview Instrument

## PY8 ComEd Business Instant Lighting Discounts Program Distributor Interview Instrument

### Email to each Distributor

Hello. You are receiving this email because your organization is participating in ComEd's Business Instant Lighting Discounts program, also known as the BILD program. As specified in the BILD program participation agreement, your organization agreed to take part in a survey that will ensure the continued success of the BILD program. Itron, Inc. is fielding this online survey on behalf of ComEd as part of the evaluation of the BILD program.

The purpose of the survey is to learn about your company's experience with the BILD program and to better understand how program distributors are collecting, organizing, and submitting the transaction information required by the program. ComEd, the BILD program implementers, and the program evaluation team understand that some program requirements may be burdensome and are seeking information to help us minimize the burden to you while still collecting the information we require to evaluate and improve the program. BILD distributors are the backbone of this program, and your feedback is critical to future program updates. If you are not the person most knowledgeable about your organization's participation in ComEd's BILD program, please direct us to the correct contact by emailing us at [George.Jiang@itron.com](mailto:George.Jiang@itron.com). The survey should take less than 20 minutes and all information that is provided will remain strictly confidential. Based on the information you provide, you may be selected for a brief follow-up phone interview.

Your responses to this survey should be reflective of the most recent program year, which ran from **June 1<sup>st</sup>, 2015 through the present**.

If you have any questions about this survey please contact George Jiang (BILD Program Evaluator) at 858-724-2673, Sharon Madigan (BILD Program Manager) at 630-437-4638, or Steven McVoy (DNV GL Program Implementer) at 224-523-4791.

Please click on the link below to be directed to the web survey. We kindly request that you complete the survey by May 31<sup>st</sup>, 2016.

[LINK](#)

Thank you for your timely assistance with this important BILD survey.  
George Jiang

\*\*\*\*\*

**Web Survey**

\*\*\*\*\*



**BILD PROGRAM  
LIGHTING INCENTIVES**

Welcome to the ComEd Business Instant Lighting Discounts Trade Ally Survey. Please remember that all responses should be specific to the most recent BILD program year, which ran from June 1<sup>st</sup>, 2015 to the present. The survey should take less than 20 minutes, but if you are not able to finish in one session, pressing the “Exit” button will save your progress. Simply return to the web address provided to continue.

**Program Participation**

1. What were the primary reasons your organization decided to participate in ComEd’s Business Instant Lighting Discounts (BILD) program? *Please select up to three.*
  1. Incentives for products the market demands
  2. Affiliation with ComEd
  3. Marketing purposes
  4. Competitive advantage
  5. Customer request
  6. Promoting energy efficiency
  7. Saving customers money
  0. Other, please specify
  
2. How many years has your organization participated in the BILD program (up through and including the current program year). [Specify number of years – drop down]

**Distributor Lamp Sales**

3. Please approximate the total volume (unit sales) of lamps (incandescent/halogen, CFLs, linear fluorescents, and LED lamps and fixtures) sold within ComEd’s service territory in the PY8 program year. This should be all sales and not just sales of lamps that are discounted by ComEd. [Specify quantity – open end].

4. Please indicate the approximate percentage of your organization’s total lamp sales (unit sales) within ComEd’s service territory that each lamp type represents. This should be all sales and not just sales of lamps that are discounted by ComEd. *The percentages should add to 100%.*

- Q4\_1. Incandescent/Halogen Lamps \_\_\_\_\_%
- Q4\_2. CFLs \_\_\_\_\_%
- Q4\_3. Full Wattage Linear Fluorescent \_\_\_\_\_%
- Q4\_4. Reduced wattage Linear Fluorescent \_\_\_\_\_%
- Q4\_5. LEDs (pin, screw based, or fixture) \_\_\_\_\_%
- Q4\_6. LED Exit Signs \_\_\_\_\_%
- Q4\_7. Other – TYPE: \_\_\_\_\_ %

### Efficient Lamp Sales

5. On a scale of 1 to 5, with 1 being not at all involved and 5 being very involved, how involved is your organization in helping your customers determine which light lamps to purchase? [1 – 5]

6. As a result of participating in the BILD program, has your organization been actively trying to increase the volume of efficient lamps sold relative to full wattage lamps? [Yes, No]

a. [If Q6 = yes] How often do you promote high efficiency lamps over the full wattage alternative?

- 1. Always
- 2. Usually
- 3. Sometimes
- 4. Never
- 5. Depending on the circumstance or customer, please specify

b. [If Q6 = yes] What are the primary sales tactics used by your organization to convince your customers to switch to energy efficient lighting? *Drag each box from the left column to the right column in order of most frequently mentioned (top) to most infrequently mentioned (bottom).*

- 1. Longer lifetimes
- 2. Light quality
- 3. Payback period
- 4. Annual energy reduction
- 5. Annual bill savings (\$)
- 6. Reduced O&M
- 7. “Green” or environmental benefits

c. [If Q6 = yes] Are there any other sales tactics you use to convince your customers to switch to energy efficient lighting? [No, Yes – please specify]



7. During this past program year (June 1, 2015 – present) did you sell any high efficiency lamps in ComEd’s service territory that did not receive discounts from the BILD program? [Yes, No]
- a. [If Q7 = Yes] Please estimate how many lamps of each of the following types you sold that did not receive rebates. If any types are not applicable, please leave them blank.
    1. CFLs \_\_\_\_\_
    2. LEDs \_\_\_\_\_
    3. LED Exit Signs \_\_\_\_\_
    4. Reduced wattage Linear Fluorescent lamps \_\_\_\_\_
    5. Other (specify) \_\_\_\_\_
  - b. [If Q7 = yes] Why did these lamps not receive discounts?
  - c. [If Q7 = yes] What effects, if any, did the BILD program have on your sales of any high efficiency non-program lamps?
8. Regarding the BILD Approved Products List:
- a. Do you feel that the qualified products available through the BILD program are sufficient to meet your customers’ needs (i.e. is there sufficient diversity in lamp types, styles, light output, and etc.)? [Yes, No. If no, explain, noting any particular types of lamps you would like to see on the APL]
  - b. Are there any products on the Approved Products List that do not meet the quality standards demanded by you or your customers (in specific or general terms)? [Yes, No. If no, specify]
  - c. Do you think the efficiency requirements for BILD qualified products are adequate and appropriate to ensure that only high quality, efficient products are sold? [Yes/No]
  - d. [If 8c = No] Please indicate the efficiency requirements that you would like to see instituted for each product class. Be as specific as possible. [Open end]

## Program Processes – Customer Information

Beginning in November of 2015, ComEd has asked distributors to provide customer contact information and the business name and address of where the lamps will be installed. This information is needed so that we can more effectively evaluate program impacts and identify ways of improving the BILD program in the future. Based on previous conversations with BILD program distributors, we know that this information can be hard to gather and organize within certain billing and customer relationship management systems. We would like to know more about how you are collecting, organizing, and submitting the required information to determine if there are ways to streamline this activity in future program years.

9. After the requirement to collect customer contact information was instituted, were you able to collect contact information for 100% of BILD transactions? [Yes, No]

a. [If Q9 = no] Approximately what percentage of transactions were you not able to collect this information for? [Specify percent]

b. [If Q9 = no] Why were you not able to collect contact information for these transactions?

1. Customer did not want to provide
2. Customer was a contractor that did not know where the lamps would be installed
3. Sales/administrative staff oversight
4. Other [Specify]

9a. Was the requirement to submit incentive requests AND customer contact information within 15 days an adequate amount of time? [Yes/No]

9b. [If Q9a = No] What amount of time would be more reasonable for providing this information? Please specify the number of days.

10. On a scale from 1 to 10, where 1 is not at all burdensome and 10 is extremely burdensome, how difficult is the BILD transaction reporting process? *Please exclude any administration challenges surrounding changing incentive levels or program suspension. Your answer should be specific to the normal reporting requirements, including the new customer information fields.* [1-10]

11. [If Q10 >= 5] Are there particular aspects of the reporting requirements that are especially burdensome? [Yes, No]

a. [If Q11 = Yes] Please describe these challenges. [Open end]

12. Please describe the software or other tools/methods you use for invoicing, customer relationship management, and BILD reporting requirements. If you are willing, please provide the names of the software you use for these different administrative tasks and if those systems are easily linked to one another. [Open end]

## Changing Incentive Levels and Copays

During the past two program years, it has been necessary to adjust the incentive amounts for certain products in the middle of the program year. These adjustments were required due to rapidly dropping prices for certain products in the LED market specifically, as well as overall availability of BILD incentive funding.

13. On a scale from 1 to 10, where 1 is not at all burdensome and 10 is extremely burdensome, how difficult is it for your organization to adapt to changing incentive levels? [1-10]

14. [If Q13<5] What aspects of your billing system or other processes make it relatively easy to update incentive levels? [Open End]

14a. [If Q13>=5] What aspects of your billing system or other processes make it difficult to update incentive levels? [Open End]

15. If external factors continue to require adjustments to incentive levels in the middle of the program year, are there any procedures that ComEd could implement to make this process less of a burden? [Open End]

16. In November of 2015, the BILD program instituted a new rule that a minimum customer co-pay of 50% of the incentive amount is required for all transactions. Since that time, please indicate the approximate percentage of BILD program bulb sales in each category below that triggered the minimum co-pay [for example, for an LED reflector, how often was the final “sale” price less than \$12.00 (\$8.00 incentive + \$4.00 minimum co-pay)]?

- 1. Reduced wattage Linear Fluorescent \_\_\_\_\_%
- 2. LED reflectors lamps and trim kits \_\_\_\_\_%
- 3. All other screw based LEDs \_\_\_\_\_%
- 3. LED Exit Signs \_\_\_\_\_%

17. Do you think the minimum customer co-pay of 50% of the incentive amount is beneficial to the program? Why or why not? [Open end]

**Program Funding Periods**

In the past program year, there were several different strategies for incentive budget allocation. In July, a 30-day funding period was instituted, and then in November, 45-day to 60-day funding periods were defined for the remainder of the program year. ComEd understands that these funding cycles were difficult for some distributors. For the next program year (beginning June 1, 2016), ComEd plans to authorize an incentive allocation to each distributor for the entire program year and may allow distributors to apply for more funding as needed/available.

18. To inform the design of potential additional funding cycles, over what time period can you accurately forecast your need for BILD funds (within 10%)?

- 1. 1 month
- 2. 2 months
- 3. 3 months
- 4. 6 months
- 5. Other [Specify]

19. On a scale from 1 to 10, where 1 is not at all burdensome and 10 is extremely burdensome, please rate the level of difficulty associated with the BILD program's discontinuing incentive payments in the middle of the program year. [1-10]

19a. If you have additional comments regarding the discontinuation of incentives mid-program year, please provide them here: [Open End]

## Program Satisfaction

20. Beyond those already covered, did you experience any challenges resulting from your participation in the BILD program? [1=Yes, 2=No]

[If 20=1 ASK, ELSE SKIP to 24]

21. What type of challenges did you experience? [Open end]

22. Were these challenges addressed? [1=Yes, 2=No]

[If 22=2 ASK 23]

23. What could the program have done to address the challenges you experienced? [OPEN END]

24. Do you have any recommendations on how the BILD program could be improved?

This concludes the survey. In the event that we have clarifying questions about your responses, we may need to call you for a brief (5 – 10 minute) follow up phone call.

Followup1. Is there a best time or day of the week to reach you?

Followup2. What is the best phone number to reach you at?

END. On behalf of ComEd, thank you very much for your time, and for the information you provided.

*7.3.2 PG&E Battery Charger*



*Pacific Gas and  
Electric Company®*

## **Pacific Gas and Electric Company**

Emerging Technologies Program

Application Assessment Report #0808

### **Industrial Battery Charger Energy Savings Opportunities**

Issued: May 29, 2009

**Project Manager:** **Ryan Matley**  
**Pacific Gas and Electric Company**

**Prepared by:** **Ecos Consulting**  
Suzanne Foster Porter  
Brian Maloney  
Jonathan Carter Hebert, P.E.

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## 1. Executive Summary

Large battery chargers are used with such products as forklifts, airport transport equipment, neighborhood electric vehicles and golf carts. Large battery chargers can be found in residential, commercial and industrial applications using both single phase and three phase power. Industrial battery-powered motive equipment has been utilized in warehouses, ports, airport baggage systems and manufacturing facilities for decades. In addition, smaller single phase golf cart chargers are common on courses and in retirement neighborhoods. California's population of approximately 275,000 large chargers uses over 4,200 GWh per year. A test procedure for consumer battery chargers was finalized in April 2008 to support Title 20 standards for small chargers, but that procedure did not include the ability to test the efficiency of large chargers.

This project facilitated the development of a technically rigorous large battery charger efficiency test procedure, which was adopted as the official California Energy Commission procedure in December of 2008. Using data gathered by PG&E Applied Technology Services Group, Southern California Edison and one charger manufacturer, PG&E's consultant Ecos compared the efficiency of charger technologies, and estimated opportunities for energy and peak demand savings in PG&E's service territory.

Results indicate that the most common technologies installed today, ferroresonant and silicon controlled rectifier (SCR), tend to use more energy than newer technologies. Encouraging early retirement of ferroresonant and SCR chargers and replacing them with the average high frequency chargers, could save nearly 4 MWh per unit annually. If 5% of PG&E's total three phase lift-truck battery charger stock were replaced, 14,300 MWh could be saved per year. Coincident peak demand savings are likely negligible because of the duty cycle requirements associated with shift work. However, smart technologies may be explored for demand response load management opportunities.

Because there are significant variations in energy use even within technologies, a technology neutral program specification based on the test procedure could help ensure energy savings. Review of the data demonstrated that charge return factor and power conversion efficiency were the two metrics that had the greatest impact on annual energy performance. A program standard based on annual energy consumption as determined by the accepted test procedure would help to capture available energy savings from the best performing chargers.

Further research would allow for an adequate population of data points to set program standards. Additional testing of golf cart battery chargers would inform an analysis of saving opportunities for this product. The savings opportunities that have been identified merit further investigation by PG&E's Emerging Technology and ATS group.

## 2. Project Background

Industrial battery-powered motive equipment has been utilized in warehouses, airport baggage systems and manufacturing facilities for decades. Although the typical product is usually known as a forklift, the category of lift-truck has been created to encompass all machines used for this purpose. Smaller single phase golf cart chargers are utilized on courses and in retirement

neighborhoods all over California. PG&E's consultant Ecos estimates that the population of these large battery chargers in California is approximately 275,000 units. Table 1 shows the break out of existing stock and annual energy use by battery charger type. As shown in Table 1, the energy use in California associated with these chargers is estimated to be over 4,200 GWh per year (Hebert, Porter et al. 2009). Little data are publicly available on the efficiency of large battery charger systems, although Southern California Edison (Smith 2008) and EPRI (2002) have independently conducted testing and research on these chargers. PG&E and its consultant Ecos finalized a consumer battery charger test procedure version 1.2 in April 2008 (Porter, Bendt PhD et al. 2008), but this test procedure did not include provisions for testing larger single phase and three phase systems such as lift-trucks. This project filled this gap by supporting the development of a comprehensive large battery charger test procedure, which was officially adopted by the California Energy Commission in December 2008.

Battery Charger Type	Estimate of Existing CA Stock	Annual Energy Use (GWh)
Three Phase Lift-trucks	27%	3,400
Golf Carts/Electric Carts	56%	635
Single Phase Lift-trucks	19%	246

**Table 1: Industrial Battery Charger Technologies (Hebert, Porter et al. 2009)**

Ferroresonant and silicon controlled rectifier (SCR) have been the dominant large battery charger technologies for decades. Two emerging technologies, hybrid (controlled ferroresonant) and high frequency (switch mode) chargers, typically have more sophisticated charge control and improved power conversion efficiency than then dominant technologies. A more detailed discussion of industrial battery charger technologies can be found in Appendix C. Table 2 summarizes market trends for the four major technologies.

Technology	Estimate of Existing CA Stock <sup>a</sup>	Market Share Projection	Relative Efficiency	Cost Range <sup>b</sup>	Average Cost <sup>b</sup>	Status of Technology
Ferroresonant	50%	Decreasing	Average	\$1,500 - \$2,300	\$1,840	Proven
SCR	30%	Decreasing	Average	\$1,300 - \$2,700	\$2,100	Proven
Hybrid	5%	Marginally Increasing	Good	\$2,000 - \$3,500	\$2,540	Developing
High Frequency	10%	Increasing	Best	\$2,000 - \$3,500	\$2,810	Developing

Source: <sup>a</sup> Stock share was estimated based on conversations with manufacturers and industry experts (Wilson, 2008), (Smith 2009), and (Munton 2008). <sup>b</sup> Cost range and average cost was estimated based on cost data for 22 chargers provided by a manufacturer and industry expert (Smith 2008) (Munton 2008). One industry expert suggests that the cost difference between

ferroresonant and high frequency may be closer to zero than these in the table above. Recent increases in raw materials in ferroresonant chargers are driving up cost. First cost may possibly exceed high frequency chargers (Smith 2009).

### **Table 2: Industrial Battery Charger Technologies**

## **3. Project Objectives**

The objectives of this project included:

- With input from PG&E Applied Technology Services (ATS) Group, Southern California Edison (SCE) and other stakeholders, adapt the consumer battery charger test procedure to enable testing of high-power single phase and three phase battery charger systems
- Provide technical and logistical support to PG&E's ATS Group during charger testing
- Develop metrics that account for all modes of battery charger operation for comparing the energy use of these large battery chargers
- Calculate the energy consumption and peak demand contributions for each battery charger tested using different assumed facility operating profiles (single shift, two shift, 24-hour operation)
- Calculate energy and peak demand savings opportunities associated with moving the market to more efficient technology

In addition, the data collected in this project supported PG&E's 2009 codes and standards work to develop a minimum efficiency performance standard for large battery charger systems (Hebert, Porter et al. 2009).

## **4. Project Methodology**

The project occurred in three key phases:

1. Test procedure revision and finalization (June 2008 to December 2008)
2. PG&E test set up and collection of test data (December 2008 to April 2009)
3. Data analysis and reporting (March 2009 to May 2009)

In 2003, The California Energy Commission's Public Interest Energy Research Program (PIER) funded PG&E's consultant Ecos to begin developing a battery charger test procedure that measured the efficiency of small consumer battery chargers sold with cell phones, power tools, toothbrushes, and other rechargeable appliances. This test procedure, known as version 1.2 (Porter, Bendt et al. 2008), was finalized by PG&E's consultant Ecos in April 2008, but did not include technical details needed to test high-power battery charger systems, such as golf carts and lift-trucks. Southern California Edison (SCE) had developed an informal method for testing these products, but there was no public written record of the test protocol. Under this project, PG&E's consultant Ecos coordinated with SCE to incorporate its draft large charger test procedure as "Part 2" of the already developed consumer test procedure. This became version 2.1.4 (Porter, Bendt, et al. 2008).

With input from PG&E's ATS Group and charger manufacturers, PG&E's consultant Ecos worked with SCE to clarify the required data to be reported and included technical details needed

for a wide variety of chargers. The test procedure was publicly reviewed in a California Energy Commission rulemaking process and a revised procedure was adopted as version 2.2 by the California Energy Commission in December of 2008. A full copy of the California Energy Commission adopted test procedure version 2.2 may be reviewed in Appendix E and is available on [www.efficientproducts.org](http://www.efficientproducts.org).

Once the test procedure was finalized, the testing phase began. PG&E's consultant Ecos facilitated conversations with SCE and PG&E's ATS Group to clarify the intent of certain sections of the test procedure, and provided PG&E's ATS Group a data collection template based on the publically available template created to collect data for the Title 20 standards process at the California Energy Commission (California Energy Commission 2008). PG&E's consultant Ecos advised PG&E's ATS Group on which chargers should be tested first to best inform the 2009 PG&E CASE report for battery charger systems (Hebert, Porter et al. 2009). PG&E's ATS Group successfully used the test procedure to collect data for five chargers. PG&E's consultant Ecos garnered an additional 22 charger tests from SCE and one test from manufacturer Ametek for a total of 28 raw data points. For more details on the test procedure approach and required equipment, please refer to the California Energy Commission adopted test procedure version 2.2.

In order to compare the efficiency of the chargers, PG&E's consultant Ecos conferred with SCE to develop efficiency metrics for large three phase chargers. The metrics were designed to enable policymakers and program implementers to distinguish not only the highest but also the lowest efficiency products in the market. They therefore work equally well for minimum performance standards and market transformation programs. PG&E's consultant Ecos then gathered market information to estimate the number and technology types of installed units, and identified the relative efficiency of all chargers in the data set. Using these data, PG&E's consultant Ecos calculated energy and peak demand savings associated with replacing installed lift-truck chargers with high efficiency chargers under three duty cycle scenarios: single shift, double shift, and 24-hour shift scenarios.

## 5. Project Results

Part 2 of the California Energy Commission test procedure version 2.2 calls for the charger to be engaged in three discharge/charge cycles at three different depths of discharge. The measurements taken distinguish between energy lost in the charger and energy lost in the battery. Five energy efficiency metrics are used to compare the efficiency and energy use of the chargers in the data set:

- *Charge return factor*: the number of ampere hours (Ah) returned to the battery during the charge cycle divided by the number of ampere hours delivered by the battery during discharge. This metric measures how well the charger tailors its charge profile to the battery's depth of discharge. For example, all lead acid batteries require some amount of over charge to prevent the build-up of sulfides on the electrodes and ensure proper battery health, but excessive overcharge taxes the battery and shortens its useful life. Charge return factor should never fall below 1.05 and should not exceed 1.15 in order to maintain proper battery health. Charge return factor in this data varies between 1.05-1.30.
- *Power conversion efficiency*: the instantaneous dc output power of the charger (to the battery) divided by the instantaneous ac input power. Power conversion efficiency at the

maximum, median and minimum power levels of the charge are used to evaluate the power conversion efficiency performance of the charger.<sup>1</sup>

- *Maintenance power*: the average ac power when the battery charger is connected to the battery and delivering current in order to counteract or compensate for the self discharge of the battery. Energy consumption is measured for 72 hours to determine average power of the charger during maintenance mode.
- *No battery power*: the average ac power when the battery charger is not connected to the battery. The no battery mode test is conducted for one hour. The average power over that one hour is reported as the no battery power.
- *Power factor*: the ratio of the active power consumed by the battery charger in watts to the apparent power drawn in volt-amperes.

PG&E's consultant Ecos evaluated 28 raw data points from PG&E's ATS Group, SCE, and Ametek. Only nine unique chargers were tested by SCE (11 were duplicative tests). In some cases, the test results among these duplicative tests varied up to 14%, so PG&E's consultant Ecos averaged data points from duplicate chargers and used these averages for the analysis.

Variation in charge return test results among identical SCR and ferroresonant charger models can generally be attributed to imprecise technology used to detect charge completion. Variation in charge return factor for hybrid and high frequency chargers was within test procedure margins of error. Variation in power conversion efficiency for duplicative tests was typically less than 1% for all technology types.

The data set included only two golf cart battery charger data points and no single phase lift-truck battery charger data points, making it impossible to provide meaningful quantitative analysis of golf cart charger or single phase lift-truck trends by technology. The results below focus on the results of 15 three phase lift-truck battery chargers, nine from SCE, five from PG&E's ATS Group, and one from Ametek. Complete results used for this lift-truck analysis and the two golf cart charger points are summarized in Appendix B.

The most common depth of discharge (DOD) is 80%; however, the test procedure requires the charger to be tested at 100% and 40% DOD as well. The charge return factor for the 100% depth of discharge was generally lower than the 80% value, and the charge return factor for the 40% depth of discharge was generally higher than the 80% value. Ideally a charger should provide the same amount of overcharge for every depth of discharge. The data include eight complete charger tests with 100%, 40%, and 80% depth of discharge results. The worst case showed a difference between the charge return factor of 80% DOD and 40% DOD of 0.10. The best case varied less than 0.01.

---

<sup>1</sup> For some of the data provided by SCE, power conversion efficiency was not available at all three of these charge cycle points. For the purposes of this analysis, PG&E's consultant Ecos averaged the data points that were available.

Technology		Charge Return Factor	Average <sup>a</sup> Power Conversion Efficiency	Maintenance Power (W)	No Battery Power (W)	Average <sup>a</sup> Power Factor
Ferroresonant	Range	1.12 - 1.21	84% - 87%	7.0 - 293.5	7.0 - 39.5	0.91 - 0.97
	Average	1.15	85%	81.7	18.2	0.92
SCR	Range	1.09 - 1.35	81% - 88%	10.0 - 262.8	10.0 - 285.0	0.60 - 0.85
	Average	1.18	85%	137.1	125.3	0.76
Hybrid	Range	1.10 - 1.14	80% - 89%	53.0 - 73.9	6.0 - 19.0	0.87 - 0.97
	Average	1.12	86%	62.3	14.1	0.91
High Frequency	Range	1.06 - 1.29	91% - 92%	23.8 - 108.0	23.8 - 108.0	0.93 - 0.99
	Average	1.15	92%	48.4	48.4	0.96

Note: Charge return factor varies based on depth of discharge of the battery; the charge return data in this table represents 80% depth of discharge, which is the most common state of discharge. Battery capacity was normalized to 760 Ah to account for the different size batteries that were used in individual tests. <sup>a</sup> Average values represent the average of the data at the high, low, and middle power levels.

**Table 3: Three Phase Lift-truck Battery Charger Range of Performance**

Table 3 shows the four major charger types and associated efficiency metrics. Note that there are significant differences in all the metrics, even within one technology. Because of the wide variation, the average does not necessarily represent a typical product, but it does provide some insight into strengths and weakness of each technology type. Power conversion efficiency and power factor are characteristics associated with technology type. The charge return factor, maintenance, and no battery power averages are less meaningful because these characteristics are associated with charge control circuitry design and sophistication of standby power circuitry. Charge return factor, maintenance, and no battery power can be improved in any of the four technologies.<sup>2</sup>

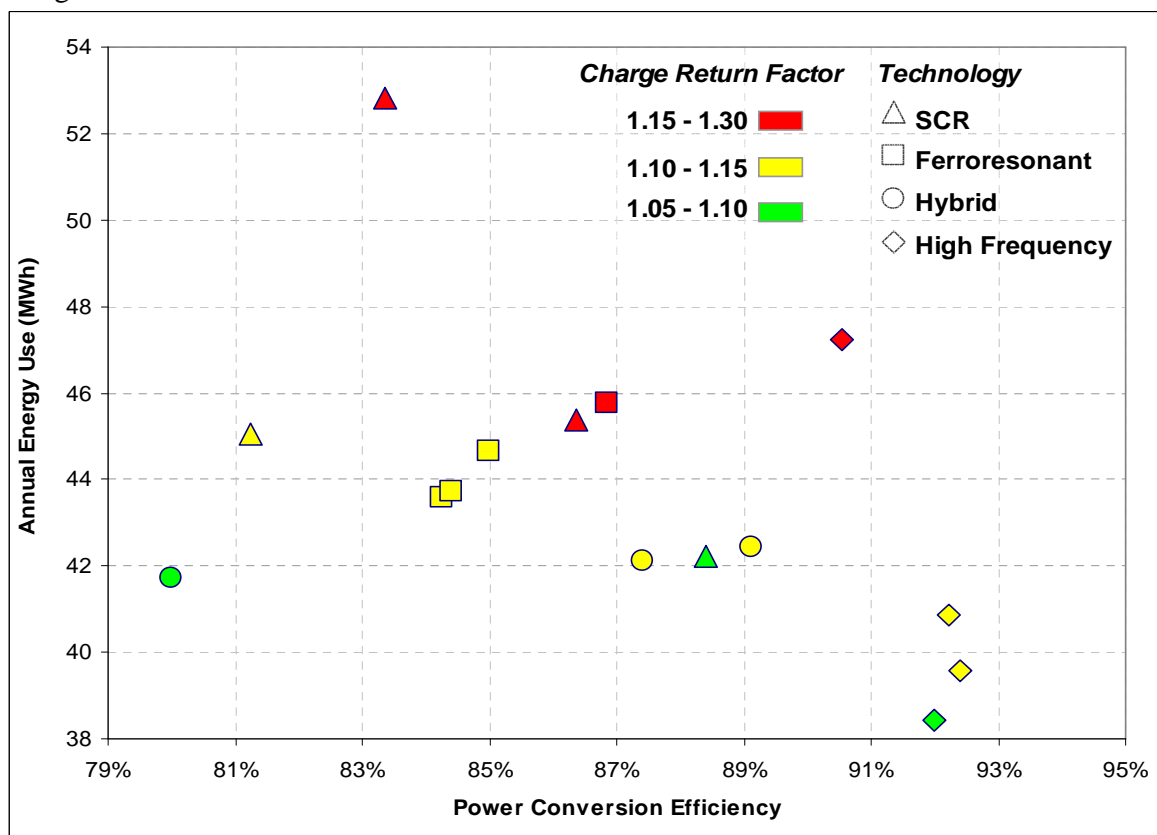
Figure 1 compares annual energy use of 15 three phase lift-truck battery chargers<sup>3</sup> to the two most important energy use performance factors: charge return factor and power conversion efficiency. Chargers closest to the bottom of the chart are the most efficient (lowest energy use). Although it is possible to group battery chargers by technology, it is also notable that there are

<sup>2</sup> The data set supports this conclusion for SCR, hybrid, and high frequency (Figure 1 green marks), but no ferroresonant chargers in the data set have excellent charge return factor. PG&E's consultant Ecos technical research suggests that better charge control circuitry could be implemented in a ferroresonant design.

<sup>3</sup> For many of these lift-truck chargers, there are duplicative tests in the data set.

significant variations within each technology suggesting that charger type alone is not the sole indicator of energy use.

The most efficient chargers have the best charge return factor (green) and efficient power conversion above 91%. Charge return factor, or how well the charge control is implemented, is the most important indicator of overall charger energy use. Poor charge control (red marker in Figure 1) can not only shorten the life of the battery, but can also be the greatest source of energy waste in the charging system. Implementing good charge control strategies is cost effective, is applicable to all technologies, and can garner significant energy savings. Power conversion, the second most important metric of energy use, is limited by charger technology. The different battery charger technologies primarily fall within bands of power conversion efficiency; high frequency chargers are 90% and above, ferroresonant chargers 83% to 87%, and SCR/hybrid chargers 80% to 90%.



Note: Annual energy use is calculated using the assumptions of a 24-hour shift, which is equivalent to 20 charges a week at 7.5 hours per charge. 24-hour shift assumptions show the largest energy use, but even for single or double shift scenarios, the power conversion efficiency and charge return factor are the two most important predictors of annual energy use. The charge return data in this figure represents 80% depth of discharge.

**Figure 1: Three Phase Lift-truck Energy Usage Sensitivity Plot**

Even though there were variations within technology, it was useful to compare technology averages to identify savings opportunities. PG&E’s consultant Ecos created energy savings estimates associated with replacing an average ferroresonant, SCR, or hybrid charger with an average high frequency charger. The data set indicated that high frequency chargers have the lowest energy use.

Table 4 gives a range of possible energy savings, peak demand savings, and payback periods in the absence of incentives. Note that the largest opportunities for savings are associated with replacing SCR and ferroresonant chargers with high frequency chargers. Replacing SCR or ferroresonant chargers with high frequency charges could save industrial customers \$371 to \$1,008 per year. This replacement would give the customer a simple payback period of two to five years. Payback period for replacing SCR or ferroresonant chargers with more efficient units would occur long before the expected 20-year useful life of a three phase lift-truck battery chargers (Smith 2008).

<b>Technology Replaced</b>	<b>Savings Achieved from Average High Frequency</b>	<b>8-hour Shift<sup>e</sup></b>	<b>16-hour Shift<sup>f</sup></b>	<b>24-hour Shift<sup>g</sup></b>
Average Ferroresonant	Annual Savings per Unit (kWh) <sup>a</sup>	1,035	2,125	2,911
	Peak Demand Reduction per Unit (kW) <sup>b</sup>	1.3	1.3	1.3
	Payback Period: Incremental Cost (years) <sup>c</sup>	8.5	4.2	3.0
	Payback Period: Full Replacement Cost (years) <sup>d</sup>	16.2	7.9	5.7
Average SCR	Annual Savings per Unit (kWh) <sup>a</sup>	2,169	3,627	4,849
	Peak Demand Reduction per Unit (kW) <sup>b</sup>	0.4	0.4	0.4
	Payback Period: Incremental Cost (years) <sup>c</sup>	2.5	1.5	1.1
	Payback Period: Full Replacement Cost (years) <sup>d</sup>	8.8	5.3	3.9
Average Hybrid	Annual Savings per Unit (kWh) <sup>a</sup>	149	439	575
	Peak Demand Reduction per Unit (kW) <sup>b</sup>	1.1	1.1	1.1
	Payback Period: Incremental Cost (years) <sup>c</sup>	16.3	5.5	4.2
	Payback Period: Full Replacement Cost (years) <sup>d</sup>	155.3	52.6	40.2

Note: <sup>a</sup> Details of calculation can be found in Appendix C. <sup>b</sup> Peak demand savings in this case represents the total peak power reduction during the charge mode of the battery chargers operation. This number does not represent coincident peak demand reduction. <sup>c</sup> \$110 per megawatt hour is used to calculate payback period. PG&E's consultant Ecos estimated the average incremental cost difference between ferroresonant and high frequency chargers is about \$970, between SCR and high frequency: \$593, between hybrid and high frequency: \$267. These estimates are based on a price list of 18 products from SCE (Smith 2008) as well as sales and cost data on four chargers from EnerSys (Munton 2008). <sup>d</sup> The average costs shown in Table 2 are used to calculate payback period associated with replacement costs. <sup>e</sup> An 8-hour shift is defined as seven charges per week with a charge time of 7.5 hours, 63 hours per week of maintenance time and 52.5 hours of no battery time. <sup>f</sup> A 12-hour shift is defined as 14 chargers per week with a charge time of 7.5 hours, 63 hours of maintenance time and 0 hours of no battery time. <sup>g</sup> 24-hour shift as 20 chargers per week, 18 hours of maintenance time, and 0 hours of no battery time.

**Table 4: Three Phase Lift-truck Battery Charger Savings of Average of Technology Performance**



Performance	Technology	Charge Return Factor	Power Conversion Efficiency	Maintenance Power (W)	No Battery Power (W)	Power Factor
Best	High Frequency	1.06	92%	23.8	23.8	0.93
Average	Ferroresonant	1.12	84%	239.5	39.5	0.91
Poor	SCR	1.35	83%	10.0	10.0	0.85

Note: Charge return data in this table represents 80% depth of discharge.

**Table 5: Key Three Phase Lift-truck Battery Chargers by Performance**

Another way to consider energy savings is to select three actual products in the data set (Table 5) that represent poor, average and best efficiency. PG&E's consultant Ecos determined energy use savings associated with replacing the average and poor performers with the best performer in a hypothetical retrofit scenario (Table 6). Creating an efficiency program standard that required the best of the high efficiency chargers, similar to the high frequency shown in Table 4, and identifying and replacing the worst of the SCR and ferroresonant chargers would enable payback periods of less than one year to five years. Customer energy savings would range from 2,500 to 14,000 kWh per year.

Performance	Technology	Savings compared to <i>Best High Frequency</i>	8-hour Shift	16-hour Shift	24-hour Shift
Average	Ferroresonant	Annual Savings Per Unit (kWh)	2,694	4,419	5,303
		Peak Demand Reduction per Unit (kW)	n/a <sup>a</sup>	n/a <sup>a</sup>	n/a <sup>a</sup>
		Payback Period: Incremental Cost (years)	3.3	2.0	1.7
		Payback Period: Full Replacement Cost (years)	6.2	3.8	3.2
Poor	SCR	Annual Savings Per Unit (kWh)	4,963	10,046	14,403
		Peak Demand Reduction per Unit (kW)	n/a <sup>a</sup>	n/a <sup>a</sup>	n/a <sup>a</sup>
		Payback Period (years): Incremental Cost	1.1	0.5	0.4
		Payback Period: Full Replacement Cost (years)	3.8	1.9	1.3

Note: Methodology and assumptions identical to Table 4. <sup>a</sup> The peak power demand of the best high frequency charger is higher than the alternatives, thus no reduction is realized.

**Table 6: Three Phase Lift-truck Battery Charger Savings Table: Moving to Best High Frequency**

The data suggest that reducing large battery charger energy use by replacing the least efficient units with high efficiency units is unlikely to produce product peak power reductions (Table 6) and unlikely to produce coincident peak power demand reductions (Table 7). Coincident peak demand reductions could potential be realized through demand response devices although these devices are not yet integrated into chargers.

Technology <sup>a</sup>	Coincident Peak Demand Reduction Per Unit Compared to Average <sup>b</sup> High Frequency (kW)		
	8-hour Shift	16-hour Shift	24-hour Shift
Ferroresonant	0.39	0.39	1.3
SCR	0.12	0.12	0.4

Note: <sup>a</sup> Hybrid chargers were not considered here because they were not the likely targets for programmatic replacement. <sup>b</sup> There were minimal peak power demand reductions garnered by switching to the best high frequency charger in this study. The average of the data set was used to illustrate the opportunities. Coincident peak demand reduction was calculated using the following load factors<sup>4</sup> per shift operation: *8-hour shift*: The load factor is 30%, because on average the charge cycle will begin at 5:00 pm and last for 7.5 hours; this equates to 2 hours of charge during peak period, *16-hour shift*: The load factor is 30%, because on average one charge cycle will begin at 5:00 pm and last for 7.5 hours and the other charge cycle will be at night; this equates to two hours of charge during peak period. *24-hour shift*: The load factor is 100%, because on average the charger will be charging the battery during the peak demand period. Maintenance and no battery mode power levels were not included in the coincident peak demand calculation because the power levels on average are negligible.

**Table 7: Coincident Peak Demand Reduction <sup>5</sup>**

## 5. Discussion

Based on technical work in this project, widespread implementation of high efficiency charger technology is likely to be feasible, cost effective, and to garner significant energy savings.

Research findings suggest:

- Because efficiency varies even within each technology type, a program specification based on the California Energy Commission test procedure version 2.2 metrics could help ensure program savings and enable fair comparison of products. Making requirements more stringent over time would continue to encourage market transformation.
- An initial program standard could be set based on annual energy use consumed in MWh based on the test results created by using the California Energy Commission approved test procedure version 2.2. More data points would be necessary to select a standard. In examining figure 1, a standard could be selected for chargers that demonstrated reduced

<sup>4</sup> Coincident peak demand reduction is calculated by multiplying the connected load reduction during the system peak demand period by a load or duty cycle factor during the system peak demand period.

<sup>5</sup> Peak demand period, as defined in the CPUC Energy Efficiency Policy Manual Version 2 (prepared by the Energy Division and dated August 2003) is noon to 7 p.m. Monday through Friday, June 1 through September 30.

consumption by having improved charge return factor, power conversion efficiency or both.

- A retrofit program may be preferable, as it could encourage early retirement of the worst performing chargers. The proposed Title 20 standard, which is scheduled for rulemaking this year, will address efficiency opportunities in new installations. A retrofit program could continue to deliver savings long after the most stringent proposed standards are projected to take effect.
- Three Phase Lift-truck battery chargers could be added to PG&E industrial site auditing programs. Targeting large industrial ports with significant lift truck use could enable extremely cost-effective retrofits. A similar approach could target golf courses with large banks of golf cart chargers that may add significant load during peak periods.
- Demand response systems are not integrated into existing large chargers although the most efficient and sophisticated chargers give consumers detailed information about the state of health of the battery and other parameters. The more sophisticated controls may provide PG&E an opportunity to work with manufacturers to develop smart controls with demand response features.
- In addition to PG&E customer energy savings, increased use of high efficiency chargers may lead to longer battery lifetime, and therefore reduced waste and lower long term customer costs for replacement batteries. (High efficiency chargers have more sophisticated charge control that avoids battery overcharge, which shortens the life of the battery.)

Table 8 shows the potential PG&E territory savings associated with early retirement of the average SCR and ferroresonant three phase lift-truck chargers. Replacing a modest 5%, or 3,600, of these low efficiency units with products that have high efficiency could garner 14,300 MWh of energy savings annually. If only the highest efficiency high frequency chargers were installed, the total savings would more than double (Table 9). Given that lower efficiency ferroresonant and SCR chargers make up approximately 80% of the installed stock, replacing 5% of the total stock could be a reasonable programmatic goal.

<b>Percentage of Three Phase Lift-truck Units Retrofitted in PG&amp;E Service Territory to Average High Frequency</b>	<b>Number of Three Phase Lift-truck Units Retrofitted in PG&amp;E Service Territory</b>	<b>Annual Energy Savings in PG&amp;E Service Territory Associated with Retrofit (MWh)</b>
5%	3,600	14,300
10%	7,400	28,600
20%	14,700	57,200

Note: The energy savings was calculated using the difference between the “field unit” and average high frequency charger. The field unit was calculated using a blend of 50% ferroresonant and 50% SCR chargers. Calculation assumes 24-hour shift.

**Table 8: Three Phase Lift-truck Retrofitting Scenarios: Moving to Average High Frequency**

<b>Scenario: Percentage of Units Retrofitted to <i>Most Efficient High Frequency</i></b>	<b>Lift-truck Units Retrofitted in PG&amp;E Service Territory</b>	<b>Annual Energy Savings in PG&amp;E Service Territory (MWh)</b>
5%	3,600	36,300
10%	7,400	72,500
20%	14,700	145,100

Note: The energy savings was calculated using the difference between the “field unit” and most efficient high frequency charger. The field unit was calculated using a blend of 50% ferroresonant and 50% SCR chargers. Calculation assumes 24-hour shift

**Table 9: Lift-truck Retrofitting Scenarios: Moving to Most Efficient High Frequency**

## 5. Conclusions

Large battery chargers are more efficient than the wide variety of small consumer battery chargers, such as cell phone, laptops, and power tool chargers. However, large battery chargers consume more than 4,200 GWh in California each year. A careful investigation reveals that modest improvements in large battery charger efficiency metrics translate into substantial energy savings. This can be attributed to the high power required by large battery chargers and their extended duty cycles.

Although research by PG&E’s consultant Ecos suggests that there is significant efficiency variation even within one technology type, high frequency chargers tend to be the best performers. The older and more common SCR and ferroresonant chargers tended to be the least efficient.

Part 2 of the California Energy Commission test procedure version 2.2 provides a technology neutral methodology to accurately measure large battery charger performance. Although all five metrics are important to measure, power conversion efficiency and charge return factor are the two most significant contributors to annual energy use. The wide disparity in the estimated annual energy consumption of battery chargers in the data set suggests a retrofit program could yield substantial cost-effective savings. A technology neutral specification, which could be increased in stringency over time would encourage early retirement of the least efficient chargers. Preliminary finding suggest that replacing only 5% of low efficiency units in PG&E’s service territory could yield 36,300 MWh per year in energy savings.

## 6. Recommendations for Future Work

The purpose of this project was to conduct an initial analysis of testing results and identify energy savings opportunities for large battery chargers. The scope of the study required PG&E’s consultant Ecos to use some preliminary assumptions to generate comparisons. This preliminary research also generated some research questions that could merit further study. Below is a brief

list of topics PG&E and its consultant Ecos identified that could benefit from more detailed research. Opportunities may exist to partner with PIER or other IOUs to fund this research.

- Increasing the overall population of the dataset would enable researchers to more clearly define the best performing chargers. Testing more hybrid chargers to investigate whether there are units with both high conversion efficiency and good charge control available in the market would be valuable. In addition, SCR chargers had a wide disparity of results and could be better understood with further testing. No ferroresonant chargers were identified that had exceptional charge return factor in the sample set although this could be technically feasible.
- Further testing of at least ten more golf cart chargers could help identify whether or not opportunities exist to garner savings from this product class. Efforts could be made to continue to acquire golf cart test information from SCE and combine this with tests from PG&E's ATS Group.
- The variation charge return efficiency for SCR and ferroresonant chargers could use additional study to ensure estimates of accurate potential energy savings associated with moving from these lower efficiency units to higher efficiency chargers.
- A concise site audit study in the PG&E service territory could be conducted with utility customers that use lift-truck chargers heavily. Further information could be gathered about baseline chargers to verify duty cycle assumptions, battery life, frequency of battery failure, and the potential for demand response or load shifting.
- A qualitative study with manufacturers of the best battery chargers may better inform the potential for improvement. Understanding what barriers exist to technical improvement, market dynamics, product differentiation by efficiency and demand response capabilities could inform program design.
- If utility customers indicate that charging lift-truck batteries could be shifted off-peak, conversations with manufacturers about the feasibility of incorporating smart demand response controls into large chargers could identify if there are coincident peak demand opportunities. Time of use rates could create financial incentives for end users to shift load.
- Although outside of the scope of this project, more information needs to be gathered to understand if there are operational limitations associated with hybrid and high frequency chargers (temperature, sturdiness, etc.).
- Aspects of this preliminary research and research topics mentioned above may also inform policy on automobile battery chargers for electric and hybrid vehicles that are outside the scope of this project. Advancements in battery charger technologies for vehicles could be monitored as the extended battery life and efficient charging technologies would be a highly desirable as well.

## Appendix A: References

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## Appendix B: Test Data

Tables 10 & 11 show test data compiled for this project. Test data is for 80% depth of discharge.

Technology	Index Number	Charge Return	Average <sup>a</sup> Power Conversion Efficiency	Maintenance Power (W)	No Battery Power (W)	Average <sup>a</sup> Power Factor
<b>Ferroresonant</b>	1	1.12	84%	293.5	39.5	0.91
	2	1.13	84%	7.0	7.0	0.92
	3	1.21	87%	18.2	18.2	0.91
	4	1.15	85%	8.0	8.0	0.97
<b>SCR</b>	5	1.18	86%	262.8	188.0	0.80
	6	1.11	81%	257.2	285.0	0.78
	7	1.09	88%	18.3	18.3	0.60
	8	1.35	83%	10.0	10.0	0.85
<b>Hybrid</b>	9	1.14	89%	73.9	19.0	0.90
	10	1.10	80%	53.0	17.4	0.87
	11	1.12	87%	59.9	6.0	0.97
<b>High Frequency</b>	12	1.14	92%	108.0	108.0	0.99
	13	1.06	92%	23.8	23.8	0.93
	14	1.29	91%	28.8	28.8	0.99
	15	1.11	92%	32.9	32.9	0.93

<sup>a</sup> Average values represent the average of the data at the high, low, and middle power levels.

**Table 10: Lift-truck Battery Charger Test Data**

Technology	Index Number	Charge Return	Average <sup>a</sup> Power Conversion Efficiency	Maintenance Power (W)	No Battery Power (W)	Average <sup>a</sup> Power Factor
Ferroresonant	16	1.13	74%	50.0	50.0	0.95
High Frequency	17	1.13	91%	50.0	50.0	0.97

Note: Battery capacity normalized to 112 Ah for golf cart battery charger efficiency metric analysis.

<sup>a</sup> Average values represent the average of the data at the high, low, and middle power levels.

**Table 11: Golf Cart Battery Charger Test Data**

## Appendix C: Energy Savings Calculations

$$E_{\text{annual}} = (E_{\text{per charge}} * \frac{\text{Charges}}{\text{week}} + P_{\text{maintenance}} * t_{\text{maintenance per week}} + P_{\text{no battery}} * t_{\text{no battery per week}}) * \frac{\text{weeks}}{\text{year}}$$

$$E_{\text{savings}} = E_{\text{high frequency annual}} - E_{\text{charger annual}}$$

where  $E$  is energy in watt hours,  $P$  is power in watts,  $t$  is time in hours,  $E_{\text{annual}}$  is annual energy use, and  $E_{\text{savings}}$  is annual energy savings.

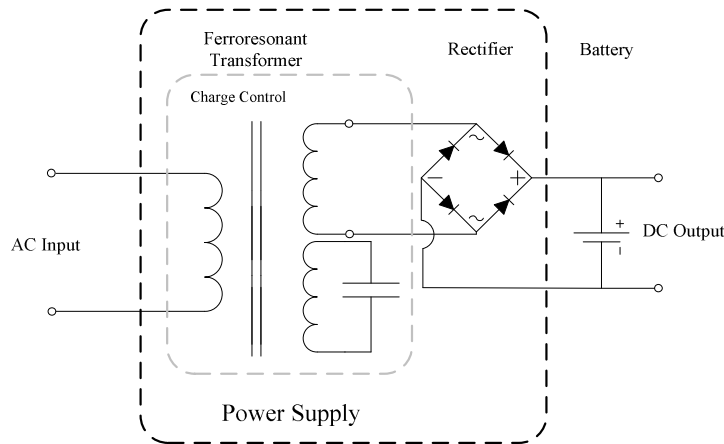
## Appendix D: Large Charger Technology Description

### Ferroresonant

Ferroresonant battery chargers are the most durable and widely used battery charger for industrial applications. They are composed of a transformer and a tank circuit that resonates at the designed ac input frequency to provide a flux regulated circuit. The capacitor in parallel with the inductive winding of the transformer creates a resonance at the specific ac input frequency. Then the current through the winding and the voltage on across the capacitor dictates the amount of flux through the transformer. Thus, the voltage and current delivered to the battery are limited as a function of flux. See Figure A for the circuit diagram.

Even the most modern ferroresonant charger are limited in power conversion efficiency to approximately 86% because of eddy current and magnetic saturation heating losses in the transformer core.



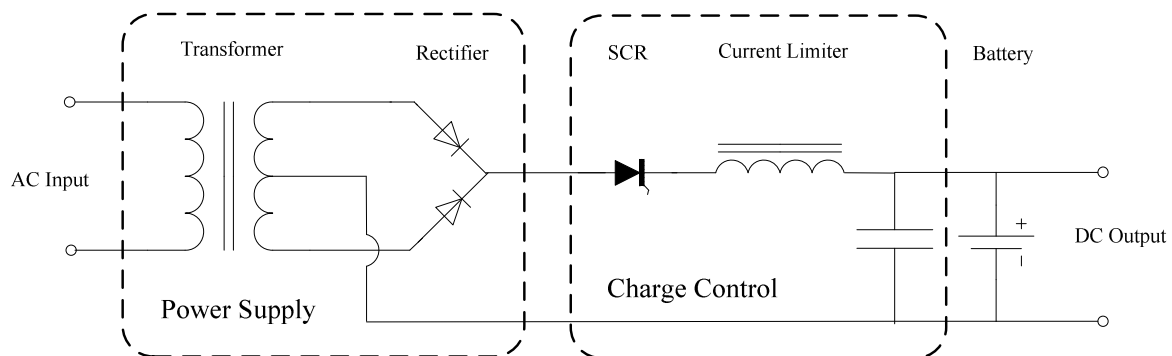


**Figure A: Basic Ferroresonant Battery Charger**

**Silicon Controlled Rectifier**

SCR battery chargers are also very popular in industrial applications because of their low cost and durability. SCR battery chargers are high powered cousins to typical switch mode battery chargers. A silicone controlled rectifier (SCR) is used to regulate voltage and current to the battery. SCRs are a mature technology that is able to withstand high power applications. They are limited in power conversion efficiency by switching losses. This is primarily due to the fact that they have a significantly limited frequency at which they can switch.

SCR's are being steadily supplanted by high frequency, insulated gate bipolar transistor (IGBTs), because IGBTs have significantly lower switching losses and can obtain much power conversion efficiencies.



**Figure B: Basic SCR Battery Charger****Hybrid**

Hybrid, also known as controlled ferroresonant, battery chargers uses a switching circuit in place of the capacitor in the tank circuit to optimize the resonances and reduce losses in the transformer core. Power conversion efficiency can be increased to approximately 89% with this change and charge return can also be improved.

**High Frequency**

High frequency battery chargers are composed of a switching circuit that utilizes insulated-gate bipolar transistors (IGBTs), which can switch at much at much higher frequencies than SCRs. High switching frequencies reduce loss and improve power conversion efficiency. IGBTs also enable better voltage and current control, because of their ability to be switched on and off precisely, and can improve charge return, reduce maintenance, and no battery power. Power conversion efficiencies as high as 92% are common in high frequency chargers.

**Appendix E: Energy Efficiency Battery Charging System Test Procedure Version 2.2, January 26, 2009*****Energy Efficiency Battery Charger System Test Procedure*****Version 2.2, January 26, 2009****Suzanne Foster Porter and Paul Bendt, Ph.D., Ecos Consulting****Haresh Kamath and Tom Geist, EPRI Solutions****Jordan Smith, Loïc Gaillac, and José Salazar, SCE****Development funded by: Pacific Gas and Electric,****California Energy Commission-Public Interest Energy Research (PIER)  
Program,****and Southern California Edison**

## **Scope**

### **General Scope**

The purpose of the test procedure is to measure the energy efficiency of battery chargers coupled with their batteries, which together are referred to as **battery charger systems**. This term covers all rechargeable batteries or devices incorporating a rechargeable battery and the chargers used with them. Battery charger systems include, but are not limited to:

- 1) electronic devices with a battery that are normally charged from ac line voltage or dc input voltage through an internal or external power supply and a dedicated battery charger;
- 2) the battery and battery charger components of devices that are designed to run on battery power during part or all of their duty cycle (such as many portable appliances and commercial material handling equipment);
- 3) dedicated battery systems primarily designed for electrical or emergency backup (such as emergency egress lighting and uninterruptible power supply (UPS) systems);
- 4) devices whose primary function is to charge batteries, along with the batteries they are designed to charge. These units include chargers for power tool batteries and chargers for automotive, AA, AAA, C, D, or 9 V rechargeable batteries, as well as chargers for batteries used in motive equipment, such as golf carts, electric material handling equipment and vehicles, including lift trucks (forklifts), airport electric ground support equipment (EGSE), port cargo handling equipment; tow tractors, personnel carriers, sweepers and scrubbers are examples of these types of motive equipment.
- 5) The scope of this procedure is limited to battery charger systems that are rated for ac input of 600 volts or less and that connect to the utility grid with a plug or are permanently connected.

### **Part 1 and Part 2**

This test procedure contains two parts: Part 1 and Part 2. Battery charger systems are to be tested using either Part 1 or Part 2, based upon the specific scopes in C and D. Note that the test procedures in Parts 1 and 2 share common reference and definition sections.

If a battery charger system appears to be described by the scope of both parts, it is to be tested using Part 2.

### **Part 1 Scope**

The scope of Part 1 is limited to those battery charger systems that operate on single-phase ac input power or dc input power and that have a nameplate input power rating of 2 kW or less.

This scope for Part 1 specifically excludes any battery charger system which meets the criteria of Part 2 in Section D of this Scope.

Excluded from the scope of Part 1 are battery charger systems for on-road full-function electric or plug-in hybrid-electric vehicles.

Laboratory testing equipment used to test and analyze batteries is specifically excluded from the scope of this test procedure. However, battery charger systems that provide power for portable laboratory testing equipment are included.

The scope of Part 1 includes any battery charger that meets the other criteria and that is packaged or sold without batteries. Part 1, Section II.C herein specifies the selection of suitable batteries for test using the procedures contained in Part 1.

Some examples of battery charger systems included in the scope of Part 1 are: cellular and cordless telephones, cordless power tools, laptop computers, cordless shavers, uninterruptible power supplies emergency egress lighting, portable lawn tools, rechargeable toys, and marine and recreational vehicle chargers,.

Note: The charging circuitry of battery charger systems may or may not be located within the housing of the end-use device itself. In many cases, the battery may be charged with a dedicated external charger and power supply combination that is separate from the device that runs on power from the battery.

Note: This test procedure is not intended to test batteries in the absence of a corresponding charger.

### **Part 2 Scope**

Part 2 includes test and analysis methods to evaluate the energy usage and impact of battery charger systems for powering motive equipment.

Some examples of battery charger systems included in the scope of Part 2 are chargers for batteries used in motive equipment, such as golf carts, neighborhood electric vehicles, electric material handling equipment and vehicles, including lift trucks (forklifts), airport electric ground support equipment (EGSE), port cargo handling equipment; tow tractors, personnel carriers, sweepers and scrubbers.

Part 2 of this procedure does not cover the following:

- a) Consumer electronics products and/or household-type devices, with either internal or external charger.
- b) On-road full-function electric or plug-in hybrid-electric vehicles.

- c) Battery chargers for automotive, marine and/or recreational vehicle starter batteries, or batteries used in conjunction with starting or running internal combustion engines and their accessories.
  - d) Battery chargers for signaling devices.
  - e) Electric wheelchairs or personal mobility devices.
  - f) Systems rated for input greater than 600V.
- If they meet the criteria in Section C, above, these excluded devices may be covered by the scope of Part 1.

### ***References***

This list is included for informational purposes only, and a manufacturer/tester is not required to follow the provisions of all of the following reference material to conform to this test method:

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IEEE 100: Institute of Electrical and Electronics Engineers, *The Authoritative Dictionary of IEEE Standards Terms*, IEEE 100, Edition 7.0, 2006.

IEEE Std 1625™ - 2008, revision of IEEE 1625-2004, IEEE Standard for Rechargeable Batteries for Multi-cell Mobile Computing Devices. The Institute of Electrical and Electronics Engineers, Inc., New York, NY, USA.

USABC *Electric Vehicle Battery Test Procedures Manual*, DOE/ID-10479, Rev. 2, INEL, U.S. DOE, 1996.

## **Definitions**

### **Active Power (P)**

Active power is the average value, taken over one or more cycles, of the instantaneous power (which is the product of instantaneous voltage and current).

### **Ambient Temperature**

Ambient temperature is the temperature of the ambient air surrounding the UUT.

### **Ampere-hour (Ah) Capacity**

See "Rated Charge Capacity."

### **Apparent Power (S)**

The apparent power (S) is the product of rms voltage and rms current (VA).

### **Batch Charger**

A batch charger is a battery charger that charges two or more identical batteries simultaneously in a series, parallel, series-parallel, or parallel-series configuration. A batch charger does not have separate voltage or current regulation nor does it have any separate indicators for each battery in the batch. When testing a batch charger, the term "battery" is understood to mean, collectively, all the batteries in the batch that are charged together. A charger can be both a batch charger and a multi-port charger or multi-voltage charger.

### **Battery Chemistry**

The chemistry of the rechargeable battery, such as nickel cadmium, nickel metal hydride, lithium ion, lithium polymer, rechargeable alkaline, or lead-acid.

Note: The chemistry of the battery is typically printed on the label of the battery itself, can be found in the manufacturer's instructions, or can be obtained from the manufacturer of the battery system.

**Battery Conditioning**

A special procedure performed on a battery to ensure optimal performance.

**Battery Discharge Energy**

The energy, in watt-hours (Wh) delivered by the battery as measured by this test procedure.

Note: This is the *measured* battery discharge energy as distinct from the *Rated Battery Energy* defined below.

**Battery Maintenance Mode**

The state in which the battery charger system is connected to input power, and the battery charger may be delivering current to the battery in order to counteract or compensate for self-discharge of the battery.

Note: In this state, the battery is at or near 100% capacity.

**Battery Rest Period**

A period of time, between discharge and charge or between charge and discharge, during which the battery is resting in an open-circuit state in ambient air.

**Calculated Energy Capacity**

The product (in Wh) of the Rated Battery Voltage and the Rated Charge Capacity.

Note: This is distinct from the *measured* Battery Discharge Energy defined below.

**Charge Energy Management**

The interactive way in which the battery is returned to proper charge and health with the optimum amount of energy.

**Charge Mode**

The state in which the battery charger system is connected to input power, and the battery charger is delivering current in order to bring the battery from a state of discharge to a state at or near 100% capacity.

Note: a battery charger system may have more than one charge mode.

**Charge Return Factor**

The number of Ah returned to the battery during the charge cycle divided by the number of Ah delivered by the battery during discharge.

**C-Rate**

The rate of charge or discharge, expressed in terms of the rated charge capacity (see definition) of the battery. A discharge rate of one-C draws a current (in A or mA) equal to the rated charge capacity (in Ah or mAh) and would theoretically discharge the battery in one hour. Other currents are expressed as multiples of one-C, so 0.2C is one fifth of that current.

**Cradle**

Electrical interface between integral battery product and the rest of the battery charging system designed to hold the product between uses.

**Crest Factor**

For an ac or dc voltage or current waveform, the crest factor is the ratio of the peak instantaneous value to the root-mean-square (rms) value.

Note: Crest factor is expressed as a ratio, for example a pure sine wave has a crest factor of 1.414.

**Detachable Battery**

A battery which is separable from the appliance and is intended to be removed from the appliance for charging purposes. The battery pack may contain additional circuitry.

**End-of-Discharge Voltage**

Specified closed-circuit battery voltage at which discharge of a battery is terminated.

**Equalization**

A process whereby a battery is overcharged, beyond what would be considered “normal” charge return, so that cells can be balanced, electrolyte mixed, and plate sulfation removed.

**External Power Supply (EPS)**

An external power supply is an external module which connects to ac line power and provides power to other components of the battery charger system. In this test procedure, this term is used broadly and generically. It is not limited to nor does it exclude power supplies that may be regulated by any particular jurisdiction or standard.

External power supplies are designed to convert ac line voltage into low voltage output (either ac or dc) and are contained in a separate housing from the product they are powering.



Note: For further clarification, see Test Method for Calculating the Energy Efficiency of Single Voltage External Ac-Dc and Ac-Ac power Supplies, August 11, 2007, at [www.efficientpowersupplies.org](http://www.efficientpowersupplies.org).

### **Integral Battery**

A battery which is contained within the appliance and is not intended to be removed from the appliance for charging purposes. A battery that is to be removed from the appliance for disposal or recycling purposes only is considered to be an integral battery.

### **Instructions**

The instructions (or “manufacturer’s instructions”) shall mean the documentation packaged with the product in printed or electronic form and any information about the product listed on a website maintained by the manufacturer and accessible by the general public. “Instructions” includes any information on the packaging or on the product itself. “Instructions” also includes any service manuals or data sheets that the manufacturer offers for sale to independent service technicians, whether printed or in electronic form.

### **Maintenance Management**

The way in which the charger maintains the battery when the battery is left connected and not used for long periods.

### **Measured Charge Capacity**

Measured charge capacity of a battery is the product of the discharge rate in amperes and the time in decimal hours required to reach final voltage.

### **Multi-port Charger**

A multi-port charger is a battery charger which charges two or more batteries (which may be identical or different) simultaneously. The batteries are not connected in series or in parallel. Rather, each port has separate voltage and/or current regulation. If the charger has status indicators, each port has its own indicator(s). A charger can be both a batch charger and a multi-port charger if it is capable of charging two or more batches of batteries simultaneously and each batch has separate regulation and/or indicator(s).

### **Multi-voltage Charger**

A battery charger that, by design, can charge a variety of batteries (or batches of batteries if also a batch charger) that are of different rated battery voltages. A multi-voltage charger can also be a multi-port charger if it can charge two or more batteries simultaneously with independent voltage and/or current regulation.

### **No-Battery Mode**

The state in which the battery charger system is connected to input power, is configured to charge a battery, but there is no battery connected to the charger output.

Note: Under normal operation by the user, the system would begin charging a battery if one were connected. For no-battery mode test setup of specific products, please refer to section IV. A. of the test procedure.

### **No-Battery Energy**

The energy used by the charger when in no-battery mode.

### **Off Mode**

The state in which the battery charger is switched “off” using a switch located on the charger, if such a switch is included, while the charger is connected to the input power source and used in accordance with the manufacturer’s instructions.

Note: If the charger does not have an on/off switch, off mode is the same as no-battery mode. If the charger does have an on/off switch, the charger will not begin charging a battery if one is connected while the charger is switched off. Products operating in Off Mode may still have some residual power consumption, which is the purpose of measuring power consumption in the Off Mode.

### **Overcharge**

See “Charge Return Factor.”

### **Periodic Equalization Strategy**

A part of charge energy management: the length, power, and frequency of cell overcharge and balancing sessions necessary for the long-term health of a battery.

### **Power Conversion Efficiency**

The instantaneous DC output power of the charger divided by the simultaneous utility AC input power.

### **Power Factor**

The power factor is the ratio of the active power (P) consumed in watts to the apparent power (S), drawn in volt-amperes (VA).

$$PF = \frac{P}{S}$$

Note: This definition of power factor includes the effect of both harmonic distortion and phase angle displacement between the current and voltage.

### **Power Quality**

The nonlinear effects of a battery charger system (power factor, harmonic distortion) on the interactive utility grid – an impact on system energy efficiency.

**Rated Battery Voltage**

The battery voltage specified by the manufacturer and typically printed on the label of the battery itself. If a batch of batteries includes series connections, the Rated Battery Voltage of the batch is the total voltage of the series configuration, that is, the rated voltage of each battery times the number of batteries connected in series. Connecting multiple batteries in parallel does not affect the Rated Battery Voltage.

Note: if not printed on the battery, the rated battery voltage can be derived from the electrical configuration and chemistry of the battery.

**Rated Charge Capacity**

The capacity, usually given in ampere-hours (Ah) or milliampere-hours (mAh), specified by the manufacturer and typically printed on the label of the battery itself. If a batch of batteries includes parallel connections, the rated charge capacity of the batch is the total charge capacity of the parallel configuration, that is, the rated charge capacity of each battery time the number of batteries connected in parallel. Connecting multiple batteries in series does not affect the rated charge capacity.

Note: it is the quantity of electric charge the manufacturer declares the battery can store under particular pre-specified test conditions.

**Rated Input Frequency**

Range of ac input frequencies designed to operate the UUT; assigned by the manufacturer and usually printed on the housing of the charging device. If the UUT includes an EPS, this is the frequency of the input to the EPS, not the frequency of the input to the other component(s) of the UUT.

**Rated Input Voltage**

Range of ac or dc input voltage designed to operate the UUT; assigned by the manufacturer and usually printed on the housing of the charging device. If the UUT includes an EPS, this is the voltage of the input to the EPS, not the voltage of the input to the other component(s) of the UUT (from the EPS).

**Specific Gravity**

The ratio of the density of a given substance (e.g. battery electrolyte) to the density of water, when both are at the same temperature.

**Swappable Battery**

A battery that is intended to be charged in the appliance but which may be detached from the appliance so that another battery can be attached to the appliance.

**Total Harmonic Distortion (THD)**

Total harmonic distortion is a measure of the degree to which a waveform departs from a pure sinusoidal waveform. It is defined as the ratio of the vector sum of all harmonic components (greater than 1) to the magnitude of the fundamental. For instance, for a voltage waveform, THD is defined by the equation:

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \dots + V_n^2}}{V_1}$$

where  $V_i$  is the rms voltage of the  $i^{\text{th}}$  harmonic.

**UPS**

Uninterruptible Power Supply

**UUT**

UUT is an acronym for “unit under test,” which in this document refers to the combination of the battery charger and battery being tested.

**PART 1:*****I. Standard Test Conditions*****General**

The test sequence is summarized in the table below. Measurements shall be made under test conditions and with the equipment specified below. For some products, multiple tests are required. The required tests may be at different input voltages (see Part 1, Section I.D), different charge rates (see Part 1, Section II.A), and using different batteries (see Part 1, Section II.C). When two or more of these apply, all combinations of specified input voltages, specified charge rates, and specified batteries shall be tested.

**Table A: Test Sequence**

Step	Description	Data Taken?	Equipment Needed			
			Battery	Charge r	Battery Analyzer	Ac Power Meter
1	Record general data on UUT	Yes	X	X		
2	Battery conditioning, Section VI.A	No	X		X	
3	Prepare battery for test, Section VI.B	No	X		X	
4	Battery rest period, Section VI.C	No	X			
5	Conduct Charge Mode and Battery Maintenance Mode Test, Section VI.D	Yes	X	X		X
6	Battery rest period, Section VI.E	No	X			
7	Conduct Battery Discharge Energy Test, Section VI.F	Yes	X		X	
8	Conduct No-Battery Mode Test and Off Mode Test, Section VII	Yes		X		X
9	Compile data into report	No				

### Measuring Equipment

All input power measurements shall be made with a suitably calibrated power analyzer. Measurements of active power of 0.5 W or greater shall be made with an uncertainty of  $\leq 2\%$ . Measurements of active power of less than 0.5 W shall be made with an uncertainty of  $\leq 0.01$  W. The power measurement instrument shall have a power resolution of:

- 0.01 W or better for measurements up to 10 W,
- 0.1 W or better for measurements of 10 to 100 W,
- 1 W or better for measurements over 100 W.

Measurements of energy (Wh) shall be made with an uncertainty of  $\leq 2\%$ .

Measurements of voltage and current shall be made with an uncertainty of  $\leq 1\%$ .

Measurements of temperature shall be made with an uncertainty of  $\leq 2\text{ }^\circ\text{C}$ .

Note: For suggestions on measuring low power levels, see IEC 62301, especially Section 5.3.2 and Annexes B and D.

### Test Room

All tests, battery conditioning, and battery rest periods shall be carried out in a room with an air speed near the UUT of  $\leq 0.5$  m/s. The ambient temperature shall be maintained at  $20^\circ\text{C} \pm 5^\circ\text{C}$  throughout the test. There shall be no intentional cooling of the UUT by use of separately powered fans, air conditioners, or heat sinks. The UUT shall be conditioned, rested, and tested on a thermally non-conductive surface.

Note: Products intended for conditions outside of this specified range may be tested at additional temperatures, provided those are in addition to the conditions specified above and are noted in a separate section on the test report. When not undergoing active testing, batteries shall be stored at  $20^\circ\text{C} \pm 5^\circ\text{C}$ .

### Input Reference Source: Input Voltage and Input Frequency

If the UUT is intended for operation on ac line-voltage input, it shall be tested at two voltage and frequency combinations: 115 V at 60 Hz and 230 V at 50 Hz, if its nameplate input voltage and frequency indicate that it can operate safely under both conditions. If testing at both conditions is not possible, the UUT shall be tested at the one voltage and frequency combination above that is within its nameplate voltage and frequency ranges.

If the UUT is intended for operation on ac input at other than line voltage, it shall be tested once with the following combination of voltage and frequency:

The voltage at the midpoint of its rated input voltage range

The first of the following frequencies that is within its rated input frequency range: 60 Hz, 50 Hz, or the midpoint of its rated input frequency range.

If a charger is powered by a low-voltage dc or ac input, and the manufacturer packages the charger with an EPS, sells, or recommends an optional EPS capable of providing that low voltage input, then the charger shall be tested using that EPS and the input reference source shall be a suitable input for the EPS.

If the UUT is intended for operation only on dc input voltage (and does not include an EPS), it shall be tested with one of the following input voltages: 12.0 V dc for products intended for automotive, recreational vehicle or marine use, 5.0 V dc for products drawing power from a computer USB port, or the midpoint of the rated input voltage range for all other products.

The input voltage shall be within  $\pm 1\%$  of the specified voltage.

If the input voltage is ac, the input frequency shall be within  $\pm 1\%$  of the specified frequency. The THD of the input voltage shall be  $\leq 2\%$ , up to and including the 13<sup>th</sup> harmonic. The crest factor of the input voltage shall be between 1.34 and 1.49.

If the input voltage is dc, the ac ripple voltage (rms) shall be:

for dc voltages up to 10 V,  $\leq 0.2$  V;  
for dc voltages over 10 V,  $\leq 2\%$  of the dc voltage.

## ***II. Battery Charger System Setup Requirements***

### **General Setup**

The battery charger system shall be prepared and set up in accordance with the manufacturer's instructions, except where those instructions conflict with the requirements of this test procedure. If no instructions are given, then factory or "default" settings shall be used, or where there are no indications of such settings, the UUT shall be tested as supplied. If the battery charger unit is powered by an external power supply, it shall be tested with the external power supply packaged with the unit.

If the battery charger has user controls to select from two or more charge rates (such as regular or fast charge) or different charge currents, the test shall be conducted with each of the possible choices. If the charger has user controls for selecting special charge cycles that are recommended only for occasional use to preserve battery health, such as equalization charge, removing memory, or battery conditioning, these modes are not required to be tested. The settings of the controls shall be listed in the report for each test.

**Age of Battery Charger System**

The UUT, including the battery charger and its associated battery, shall be new products of the type and condition that would be sold to a customer. It shall be tested within 3 months of the date of purchase. If the battery is lead-acid chemistry and the battery is to be stored for more than 24 hours between its initial acquisition and testing, the battery shall be charged before such storage.

**Selection of Batteries to Use for Testing**

The battery or batteries to be used for testing are selected by a two-step process. First, the technician shall determine all the batteries that are “associated with” the charger, as described below. Then, from the set of associated batteries, the technician shall select those to be tested, as described below.

1) Batteries “associated with” the charger shall be determined using Table B. For a batch charger, technician shall follow first the procedure for either “packaged with batteries” or “not packaged with batteries,” then consider all configurations of those batteries.



**Table B. Batteries Associated with a Charger**

Conditions		Associated Batteries
Charger comes packaged with batteries		(1) All batteries included with the product, and (2) Any and all optional or high-capacity batteries sold by the same manufacturer and identified in the instructions of either the product or the battery as suitable for use with the product.
Charger is not packaged with batteries	Charger manufacturer also sells batteries	Any and all batteries sold by the same manufacturer and identified in the instructions of either the product or the battery as suitable for use with the product.
	Manufacturer does not sell batteries, but does recommend batteries in the instructions	Any and all batteries recommended in the instructions as suitable for use with the charger. If more than three manufacturers are recommended, it shall be sufficient to consider only readily available batteries by three major manufacturers.
	Manufacturer neither sells nor recommends batteries	Any and all readily-available batteries made by three major manufacturers and which the charger is capable of charging
For any batch charger (whether or not multi-port and whether or not multi-voltage)		Also include as a separate “associated battery”: every combination of two or more identical batteries (meaning same manufacturer and same model) as determined above, connected in a configuration that the charger is capable of charging.

**Note:**

Example 1: a AA charger can charge batches of either 2 or 4 AA batteries. It comes packaged with 4 standard AA batteries. The manufacturer also sells high-capacity AA batteries. Result: there are four associated batteries:

2 standard AA

4 standard AA

2 high-capacity AA

4 high-capacity AA

Example 2: Another manufacturer makes a charger that charges batches of 2 or 4 AA batteries, or it can charge 2 C or 2 D batteries. This manufacturer neither sells nor recommends batteries to use with it. A survey of some local retail stores show that

manufacturers X, Y and Z are carried at most stores. The survey also finds that: X sells both standard and high-capacity AA batteries and C and D batteries; Y sells one type each of AA, C, and D; Z sells only one capacity of AA batteries. Result: there are twelve associated batteries:

2 standard AA batteries by X	2 AA batteries by Y
4 standard AA batteries by X	4 AA batteries by Y
2 high-capacity AA Batteries by X	2 C batteries by Y
4 high-capacity AA batteries by X	2 D batteries by Y
2 C batteries by X	2 AA batteries by Z
2 D batteries by X	4 AA batteries by Z

2) From the list of associated batteries, technician shall use Table C to select the batteries to be used for testing depending on the type of charger being tested. A charger is considered as:

Single-capacity if all associated batteries have the same rated charge capacity (see definition) and, if it is a batch charger, all batch configurations have the same rated charge capacity; or

Multi-capacity if there are associated batteries or batch configurations that have different rated charge capacities.

In many cases, multiple tests are required with different batteries. Each of these batteries shall be tested at each applicable input voltage and each applicable charge rate, as specified by Part 1, Sections I.D and II.A.

In Table C, below, each row represents a mutually exclusive charger type. Technician shall find the single applicable row for the UUT, and test according to those requirements.

**Table C. Battery Selection for Testing**

Type of charger			Tests to perform	
Multi-voltage?	Multi-port?	Multi-capacity?	Number of tests	Battery selection (from all configurations of all associated batteries)
No	No	No	1	Any associated battery
No	No	Yes	2	Lowest charge capacity battery

				Highest charge capacity battery
No	Yes	Yes or No	2	Use only one port and use the minimum number of batteries with the lowest rated charge capacity that the charger can charge
				Use all ports and use the maximum number of identical batteries of the highest rated charge capacity that the charger can accommodate
Yes	No	No	2	Lowest voltage battery
				Highest voltage battery
Yes	Yes to either or both		3	Of the batteries with the lowest voltage, use the one with the lowest charge capacity. Use only one port
				Of the batteries with the highest voltage, use the one with the lowest charge capacity. Use only one port.
				Use all ports and use the battery or the configuration of batteries with the highest total calculated energy capacity

### Other Non-Battery-Charger Functions

Any optional functions controlled by the user and not associated with the battery charging process (i.e., a radio integrated into a cordless tool charger) shall be switched off. If it is not possible to switch such functions off, they shall be set to their lowest power-consuming mode during the test. The actions taken by the technician to reduce power use by non-battery charging functions shall be recorded in the report.

If the battery charger unit has other electrical connections associated with its other functionality (such as phone lines, serial or USB connections, Ethernet, cable TV lines, etc.) these connections shall be left disconnected during the testing.

Note: some examples of other functionality are:

Example 1: If there is a radio in the same housing as a tool battery charger, the radio shall be switched off for all the tests. The user is no longer able to listen to the radio, so the only functionality available to the user (to be recorded on the report) is the “On-Off switch for the radio.” If the radio also provides a digital clock display that remains operating when the radio is switched off, that shall be noted in the report as well.

Example 2: A cordless phone battery charger also contains the circuitry for monitoring the phone line for a call. This functionality cannot be disabled and so shall be recorded on the test procedure report as “monitoring phone line for incoming call.”

### **Duration of the Charging and Maintenance Mode Test**

The charging and maintenance mode test, Part 1, Section III.D, shall be 24 hours or longer, as determined by the items below, in order of preference:

If the battery charger has an indicator to show that the battery is fully charged, that indicator shall be used as follows: If the indicator shows that the battery is charged after 19 hours of charging, the test shall be terminated at 24 hours. Conversely, if the full-charge indication is not yet present after 19 hours of charging, the test shall continue until 5 hours after the indication is present.

If there is no indicator, but the manufacturer’s instructions indicate that charging this battery or this capacity of battery should be complete within 19 hours, the test shall be for 24 hours. If the instructions indicate that charging may take longer than 19 hours, the test shall be run for the longest estimated charge time plus 5 hours.

If there is no indicator and no time estimate in the instructions, but the charging current is stated on the charger or in the instructions, calculate the test duration as the longer of 24 hours or:

$$\text{Duration} = 1.4 * \frac{\text{RatedChargeCapacity(Ah)}}{\text{ChargeCurrent(A)}} + 5 \text{ Hours}$$

If none of the above applies, the duration of the test shall be 24 hours.

### **Access to the Battery for Discharge Test**

The technician may need to disassemble the end-use product to gain access to the battery terminals for the Battery Discharge Energy Test. Manufacturer’s instructions for disassembly shall be followed, except those instructions that: a) lead to any alteration of the battery charger circuitry or function or b) that contradict requirements of this test procedure. Care should be taken by the technician during disassembly to follow appropriate safety precautions. If the functionality of the device or of its safety features is damaged, the product shall be discarded after testing.

Some products may include protective circuitry between the battery cells and the remainder of the device. In some cases, it is possible that the battery cannot be discharged without activating protective control circuitry. If the manufacturer provides a description for accessing connections at the output of the protective circuitry, the energy measurements shall be made at the terminals of the batteries, so as to not include energy used by the protective control circuitry.

If the battery terminals are not clearly labeled, technician shall use a voltmeter to identify the positive and negative terminals. If there are more than two terminals, the additional ones are usually a temperature sensor and/or data lines. Technician shall search for the two terminals that give largest voltage difference and are able to deliver significant current (0.2C) into a load.

If the technician, despite diligent effort and use of the manufacturer's instructions:

- a) is unable to access the battery terminals;
- b) determines that access to the battery terminals destroys charger functionality; or
- c) is unable to draw current from the battery

then the Battery Discharge Energy and the Charging and Maintenance Mode Efficiency shall be reported as "zero." The notes on the report shall describe the problems encountered.

**Batteries with No Rated Charge Capacity.**

If there is no rating for the battery charge capacity on the battery or in the instructions, then the technician shall determine a discharge current which meets the following requirements. The battery shall be fully charged and then discharged at this constant-current rate until it reaches the end-of-discharge voltage specified in Table D. The discharge time must be not less than 4 hours nor more than 5 hours. In addition, the discharge test (Part 1, Section III.F) (which may not be starting with a fully-charged battery) shall reach the end-of-discharge voltage within 5 hours. The same discharge current shall be used for both the preparations step (Part 1, Section III.B) and the discharge test (Part 1, Section III.F). The test report shall include the discharge current used and the resulting discharge times for both a fully-charged battery and for the discharge test.

For this section, the battery is considered as "fully charged" when either (a) it has been charged by the UUT until an indicator on the UUT shows that the charge is complete, or (b) it has been charged by a battery analyzer at a current not greater than the discharge current until the battery analyzer indicates that the battery is fully charged.

Note: When there is no capacity rating, a suitable discharge current must generally be determined by trial and error. Since the conditioning step does not require constant-current discharges, the trials may also be counted as battery conditioning. Further, the preparation step may be used as the proof that a discharge current is suitable, provided that the battery is "fully charged."

### ***III. Measuring the Battery Charger System Efficiency***

#### **Condition the Battery**

No conditioning is to be done on lead-acid or lithium-based batteries.

NiCd or NiMH batteries that have not been previously cycled are to be conditioned as follows: The batteries are to be fully charged and then fully discharged (100% DOD). This cycle is repeated once, then the battery is fully charged again. This amounts to three charges separated by two discharges. Either a battery analyzer or the UUT may be used to perform the battery conditioning.

NiCd or NiMH batteries that are known to have been through at least two previous full charge/discharge cycles shall be charged only once.

Note: The full discharge, which is the battery preparation step, should erase any memory effect in NiCd or NiMH batteries. Any conditioning necessary for lead-acid or lithium batteries is generally done by the manufacturer before the product is packaged.

#### **Prepare the Battery for Testing**

Prior to testing, the battery shall be discharged. This discharge shall be done using a battery analyzer that draws a constant discharge current of 0.2C. When the battery voltage reaches the end-of-discharge voltage for that battery chemistry or the UUT circuitry terminates the discharge, the discharge shall be terminated by opening the battery circuit.

If the battery has been previously used for testing (for example, testing the charger in another mode) and the battery has just completed the Battery Discharge Energy Test (section VI.F below), that battery may be considered as having just completed this preparation step.

If the discharge time required to reach the end-of-discharge condition is less than 30 minutes, these additional steps shall be taken: The battery shall be recharged to 30% or more of its rated charge capacity (see definition). Then the battery preparation shall be conducted again. If the discharge time is again less than 30 minutes, the battery shall be considered defective. Technician shall repeat the test procedure with another suitable battery.

#### **Battery Rest Period**

The battery or batteries shall be rested between preparation and charging. The rest period shall be at least one hour and not more than 24 hours. For batteries with flooded cells,

the electrolyte temperature shall be  $< 30\text{ }^{\circ}\text{C}$  before charging, even if the rest period must be extended longer than 24 hours.

### **Charge Mode and Battery Maintenance Mode Test**

The Charge and Battery Maintenance Mode test measures the energy consumed during charge mode and some time spent in the maintenance mode of the UUT. Functions required for battery conditioning that happen only with some user-selected switch or other control shall **not** be included this measurement. (The technician shall manually turn off any battery conditioning cycle or setting.) Regularly occurring battery conditioning/maintenance functions that are not controlled by the user will, by default, be incorporated into this measurement.

During the measurement period, power values shall be recorded at least every minute. If possible, technician shall set the data logging to record the average power during the sample interval. This allows the total energy to be computed as the sum of power samples (in watts) times the sample interval (in hours). If this setting is not possible, then the power analyzer shall be set to integrate or accumulate the input power over the measurement period and this result shall be used as the total energy.

Technician shall follow these steps:

- Ensure that the battery(ies) used in this test have been conditioned, prepared, and rested as described above.

- Connect the metering equipment to the battery charger.

- Ensure that user-controllable device functionality not associated with battery charging and any battery conditioning cycle or setting are turned off.

- Record the start time of the measurement period, and begin logging the input power.

- Connect battery(ies) to the battery charger within 3 minutes of beginning logging.

- After the battery(ies) are inserted, record the initial time, power (W), power factor, and crest factor of the input current. These measurements should be taken within the first 10 minutes of active charging.

- Record the input power for the duration of the “Charging and Maintenance Mode Test” period, as determined by Part 1, Section II.E. The actual time that power is connected to the battery charger system shall be within  $\pm 5$  minutes of the specified “Charging and Maintenance Mode Test” period, as determined by Part 1, Section II.E.

- During the last 10 minutes of the test, record the power factor and crest factor of the input current.

- Disconnect power for the battery charger and terminate data logging. Record the final time.

After the measurement period is complete, technician shall determine the average maintenance mode power consumption as follows: Examine the power-versus time data. If the last 4 hours show the power consumption to be steady or slowly varying, use the average power value over the last 4 hours. If the maintenance mode power is cyclic or shows periodic pulses, compute the average power over a time period that spans an integer number of cycles and includes at least the last 4 hours.

### **Battery Rest Period**

The battery or batteries shall be rested between charging and discharging. The rest period shall be at least one hour and not more than 4 hours. For batteries with flooded cells, the electrolyte temperature shall be  $< 30\text{ }^{\circ}\text{C}$  before charging, even if the rest period must be extended longer than 4 hours.

### **Battery Discharge Energy Test**

The purpose of this test is to measure the extractable energy from the battery associated with the battery charger system. The battery used in this test shall be the same battery used for previous tests in this section.

If multiple batteries were charged simultaneously, the discharge energy is the sum of the discharge energies of all the batteries:

For a multi-port charger: batteries that were charged in the separate ports shall be discharged independently.

For a batch charger: batteries that were charged as a batch may be discharged individually, as a batch, or in sub-batches connected in series and/or parallel. The position of each battery in the batch configuration need not be maintained.

During discharge, the battery voltage and discharge current shall be sampled and recorded at least once per minute. The values recorded may be average or instantaneous values.

For this test, technician shall follow these steps:

Ensure that the battery has been charged by the UUT and rested according to the procedures above.

Set the battery analyzer for a constant discharge current of  $0.2C$  and the end-of-discharge voltage in Table D for the relevant battery chemistry.

Connect the battery to the analyzer and begin recording the voltage and current.

When the end-of-discharge voltage is reached or the UUT circuitry terminates the discharge, the battery shall be returned to an open-circuit condition. If for any reason,



current continues to be drawn from the battery after the end-of-discharge condition is first reached, this additional energy is not to be counted in the battery discharge energy.

The battery discharge energy (Wh) is calculated by multiplying the voltage (V), current (A) and sample period (h) for each sample, and then summing over all sample periods until the end-of-discharge voltage is reached.

**Table D: Required Battery Discharge Rates and End-of-Discharge Battery Voltage**

<b>Battery Chemistry</b>	<b>Discharge Rate</b>	<b>End-of-Discharge Voltage</b>
Valve-Regulated Lead Acid (VRLA)	0.2 C	1.75 volts per cell
Flooded Lead Acid	0.2 C	1.70 volts per cell
Nickel Cadmium (NiCd)	0.2 C	1.0 volts per cell
Nickel Metal Hydride (NiMH)	0.2 C	1.0 volts per cell
Lithium Ion (Li-Ion)	0.2 C	2.5 volts per cell
Lithium Polymer	0.2 C	2.5 volts per cell
Rechargeable Alkaline	0.2 C	0.9 volts per cell
Other Chemistries	0.2 C	Per appropriate IEC standard

#### ***IV. No-Battery Mode and Off Mode Tests***

These tests measure the power consumed by the charger when it is not charging a battery. The tests shall be conducted after the Charging and Battery Maintenance Mode Test (Part 1, Section III.D), while the battery is resting or being discharged.

If Part 1, Section II.C requires testing with more than one battery, the No-Battery Mode and Off Mode tests do not need to be repeated with each battery. If the charger has multiple charging modes, as described in Part 1, Section II.A, the No-Battery Mode Test shall be performed for each mode and at each input voltage (see Part 1, Section I.D). The Off Mode Test needs to be performed only once at each input voltage (see Part 1, Section I.D).

#### **Setup**

Technician shall determine which of these three categories best describes the product:

- 1) The charger, the battery, and the product being powered are never disconnected during normal use of the product. There is only a power cord between the power source and the single housing that contains all of these components.

Examples: Most emergency egress lights, UPSs and standby power supplies, many electric shavers and electric vehicles.

Note: In these products, it may be possible for the consumer to disconnect the battery for battery replacement, but the battery is not disconnected during normal use.

- 2) The charger and the product being powered are not connected. The batteries are moved between them for charge and product end use.

Examples: Many cordless power tools and most AA and universal battery chargers.

- 3) The battery and the product being powered stay connected during normal use. The product can be readily connected to or removed from a charger or a charging base. This category applies even if the charge control circuitry is in the device with the battery and the external “charger” is really a constant-voltage power supply, such as most laptop computers.

Examples: most cordless phones, cell phones, laptop computers, and electric toothbrushes, many cordless vacuums and most automotive and golf cart chargers.

### Category 1 Products

The no-battery test does not apply to products in Category 1. The no-battery mode power shall be reported as “not applicable” (N/A). The off mode test may or may not apply depending on the following:

- If the product does not have an “on/off” switch that turns the charger off, the off mode does not apply. The off-mode power shall be reported as “not applicable”. The off mode power and a separate test shall not be conducted.

Note: the battery should be resting open circuit at this stage in preparation for the battery discharge energy test of Section VI.F.

### Category 2 Products

Both the no-battery mode and off mode tests shall be conducted for products in category 2. After completion of the Battery Charging and Maintenance Mode Test, the batteries shall be removed from the charger and the charger shall be connected to input power. Do not change any settings or controls on the charger for the no-battery mode test.

### Category 3 Products

Both the no-battery mode and off mode tests shall be conducted on products in category 3. After completion of the Battery Charging and Maintenance Mode Test, set up the product for the no-battery mode test as follows:

- If the product has a charging base: the portable device shall be removed from the charging base and the charging base shall be connected to input power. If the charging base uses an EPS, the EPS shall be connected to input power and to the charging base.
- If the product does not have a charging base but does have an external charger or an EPS: the product shall be disconnected from the charger or the EPS. The charger or EPS shall be connected to input power.

Technician shall not change any settings or controls on the charger or charging base for the no-battery mode test.

### **No-Battery Mode Test**

After connecting and powering the UUT in its no-battery mode setup, allow it to operate for at least 30 minutes.

Integrate the energy consumed over a time period of at least 10 minutes,

Record the power factor and the crest factor of the input current at some time during or after the 10-minute period.

Divide the energy (Wh) by the integration time (in hours) to get the No-battery Mode Power (W).

### **Off Mode Test**

If there is not an “on/off” control which turns the battery charger off, the Off Mode Test is not applicable. In this case, report the Off Mode power, power factor, and crest factor as “not applicable” (N/A). If there is an “on/off” control for the charger, perform the following steps:

- 1) After completion of the No-Battery Test, if applicable, set the “on/off” control in the “off” setting.
- 2) Allow the charger to operate for at least 30 minutes.
- 3) Integrate the energy consumed over a time period of at least 10 minutes,
- 4) Record the power factor and the crest factor of the input current at some time during or after the 10-minute period.
- 5) Divide the energy (Wh) by the integration time (in hours) to get the Off Mode Power (W).

## ***V. Reporting Requirements***

The following information shall be recorded about each UUT and each test performed. Quantitative values shall be reported to the precision of the measurement, not rounded by technician.

### **General**

- 1) Name of technician performing the test
- 2) Organization performing the test
- 3) Location of the test (physical address)
- 4) Time and date of each test
- 5) Make and model of measurement equipment
- 6) Input power voltage (V)
- 7) Input frequency (hertz), if ac
- 8) Manufacturer and model number of battery charger
- 9) Other functionality of battery charger, if any (see section V.D for more details)
- 10) Manufacturer and model number of battery
- 11) Standard size or type of battery (AA, C, D, etc.) if applicable
- 12) Number of batteries employed in the test
- 13) Battery chemistry

- 14) Rated battery voltage (V)
- 15) Rated battery capacity (Ah or mAh)
- 16) Any information provided by the manufacturer regarding access to the battery, particular safety requirements, etc.
- 17) Whether the battery charger system is detachable, integral, swappable, or does not meet any of these definitions.
- 18) Whether the battery charger system includes a cradle.

#### **Charge and Maintenance Mode Test**

- 1) Total charger input energy (Charge and Maintenance Energy) accumulated over the entire duration of the test (Wh)
- 2) The total time duration of the charging test (at least 24 hours)
- 3) Average power during maintenance mode (W)
- 4) The time duration used for the maintenance mode power (at least 4 hours)
- 5) True power factor at beginning and end of the charge test
- 6) The crest factor of the input current at the beginning and end of the charge test
- 7) The length of the rest period before charging (hr:min) and, if applicable, the electrolyte temperature at the beginning of charging (°C).
- 8) Sample rate used during test(s)
- 9) The steps taken, if any, to turn off or reduce the power consumption of other functionality and a description of the other functionality that could not be turned off, if any.

#### **Battery Discharge Test**

- 1) Energy delivered during discharge (Wh)
- 2) Starting battery voltage (V)
- 3) Ending battery voltage (V)
- 4) The length of the rest period before discharge (hr:min) and, if applicable, the electrolyte temperature at the beginning of discharge (°C)
- 5) Sample rate used during test(s)
- 6) A brief description of the steps taken, if any, to gain access to the battery terminals.

#### **No-Battery Mode and Off Mode Tests**

- 1) Category of product
- 2) Average no-battery mode power (W)
- 3) No-battery mode power factor and input current crest factor
- 4) Average off mode power (W)
- 5) Off mode power factor and input current crest factor

#### **Additional Information**

- 1) Any observations, notes or comments by the lab technician, in general or as required for certain special cases and exceptions.

**PART 2:*****I. Standard Test Conditions:*****A. Measuring Equipment**

The following test equipment is required.

- 1) Power meter (AC and DC) with kWh integration and with a sampling rate of at least 128 samples per 60 Hz cycle.
- 2) Power analyzer integrated with data logger (for continuous recording of Total Harmonic Distortion & Power Factor).
- 3) An Ah counter or meter on the battery side.
- 4) A device to discharge a battery at a specified rate and duty cycle down to a specific depth of discharge. This can be a battery cycler or load bank.
- 5) Personal computer.
- 6) Thermometers – for ambient and battery conditions.
- 7) Barometer – for environmental pressure.
- 8) Hygrometer – for environmental humidity.
- 9) Temperature compensated specific gravity meter – used to verify condition and state of charge of a flooded, lead-acid battery.
- 10) Volt meter.
- 11) Timer.

Note: the state of health of the battery must be ascertained. The battery must be in a state of condition to provide a minimum of 80% of nameplate capacity at the nominal rate in order to be used in this test procedure, and must maintain that level of health throughout the procedure. To determine state of health, have the battery certified by a qualified agency, or perform the state of health verification per BCIS-14 (see References). A test battery used for a series of tests by a lab over an extended period shall be tracked for state of health and tested appropriately to ensure that it is above 80% of nameplate capacity.

**B. Equipment Tracking and Accuracy**

All equipment used to conduct the tests must be identified and recorded by tracking or serial number. It is required that equipment be calibrated. The calibration should meet the National Institute of Standards and Technology's (NIST) calibration policy and meet the intent of ANSI/NCSL Z540-1-1994. The NIST's calibration policy requires the reporting of calibration results, with measurement results accompanied by the associated measurement uncertainties.

Each (voltage, current, temperature, etc.) measurement shall be made with an uncertainty of  $\leq 1\%$ .

Total uncertainty with calculated data (energy, power, etc.) shall be  $\leq 2\%$ .

Equipment data of all devices used in the test will be recorded, along with test equipment ID and calibration date. The information that shall be recorded includes:

- 1) ID number
- 2) Calibration date
- 3) Calibration expiration date
- 4) Type of instrument (power meter, battery discharger, etc.)
- 5) Comments on sample rate

### **C. Input Reference Source: Input Voltage and Input Frequency**

In order to help separate the local infrastructure effects on the readings, follow these guidelines to ensure accurate power quality assessment:

- 1) Test voltage harmonic distortion: Must be less than 2% total under normal operating conditions, from no load to full load. Measure AC source THD after AC input power meter and before UUT.
- 2) Voltage (RMS) Tolerance:  $\pm 3\%$
- 3) Frequency: 50 or 60 Hz  $\pm 1\%$

## ***II. Battery Charger System Setup Requirements***

### **A. Outline of Test Procedure**

- 1) Assure compatibility and effectiveness of charger/battery combination (II.B)
- 2) Receive certified battery to be used for the procedure (I.A)
- 3) Record nameplate and equipment data (I.B)
- 4) Set-up test (I.A,B,C)
- 5) Prepare battery with preliminary cycles (II.C,D)
- 6) Discharge battery – 3 scenarios (II.D, III.A.1)
- 7) Charge battery – 3 scenarios (II.E, III.A.2)
- 8) Monitor Battery Charge Maintenance – 72 hours (III.B)
- 9) Monitor “No-Battery” state – 1 hour (III.C)
- 10) Compile data and analyze (IV)
- 11) Report (IV)

### **B. Charger/Battery Selection and Qualification**

A battery and charger combination to use for the test must be selected and qualified. The battery shall be matched to the charger capabilities.

If the charger is capable of charging a range of battery sizes, test both the highest and lowest capacity values, as well as the highest and lowest voltage levels for the battery, if applicable. If the charger has multiple charging profile options, each charging profile shall be tested. This means if the charger is capable of charging multiple battery capacities for each charge profile, each profile

shall be tested with both the highest and lowest battery capacities, as well as the highest and lowest voltage levels for the battery if applicable.

Determine that the charger/battery system performs in a way that charges the battery properly and maintains the health of the battery by reading the specifications and operational parameters and verifying with the manufacturers of both the battery and the charger that they are compatible and effective as described in BCIS-16 (see References Section).

Report the specifications and operational parameters, of both the battery and the charger, regarding periodic equalization, as published by the manufacturers.

For the charger, the information that shall be recorded includes:

- 1) Manufacturer
- 2) Model name
- 3) Model number
- 4) Serial number
- 5) Electronics type (silicon controlled rectifier, ferroresonant, etc.)
- 6) Rated input voltage and current
- 7) Rated battery size(s)
- 8) Rated output voltage and current
- 9) Charge method (fast, pulse, intelligent, inductive, trickle)
- 10) Number of ports

Pertinent charger observations, or accompanying instructional manual descriptions shall also be recorded on the test forms.

For batteries, the information that shall be recorded includes:

- 1) Manufacturer
- 2) Model name
- 3) Serial or ID Number
- 4) Chemistry
- 5) Construction (flooded lead acid, value regulated lead acid, gel, etc.)
- 6) Number of cells
- 7) Rated Voltage
- 8) Rated Ah
- 9) Discharge rate for above
- 10) Manufacturer approved for charger under test?
- 11) BCI-14 Capacity

Verify from the information provided by the BCS manufacturer, that the charger, or charger/battery system, performs regular equalization in a way that maintains the health of the battery, i.e. verify that the battery used in the test is appropriate for the BCS being tested according to the manufacturer. Have the battery certified, or perform the state of health verification per BCIS-14 (see References).

### **C. Battery Conditioning**



After receiving a qualified battery (see the note in Part 2, Section I.B, above) conduct some preparatory cycles on the battery and charger if it has not been used in testing within 24 hours. This is for battery conditioning in the test environment, as the performance can change for various reasons. The battery shall be depleted to roughly 80% depth of discharge, and then recharged with the charger under test. Do this two times. If available per manufacturers instructions, one of those times shall include the equalization cycle. Rest time shall be included to avoid overheating the battery (according to battery specifications). The final full charge must be completed within 24 hours of beginning the discharge test procedure. Record environmental parameters at the beginning and end of each charge and discharge. The following information shall be recorded for each conditioning cycle:

- 1) Start Date and time for each cycle
- 2) End Date and time for each cycle

#### **D. Battery Preparation**

The discharge test must be begun no sooner than 3 hours, and no more than 24 hours after the last full charge.

Verify full charge of the battery using one of two methods:

- 1) Flooded batteries – At least one hour after the full charge is completed, and before beginning the discharge test, take temperature-compensated specific gravity measurements of the electrolyte in each cell, and ensure that the specific gravity corresponds to full charge according to the battery manufacturer’s specifications.
- 2) Valve regulated batteries (VRLA) – At least one hour after the full charge is completed, take voltage measurements and ensure that the voltage corresponds to full charge according to the battery manufacturer’s specifications.

Measure the temperature of the electrolyte (preferred, for flooded batteries, or negative terminal post for VRLA batteries). The battery temperature at the start of discharge must be between 17°C and 33°C. Configure the battery (or pack) with the appropriate data acquisition equipment to record voltage and current at 1 minute intervals.

#### **E. Charger Preparation**

The charger shall be in proper working condition, and connected and adjusted properly for the battery and the utility, as verified in the battery preparation process. Configure the data acquisition equipment on both the input and the output side of the charger to measure AC and DC power and power quality. Set up to record the DC power for the entire charge to view the charge profile.

It is important to locate the PQ monitoring device as close as possible to the tested charger, but avoid being too close to service entrance equipment such as step-down transformers or UPS equipment. The monitoring device must see the same electrical variations the charger does. Harmonic content, in particular can be significantly different if there is a large separation between the monitor and the charger. The monitoring equipment shall be placed after any circuit protection device, and as close as possible to the charger.



### III. Test Procedure: Part 2

#### A. Battery Discharge/Recharge Sequence

The discharge/recharge sequence is completed at three different levels of battery discharge: fully discharged (100% DOD), 40% depth of discharge (DOD), and 80% DOD. After the proper amount of rest and within temperature limits, according to Part 2, Section II.D, proceed with the battery discharge. After each discharge (as in Part 2, Section III.A.1), recharge the battery (as in Part 2, Section III.A.2.).

##### **Battery Discharge**

Using a battery cycler or load bank, discharge the battery pack at a constant nominal current rate  $\pm$  3%. The discharge rate shall be:

**C<sub>6</sub>/6** for batteries used in industrial equipment like lift trucks, airport ground support equipment, port cargo handling equipment, tow tractors, sweepers, scrubbers, and material handling equipment;

**C<sub>5</sub>/5** for batteries used in personnel carriers like golf carts and neighborhood electric vehicles.

The battery shall be discharged at a rate specified above, unless this rate conflicts with manufacturer's recommendations. In that case, the technician may choose either C<sub>6</sub>/6 or C<sub>5</sub>/5 and this shall be noted on the test sheet. No other discharge rate may be used.

Discharge the battery to 100% DOD (measured with an accuracy of 1%), or until reaching the cutoff voltage (as specified in Part 1, Section III.F. "Table D" of this Test Procedure). Measure and record the following data:

- 1) Discharge Test Date
- 2) Start Time
- 3) Maximum and Minimum Ambient Temperature
- 4) Start Pressure
- 5) Start Humidity
- 6) Starting Voltage
- 7) Starting Battery Temp Avg (Near Center of Cell)
- 8) Total Ah Delivered
- 9) Total Energy Delivered (Wh)
- 10) End Time
- 11) End Pressure
- 12) End Humidity
- 13) End Voltage
- 14) End Battery Temp Avg (Near Center of Cell)
- 15) Actual Depth of Discharge (Not Nominal)

After recharging according to Part 2, Section III.A.2., repeat this Battery Discharge Test sequence by discharging the battery to each of the following levels and then recharging:

- 40% DOD of measured charge capacity (within  $\pm 10\%$ ) as determined by voltage meter, Ah counter, specific gravity measurements, or discharge meter reading of Ah capacity.
- 80% DOD of measured charge capacity (within  $\pm 10\%$ ) as determined by voltage meter, Ah counter, specific gravity measurements, or discharge meter reading of Ah capacity.

Each of the measurements made above with respect to the state of discharge are required to be recorded for each battery discharge cycle.

### **Battery Recharge**

During the recharge test, the ambient environment shall be maintained between 18°C and 27°C. The battery recharge must start within 1 to 6 hours of the completion of the discharge, depending on the temperature of the battery. If the charger is capable of charging a range of battery sizes, test both the highest and lowest capacity values, as well as the highest and lowest voltage levels for the battery, if applicable. If the charger has multiple charging profile options, each charging profile shall be tested. This means if the charger is capable of charging multiple battery capacities for each charge profile, each profile shall be tested with both the highest and lowest battery capacities, as well as the highest and lowest voltage levels for the battery if applicable.

Start the charge and measure and record the following data:

- 1) Date
- 2) Start Time
- 3) Maximum and Minimum Ambient Temperature
- 4) Start Pressure
- 5) Start Humidity
- 6) Starting Battery Voltage
- 7) Starting Battery Temp Avg (Near Center of Cell)
- 8) Input Voltage
- 9) Input Frequency
- 10) Instantaneous input and output current (as described below)\*
- 11) Instantaneous input and output voltage (as described below)\*
- 12) Power Factor\*
- 13) Current THD\*
- 14) Voltage THD\*
- 15) Power Conversion Efficiency<sup>†</sup>
- 16) Total Ah Delivered
- 17) Total Energy Delivered (Wh, AC)
- 18) Total Energy Delivered (Wh, DC)
- 19) End Time
- 20) End Pressure
- 21) End Humidity
- 22) End Battery Voltage
- 23) End Battery Temp Avg (Near Center of Cell)
- 24) Average End Specific Gravity
- 25) Average Temp of All Cells at Specific Measurement
- 26) Specific Gravity Measurement Date
- 27) Charge Return Factor<sup>‡</sup>

\*Power quality measurements reported for the first full recharge from 100% DOD only.

† Power conversion efficiency reported for the three performance reporting points below and reported for first full recharge from 100% DOD only.

‡ The charge return factor is obtained by dividing the number of Ah returned to the battery pack during the charge cycle (but not an equalization charge) by the number of Ah delivered by the battery pack during discharge.

The discharge/recharge sequence is completed at three different levels of battery discharge, as described in this Section III.A.1 of Part 2. Data 1-24 shall be recorded for the 100% DOD recharge cycle. Data 1-11 and 16-24 shall be recorded for the 80% DOD and 40% DOD recharge cycles. When the charging current reaches 2% of the charging current capacity the charge is complete.

### Power Quality Measurements

For the power quality data, set up the power meters and power analyzer sampling at 128 samples per 60 Hz cycle, and recording, at 1-minute intervals. Report the required data using rms values of the sampled data.

After charge completion, select three performance reporting points as follows:

- 1) High-power: select the highest AC power data point, excluding the first three minutes after the start of the charge; this avoids initial transients.
- 2) Low-power: select the lowest AC power data point recorded during the last two hours of charge.
- 3) Mid-power: select the median power between the low and high power data points.

For each performance reporting point, look at two adjacent data points:

- 1) one point preceding that point by one minute
- 2) one point following that point by one minute.

Both adjacent points must be within 4% in absolute value of the central point. If the selected point meets this requirement, report the required performance data point.

If the adjacent points are not within 4% of the central point, reexamine the data to find the next point that most closely matches the specification for that data performance point: high, low, or mid-power. When a new performance point is found, repeat the 4% deviation procedure for the adjacent points. This should be repeated until a suitable point is found.

This process shall serve to ensure power stability prior to reporting a performance point. The 4% tolerance provides a method to distinguish between pulse phenomena and a point representative of the charger's operation.

### Electrolyte Temperature Measurements

The average electrolyte temperature, or average terminal post temperature (in the case of sealed batteries), must remain in the range of 18°C to 46°C during charging for a valid test. Temperature is to be recorded at the start of charge and again within 10 minutes of the termination of charge.

The average temperature is assumed to change linearly during the charge, so that the limits are defined by the starting and ending values. If the range is exceeded, the test results are invalid, and

the test must be repeated. Start the next test with a starting battery temperature at the lower end of the acceptable range. If the results again exceed the temperature window, consult with the battery and charger manufacturers to determine if there are any malfunctions, or problems with the health of the battery. If there is no problem identified, then record the results on the data sheet and mark the block indicating a test anomaly.

#### Equalization Phase Disabled

The equalization phase of the charger shall be disabled, if possible. If it is not possible to manually disable equalization, the technician shall plot the battery charging profile, with dc charging voltage and current vs. time to ensure the charger is not performing equalization. This plot is not a required reporting element. If the technician determines that the equalization phase is carried out by the charger, then the data are invalid and the test shall be repeated.

### **B. Battery Maintenance Charge Test**

After completing the battery charger test, leave the battery connected and leave test equipment recording data for a 72-hour period and record data at 1-minute intervals. Determine the power and amount of AC kWh drawn by the battery charger and the amount of DC kWh delivered by the battery charger to the battery pack, and the frequency and duration of any intermittent activity over the period. Note energy consumption by any auxiliary systems, such as a thermal management system maintaining the temperature of the battery. Measure and record the following data:

- 1) Start Date
- 2) Start Time
- 3) Maximum and Minimum Ambient Temperature
- 4) Start Battery Temperature
- 5) Record input and output voltage and current at one minute intervals
- 6) Average AC Power (kW)
- 7) Output Power Cycle Frequency
- 8) Total AC energy over period (kWh)
- 9) Total DC energy over period (kWh)
- 10) End Date
- 11) End Time
- 12) End Battery Temperature
- 13) Maintenance Charging Behavior Parameters: magnitudes and frequency of maintenance events\*
- 14) Comments

\* Determine and report the character of maintenance mode by evaluating the ac and dc charge behavior with respect to the amplitude and frequency of maintenance charging periods. The maintenance charging behavior shall be characterized by length, magnitudes, and frequency of maintenance events. For example: 1 hour charge at 5 kW every 4 hours.

### **C. Charger No-Battery Test**

With the battery disconnected from the charger, and the charger connected to AC power, measure the demand of the charger on the AC side for a period of up to one hour, depending on the nature

of the demand (or some time long enough to characterize demand if intermittent). Measure and record the following data:

- 1) Date
- 2) Start Time
- 3) Maximum and Minimum Ambient Temperature
- 4) Start Battery Temperature
- 5) Record input voltage and current at one minute intervals
- 6) Average AC Power (kW)
- 7) Total AC energy over period (kWh)
- 8) End Time
- 9) End Battery Temperature
- 10) Comments

#### ***IV. Reporting Requirements***

Reporting requirements are embedded in test instructions above. For a comprehensive list, see the Excel Test Data Template for part 2.

*7.3.3 Battery Charger Workpaper*





<b>Industrial 3-Phase High Frequency Battery Charger</b>	
<b>Measure Description</b>	Installation of 3-phase High Frequency Battery Charger
<b>Units</b>	Per unit
<b>Base Case Description</b>	Ferroresonant or Silicon Controlled Rectifier (SCR) Chargers

The measure consists of replacing SCR or ferroresonant chargers with high frequency chargers, or installing a new high frequency charger where no charger existed previously.

### Measure Savings

The table below shows the default savings for high-frequency battery chargers. This measure savings will be a calculated for each project. The deemed savings are not used.

**Table 157. Measure Savings for High Frequency Battery Chargers**

Shift	kWh Savings	Coin-kW Savings
8-hour shift	1405	0.2775
16-hour shift	2588	0.2775
24-hour shift	3502	0.9251

### Measure Savings Analysis

The savings for this measure are based on the application assessment report #0808 prepared for PG&E. The savings are reported based on the length of the shift, and the type of baseline technology. The savings from the different baseline technologies were averaged together, weighted according to the estimate of existing charger stock found in CA provided in the assessment report. In order to accommodate both replacement, and new construction, different savings were calculated for the two situations, the difference being that part of the market baseline for new construction included high frequency (market baseline since not mandated by code), and an assumption was made that about 75% of the units installed through the program will be replacement, and the remainder will be new units, where not existed previously.



**Table 158. Measure Savings for High Frequency Battery Chargers Based on Baseline Technology – Retrofit Only Case**

Baseline Technology	Weight Factor <sup>144</sup>	8-hour shift		16-hour shift		24-hour shift	
		kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings
Ferroresonant	63%	1035	0.39	2125	0.39	2911	1.3
SCR	38%	2169	0.12	3627	0.12	4849	0.4
Weighted Average	100%	1460	0.289	2688	0.289	3638	0.963

**Table 159. Measure Savings for High Frequency Battery Chargers Based on Baseline Technology – New Construction Case**

Baseline Technology	<a href="#">Weight Factor[1]</a>	8-hour shift		16-hour shift		24-hour shift	
		kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings
Ferroresonant	53%	1035	0.39	2125	0.39	2911	1.3
SCR	32%	2169	0.12	3627	0.12	4849	0.4
Hybrid	5%	149	0.008243	439	0.014524	575	0.047432
High Frequency	11%	0	0	0	0	0	0
Weighted Average	100%	1238	0.2436	2287	0.2439	3094	0.8130

<sup>144</sup> PG&E Application Assessment Report #0808 page 2, Table 2.



**Table 160. Measure Savings for High Frequency Battery Chargers Based on 25% Assumed New Construction Cases, 75% Replacement Cases**

Baseline Technology	8-hour shift		16-hour shift		24-hour shift	
	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings
Ferroresonant	1035	0.39	2125	0.39	2911	1.3
SCR	2169	0.12	3627	0.12	4849	0.4
Hybrid	149	0.008243	439	0.014524	575	0.047432
High Frequency	0	0	0	0	0	0
Weighted Average	1405	0.2775	2588	0.2775	3502	0.9251

**Measure Life and Incremental Measure Cost**

The incremental measure cost for this measure is \$872.50, based on information provided in the PG&E technology assessment report #0808. The measure life is 20 years, based on the same report.

**Table 161. Incremental Measure Cost for High Frequency Chargers**

Technology	Average Total Cost	Incremental Cost to High Frequency	Weight Factor
SCR	\$2,100	\$710	38%
Ferroresonant	\$1,840	\$970	63%
High Frequency	\$2,810	NA	
Average Incremental Cost		\$872.50	