Work Paper SCE13OE001

**Revision 2**

**Southern California Edison**

**Power Management Software for Networked Computers**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | OE-65003 |
| **Measure Description** | Computers with Personal Computer Power Management Software |
| **Base Case Description** | Computers without PCPM Software |
| **Units** | Computer |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | Plug-Software: EUL 5yrs, RUL 1.7yrs |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | Com-Default>2yrs, Ind-Default>2yrs, Agric-Default>2yrs: 0.6  Com-Default-HTR-di, Ind-Default-HTR-di, Agricult-Default-HTR-di: 0.85 |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 4/10/12 | James Hand, Teddy Kisch / Energy Solutions | Draft Work Paper adapted from the SCE 2010-2012 Work Paper WPSCNROE0003.4 |
| 1 | 3/05/14 | Fiela Gutierrez/ Lincus, Inc. | * Draft Work Paper adapted from the PG&E 2013-2014 Work Paper PGECOCOM105 & SCE 2013-2014 Work Paper SCE13OE001.0, and updated codes to 2013 Title 24 Requirements * Work paper updated for the reporting period, effective 7/1/14 – 12/31/14. |
| 2 | 1/26/16 | Yun Han/SCE | * New template update for 2016 program year * WP effective from 1/1/2016 thru 12/31/2016 * Removed SCE building types * No value modifications |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
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Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper details the retrofit of existing computers and monitors without power management software with personal computer power management (PCPM) software.

The base case equipment for this measure assumes a typical desktop computer on a distributed network with a single LCD monitor, and is based on monitoring data. The base case power option settings will vary based on existing business policies and individual preferences. The energy savings are provided on a per computer basis.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Computers with Personal Computer Power Management Software |
| Existing Condition | Computers without PCPM Software |
| Code/Standard | N/A |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | OE-65003 | M03 | Power Management Software for Networked Computers |
|  |  |  |  |  |

**PG&E Requirements - Catalog Description**

**M03** *—* The customer must be a PG&E electric customer. When submitting a rebate worksheet, customers must ensure proper documentation is attached (see below).

1. For control of desktop computers only
2. Installation must allow centralized control at the server level of the power management settings (sleep mode and shutdown) of desktop computers on a distributed network
3. The software must have a reporting feature that allows monitoring and validation of energy savings
4. Qualifying software must result from:

* A new installation, where none previously existed, or
* An upgrade of an operating system or other network support software where the desktop computer power management function did not previously exist

Qualifying software must be purchased and installed on or after January 1, 2013.

Customer must agree to provide PG&E with 100% of the savings for a period of three (3) years from the receipt of the rebate

* Qualifying software must be purchased and installed on or after January 1, 2013

**Exclusions**:

* Not for control of laptop and laptop stations

**Application Process**:

* The following documentation must be attached to and included with the application:
  1. Copy of Software License Agreement,
  2. A report (print-out) directly from the Network Energy Management Software that shows (a) the location and (b) the number of desktop computers that are being controlled by the system
* When contacted, customers must allow PG&E access to customers’ property site to verify:
  1. The software installation; and

The location of the installed control software (at the server level); and the number of desktop computers controlled by the system [A].

**Terms and Conditions**: Any non-residential electric account qualifies if facility computer workstations must be linked and controlled by a LAN system that permits the installation and operation of Desktop Computer network software. Other “T&Cs” are listed above.

**Market Applicability**: All non-residential PG&E electric customers using networked desktop computer workstations.

**SCE Requirements**

This work paper assumes that a complete PCPM network software application is used on a Windows PC network. The PCPM network software meets the following minimal requirements:

* + The software accurately monitors, measures, manages, and reports on the electrical demand and energy usage of individual and groups of networked PCs as proven through independent measurement and verification efforts;
  + The software is a client-server application capable of handling a large computer network with thousands of PCs across multiple geographic locations from a single application server in a single location;
  + The software has built-in security that ensures both user privacy, network security, audit trails, and data integrity;
  + The software uses a robust SQL database system and schema with audit trails;
  + The software supports and manages the power options settings in multiple versions of the Windows operating systems, from Windows 95 up to the latest version of Windows 8;
  + The software identifies and manages the power option settings on individual and groups of computers,
  + The software supports scheduling to allow the power settings to vary as necessary during the day, night, week, etc. for individual and groups of computers;
  + The software allows for individuals and groups to create their own power option settings if necessary;
  + The software allows for computers running special tasks and applications to override Power Management as needed;
  + The software can assign and track the values of the power states for computers and monitors − On, Sleep, Stand-by, Hibernate, Off − for individual and groups of computers for use in estimating the demand, energy consumption, and annual savings, i.e., the application does not rely on a hardcoded set of values; and
  + The software has a separate reporting system application that can run on any workstation on the network that allows authorized individuals, besides the system administrator, to query and produce reports from the central data repository database.

**Eligibility Requirements:** Networked personal computers are eligible only if they do not have power management software currently installed.

## 1.2 Technical Description

A number of strategies have evolved to save energy in desktop computers. One class of products uses software implemented at the network level for desktop computers that allows system administrators to manipulate the internal power settings of the central processing unit (CPU) and of the monitor. These power settings are an integral part of a computer’s operating system (most commonly, Microsoft Windows; derived from laptop technologies) including “on”, “standby”, “sleep”, and “off” modes and can be set by users from their individual desktops.

Most individual computer users are unfamiliar with these energy saving settings, and hence, settings are normally set by an IT administrator to minimize user complaints related to bringing the computer back from standby, sleep, or off modes. However, these strategies use a large amount of energy during times when the computer is not in active use. Studies have shown that energy consumed during non-use periods is large, and is often the majority of total energy consumed.

IT-based tools are used to control desktop computer and monitor power settings within a network from a central location, allowing administrators to control power consumption. They also may have programming that enables system upgrades to be performed (typically during low-use periods) and energy use evaluation and reporting capabilities.

## 1.3 Installation Types and Delivery Mechanisms

The measure installation type for this work paper is Retrofit Add-on (REA).

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

**SCE**

The delivery methods are:

* Financial Support / Down-Stream Incentive – Deemed
* Financial Support - Direct Install
* Partnership / Down-Stream Incentive – Deemed
* Partnership - Direct Install

**PG&E**

The delivery methods are:

* Financial Support / Down-Stream Incentive – Deemed
* Partnership / Down-Stream Incentive – Deemed

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.60 |
| Ind-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.60 |
| Agric-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ag | Any | Any | 0.60 |
| Com-Default-HTR-di | All other EEM with no evaluated NTGR; direct install to hard-to-reach only. | Com | Any | Any | 0.85 |
| Ind-Default-HTR-di | All other EEM with no evaluated NTGR; direct install to hard-to-reach only. | Ind | Any | Any | 0.85 |
| Agricult-Default-HTR-di | All other EEM with no evaluated NTGR; direct install to hard-to-reach only. | Ag | Any | Any | 0.85 |

Note: Direct install measures that are not hard-to-reach will use the default NTG value.

This work paper includes measures that are offered via direct install activities into hard-to-reach (HTR) customer facilities. “Final Resolution E-4700”, dated December 18, 2014, defines specific criteria to classify customer facilities as HTR and also states that two criteria are sufficient to identify HTR customers if one of the criteria met is the geographic criteria.

SCE’s Commercial Direct Install program delivers free and low cost energy efficiency hardware retrofits through installation contractors to reduce peak demand and energy savings for small and medium commercial customers. The barriers for customer participation include limited capital resources, lack of expertise and understanding of the understanding of the benefits of energy efficiency, a suspicion of the “free offer” and its legitimacy, and language and cultural barriers. The program also addresses the ongoing concern with “split incentives”, where the customer is not the owner of the property, and therefore, lack incentive to improve their energy usage. SCE’s Commercial Direct Install program will track the following three (3) customer data points to identify direct install activities in HTR customer facilities. If geography and business size criteria are satisfied, SCE will identify the customer as HTR. If geography and language criteria are satisfied, SCE will identify the customer as HTR. Other measures in the Commercial Direct Install program will receive default NTG (NTGR\_ID: Com-Default>2), unless otherwise specified in DEER.

o **Business Size** – Customer must have less than ten employees

o **Language** – Customer’s primary language spoken is not English

o **Geography** – Businesses in areas other than the United States Office of Management and Budget (OMB) Combined Statistical Areas (CSA) of the San Francisco Bay Area, the Greater Los Angeles Area and the Greater Sacramento Area or the OBM metropolitan statistical areas or San Diego County

The “Required Corrections to Measure Level Input Parameters Identified by Commission Staff per D.14-10-046 Order Paragraph 16”, dated November 3, 2014, includes additional clarification for the geographic criteria:

“Notes on OMB CSA designations:

The OMB has designated a 12-county CSA titled the San Jose-San Francisco-Oakland, CA Combined Statistical Area which includes the nine counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma which border the San Francisco Bay plus the three counties of San Joaquin, Santa Cruz, and San Benito that are economically tied to the nine counties that that border the San Francisco Bay.”

The OMB definition of this CSA includes Los Angeles, Orange, San Bernardino, Riverside and Ventura counties.

The OMB definition of this CSA includes Sacramento, Yolo, El Dorado, Placer, Sutter, Yuba, and Nevada counties.”

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| Plug-Software | Power Management Software | Com | N/A | 5 | 1.7 |

### 1.4.2 Codes and Standards Analysis

There are neither federal nor state codes applicable to power management software for networked personal computers.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2013) | N/A | July 1, 2014 |
| Title 20 (2014) | N/A | July 1, 2014 |

## 1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

The LBNL 1096E [B], LBNL-37383 [C] and the LBNL 45917 [D] were used to investigate the EUL for this measure. LBNL 1096E was a study to investigate the “lifetime” value for computer monitors. The LBNL 45917 study was used to investigate the EUL for office and network equipment and the LBNL-37383 study was used to investigate the life cycle of the network computer and server.

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

Table below summarizes the unit energy savings values from the monitoring studies reviewed for this work paper. Please see attachment 2 for a full discussion of these studies [E]. These values form the basis for the deemed values in this work paper.

Summary of Documented Unit Energy Savings for PCPM Network Software

|  |  |  |
| --- | --- | --- |
| **Cases** | **Building Type** | **Annual Energy Savings per Workstation** |
| Quantec & EZConserve PEP | Office | 165 kWh/year |
| Puget Sound Energy | Office | 176 kWh/year |
| SCE Preliminary Evaluation | Office | 323 kWh/year |
| Portland Metro Government | Office | 34 kWh/year |
| Energy Savers Participant 3 | Office | 235 kWh/year |
| Issaquah School District | K-12 School | 211 kWh/year |
| Robert Batemen School | K-12 School | 253 kWh/year |
| Energy Savers Participant 1 | K-12 School | 133 kWh/year |
| Energy Savers Participant 2 | K-12 School | 168 kWh/year |
| CSU San Bernardino | College | 137 kWh/year |
| Cerritos College | College | 314 kWh/year |
| LBNL-1096E | All Commercial | 236 kWh/year |
| TIAX 2004 | All Commercial | 245 kWh/year Auto Off Strategy  163 kWh/year Auto Sleep Strategy |
| Intel 2007 | All Commercial | 250 kWh/year |
| NEEA 2003\*\* | All Commercial | 200 kWh/year |
| NEEA 2005 | All Commercial | 200 kWh/year |
| NEEA 2008\*\*\* | All Commercial | 180 kWh/year |

\*\* Queensborough Community College is summarized in NEEA 2003

\*\*\* Reduced NEEA 2005 value by 10% as recommended in the 2005 MPER [F]

These monitoring studies took place between 2000-2006, and were installed primarily on desktop computers with Cathode Ray Tube (CRT) monitors. While the duty cycle data from these studies is likely to be still valid, there have been notable changes in monitor and desktop energy use since 2006. These changes have been primarily driven by the transition from CRT to LCD monitors and improvements in LCD monitor efficiency. Desktop computers have seen significant improvements in Sleep Mode Power, but have had limited gains in Active Mode energy use. Assuming an even stock turnover cycle, the average age of the installed desktop and monitor base is two years. This suggests that in the currently installed base, the average computer and desktop were purchased in 2014.

To account for these improvements from 2006 to 2014, we estimated a 5% annual reduction in savings, which corresponds to a 40% decrease in energy savings over the 2006-2014 period. This 5% figure is derived from average On Mode Power values taken from Energy Star Monitor lists during the 2006-2010 period.

For Offices and K-12 Schools, the recommended deemed savings summarized in table below were derived by averaging each of the Building Type values in table above and then adjusting savings values downwards by 40%. These savings values are found in table below in column “Unit Energy Savings”. The Average Unit Energy Savings was derived by averaging the values for the building types in the table below.

Energy Savings per Networked Computer

|  |  |
| --- | --- |
| **Building Type** | **Unit Energy Savings (kWh/year)** |
| Offices | 111.96 |
| K-12 Schools | 114.75 |
| College | 135.30 |
| Misc. Commercial | 108.90 |
| Average | 117.73 |

The data did not provide a differentiation between large and small offices, nor between primary and secondary schools. A conservative deemed value to represent unknown commercial building type applications and all other building types (Misc. Commercial) is derived by averaging the NEEA 2005 cases and the TIAX 2004 Auto Sleep Strategy [G, H] from table Summary of Documented Unit Energy Savings for PCPM Network Software.

All of the EM&V studies and work papers used to determine these savings consider the possibility of peak demand reduction values to be either negligible or non-existent. As the TIAX report indicated in its analysis, most PCs in the commercial sector are in use during peak demand periods [I]. However, this point of view fails to recognize that a runtime change, which is the main effect of PCPM Network Software, changes the demand timing of the controlled networked computers.

A change in timing can lead to peak demand reductions for large measure groups. The effect only becomes evident when a large population is analyzed with before and after hourly demand load profiles. A 2010 power management study by Barr et al [J] has the most available profile data. The study covered over 90,000 desktop computers in the construction, education, financial, government, healthcare, manufacturing, retail, and transportation sectors. Based on the usages profiles found in the study, 2.3% of energy savings from power management software occur during weekdays between 2-5 PM.

For estimated demand reduction:

Peak Demand Reduction

= (2.3% X Annual Unit Energy Averaged Savings) / Operating Hour by Building Type

And the values are shown in table below. The average value of unit energy savings and peak demand reduction have been applied to all 30 building types in Attachment 1.

|  |  |  |  |
| --- | --- | --- | --- |
| Building Type | Unit Energy Savings (kWh/year) | Annual Operating Hours | Peak Demand Reduction (kW) |
| Offices | 111.96 | 2640 | 0.000975 |
| K-12 Schools | 114.75 | 2140 | 0.001233 |
| College | 135.30 | 2285\* | 0.001362 |
| Misc. Commercial | 108.90 | 3600 | 0.000696 |
| Average | 117.73 |  | 0.001067 |

\*Annual Operating Hours is the average of the DEER 2014 Education - University and Education – Community College building types.

# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Assembly | Occupancy Sensor | Misc.\_Commercial |
| Education - Primary School | Occupancy Sensor | K\_thru\_12\_School |
| Education - Secondary School | Occupancy Sensor | K\_thru\_12\_School |
| Education - Relocatable Classroom | Occupancy Sensor | K\_thru\_12\_School |
| Education - Community College | Occupancy Sensor | K\_thru\_12\_School |
| Education - University | Occupancy Sensor | K\_thru\_12\_School |
| Grocery | Occupancy Sensor | Misc.\_Commercial |
| Lodging - Guest Rooms | Occupancy Sensor | Hotel\_Motel |
| Health/Medical - Hospital | Occupancy Sensor | Misc.\_Commercial |
| Lodging - Hotel | Occupancy Sensor | Hotel\_Motel |
| Manufacturing - Bio/Tech | Occupancy Sensor | Industrial |
| Manufacturing - Light Industrial | Occupancy Sensor | Industrial |
| Lodging - Motel | Occupancy Sensor | Hotel\_Motel |
| Health/Medical - Nursing Home | Occupancy Sensor | Misc.\_Commercial |
| Office - Large | Occupancy Sensor | Large\_Office |
| Office - Small | Occupancy Sensor | Small\_Office |
| Restaurant - Fast-Food | Occupancy Sensor | Misc.\_Commercial |
| Restaurant - Sit-Down | Occupancy Sensor | Misc.\_Commercial |
| Retail - Multistory Large | Occupancy Sensor | Large\_Retail\_Store |
| Retail - Single-Story Large | Occupancy Sensor | Large\_Retail\_Store |
| Retail - Small | Occupancy Sensor | Small\_Retail\_Store |
| Storage - Conditioned | Occupancy Sensor | Misc.\_Commercial |
| Storage - Unconditioned | Occupancy Sensor | Misc.\_Commercial |
| Warehouse – Refrigerated | Occupancy Sensor | Misc.\_Commercial |

# Section 4. Costs

## 4.1 Base Case Cost

For REA measures there is no base case cost.

## 4.2 Measure Case Cost

For the PCPM Network Software measure, the “equipment” measure costs may be interpreted as the per computer licensing charge for commercial software. The equipment retail prices of vendors’ software range from $15 - $20 per workstation license [K].

Some of the EM&V studies and work papers reviewed provided either direct per computer software licensing and installation cost data, or enough information that allowed per computer costs to be estimated. The available data is summarized in table below.

Available Measure and Installation Cost Data.

|  |  |  |
| --- | --- | --- |
| Case | Equipment Costs per Workstation | Installation Costs per Workstation |
| LNBL-1096E [L] | $19.98 | $9.00 |
| TIAX 2004 [I] | $8.00 to $20.00 | $9.00 |
| NEEA 2003 [M] | $15.00 | $2.50 |
| NEEA 2005 [N] | $18.00 Average | $5.00 |

Given the wide range of costs listed in table above, this work paper selected the LBNL-1096E report values that were used for estimating the U.S. commercial market potential, rounded to the nearest whole number:

Measure Equipment Cost \approx \!\, $20.00 per computer

Installation Labor Cost = $9.00 per computer

## 4.3 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| OE-65003 | REA | $29 | $29 | N/A |

# Attachments

1.2. 

# References



[A] Quantec 2005, page VI-3

[B] LBNL-1096E, Note C2, page 10.

[C] Ernest Orlando Lawrence Berkeley National Laboratory, “Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties,” LBNL-37383, J.G. Koomey, M. Cramer, M.A. Piette, and J.H. Eto, 1995.

[D] Ernest Orlando Lawrence Berkeley National Laboratory, “Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices,” LBNL-45917, Kaoru Kawamoto, Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier, February 2001, page 15.

[E] Attachment 2 – Summary of Studies.pdf

[F] Quantec 2005, page VI-3

[G] LBNL-1096E, page 4-83

[H] Quantec 2005, page VI-1 and VI-2

[I] Roth et al., December 2004, pages 4-83

[J] Barr, M., C. Harty, and J. Nero. Thin Client Investigation including PC and Imaging State Data. Draft submitted to PG&E Emerging Technologies Program. June 2010. <http://www.etcc-ca.com/component/content/article/48-Commercial/2977-thin-client-investigation-including-pc-and-imaging-state-data>

[K] THE 451 GROUP: ECO-EFFICIENT IT. 2010 THE 451 GROUP, LLC, TIER1 RESEARCH, LLC, AND/OR ITS AFFILIATES

[L] LBNL-1096E, Note C2, page 10.

[M] Quantec 2003, page VI-1

[N] Quantec 2005, page V-13