2016 PG&E Data Center Baseline and Measurement and Verification (M&V) Guidelines

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1. Introduction

1.1. Purpose

This document specifies a standard of care for estimating savings from installation of mechanical and electrical systems in data centers, and recommends baselines for modifying or installing energy-efficient equipment in data centers. This guidance document applies to all custom program incentive applications filed with PG&E for data center projects. Historically, PG&E's custom programs have included both new construction and retrofit offerings. This document covers baseline requirements for both new construction and retrofit projects and identifies rules that trigger various nuanced baseline scenarios.

This document also specifies standardized measurement and verification (M&V) approaches and provides guidance on their application across custom incentive programs. These approaches aim to minimize variations in quality across the analyses produced by program implementers and ex-ante M&V contractors.

1.2. History of Data Center Baseline & Changes for 2016

The original version of the data center baseline was published in 2009 and adopted across PG&E programs beginning in the 2010 program year. At that time, a comprehensive mechanical system baseline for data centers and computer rooms was not provided by Title 24 energy code. Title 24 is the Building Energy Efficiency Standards for Residential and Nonresidential Buildings codified by the California Energy Commission. The document therefore specified a "standard practice" baseline established based on the best judgment of the consultant tasked with writing and editing the baseline and industry experts interviewed by the lead consultant. Several versions of the document were published; the latest version was published in March, 2013.

On July 1, 2014, a new version of the California Energy Code was adopted including computer rooms and data centers as covered processes. Because Title 24 now establishes a baseline for mechanical systems in computer rooms and data centers, a standard practice baseline for these systems is no longer applicable in the utility program context. This baseline document has therefore been rewritten to address the changes established by code.

In many ways, the code baseline is simpler than the standard practice baseline established in previous versions of this document. Furthermore, code baseline requirements are accounted for natively in energy simulation tools certified for code compliance, meaning the process of generating baseline models for new-construction savings calculation purposes has been greatly simplified. It is no longer necessary to create models with baseline mechanical systems from scratch to calculate project savings. Guidance for properly applying new compliance tools to estimate new construction project savings is provided in this document. Additionally, rules for applying the Title 24 baseline in the retrofit context are also established.

In contrast to mechanical systems, data center specific electrical systems such as UPS units, transformers and DC rectifiers have not been added to the T24 energy code. These systems still require a standard practice baseline for incentive calculation purposes. This iteration of the baseline document has been updated to adopt ENERGY STAR® requirements as the baseline for both UPS units and DC rectifiers in new construction projects. The efficiency requirements governing minimum liquid-immersed and dry type transformers have also been updated to reflect new federal Department of Energy (DOE) requirements.

2. Scope

2.1. Data Center and Computer Room Definitions

A computer room is a room whose primary function is to house electronic equipment and that has a design equipment power density exceeding 20 watts/ft^2 of conditioned floor area. Electronic, or IT, equipment includes equipment found in typical computer rooms and data centers (servers, routers, switches, etc.) and specialized equipment found in telecommunication central offices and radio base stations (RBS).

A data center is a building where computer room(s)—inclusive of HVAC and other infrastructure equipment supporting them—account for more than 50% of the total annual energy use of the building. If computer rooms account for less than 50% of the total annual energy use of a building, then the building is considered mixed use for the purposes of this document.

The baselines defined in this document shall apply to any facility wherein:

- The load density exceeds 20 W/ft^2 in computer rooms, and
- The total IT load is at least 30 kW.

2.2. Project Types in Scope

This document shall apply to new construction and retrofit projects. Baselines defined in this document shall be used for custom incentive projects and programs, but not deemed/prescriptive projects and programs. Custom projects employing emerging technologies (e.g. direct-liquid server cooling) shall be compared to the same baselines and shall require the same M&V approaches as any other custom data center project subject to the guidelines of this document.

2.2.1. New Construction

New construction projects include any project where a new structure is erected or an existing facility is expanded (an addition). Additions may use or expand upon existing primary systems, or have new dedicated systems. For instance, adding a new computer room wing to a 2-story office building would be an addition.

While additions are effectively treated as new construction projects under this baseline, unique modeling requirements may apply as discussed in Section 3.1.4.

Projects involving a gut rehab, expansion, complete model, demolition or renovation requiring architectural design assistance shall also fall under the new construction category.

2.2.2. Retrofits

Any project involving the replacement or modification of existing building systems is a retrofit. In the data center context, retrofit measures include replacement of existing air handlers, CRAC units and chillers; the addition of variable frequency drives to pumps; the upgrade of existing controls systems; and the replacement of UPS units, to name just a few.

Retrofit project subcategories utilized by PG&E include:

- **Replace on Burnout (ROB):** Projects wherein the existing equipment to be replaced is non-functional or failing.
- **Normal Replacement (NR):** Projects wherein equipment is replaced at the end of its Effective Useful Life (EUL) or evidence does not support program induced replacement.
- **Early Retirement (ER):** Projects wherein the incentive program can be demonstrated, under burden of proof, to have directly led to the retirement of the pre-existing equipment.
- **New Load/New Added Equipment (NEW):** Projects including the installation of new equipment to meet a load increase in an existing IT space.
- **Retrofit Add-On (REA):** Projects involving the addition of controls or other equipment to existing systems to increase operational efficiency.

Unique baseline and analysis considerations for each of these project types are discussed in Section 4. Refer to the CPUC Baseline guidance document for further details regarding the aforementioned project types.[1]

2.3. Sources for Program Rules and Requirements

This baseline is adopted in the Savings by Design and Customized Retrofit Programs for all projects including spaces subject to the Data Center and Computer Room Definitions in Section 2.1 above. Refer to the program websites below for specific information regarding applying for incentives under these programs.

Savings by Design:

http://www.savingsbydesign.com/

PG&E Customized Retrofit:

http://www.pge.com/cr

Additional custom program offerings may apply to this baseline as well. Contact a PG&E representative to identify all program offerings.

3. New Construction Projects

3.1. Project Aspects Covered by Title 24

With the adoption of 2013 Title 24, the following aspects of data centers and computer rooms are now covered by a code baseline: mechanical systems, lighting, and envelope. Electrical systems (UPS, transformers and rectifiers) are not covered by Title 24 but are eligible for incentives subject to exceeding the baselines specified in this document. Other data center efficiency opportunities, namely efficiency improvements to the servers themselves, are not covered by this document.

[1] http://www.doe2.com/download/CPUC/ExAnteProcess/ProjectBasis_EULRUL_Evidencev1July172014.pdf

3.1.1. Title 24 Modeling Requirements

Because the energy code now applies to data centers and computer rooms the same way it does to other commercial occupancies, all certified code compliance energy simulation tools must be capable of simulating baseline requirements for computer room occupancies and estimating savings relative to that baseline. There are currently three tools on the market certified for compliance calculations:

- IES: http://www.iesve.com/software/title24
- CBECC-COM: http://bees.archenergy.com/software.html
- EnergyPro v6: http://www.energysoft.com/

Any of these tools may be used for calculating energy savings. A current list of certified programs is available on the CEC website at:

http://www.energy.ca.gov/title24/2013standards/2013_computer_prog_list.html

New construction projects applying for incentives should, if possible, be modeled identically as they would for compliance. If the chosen compliance tool cannot accurately model the as-designed mechanical systems, then a separate simulation model may be constructed in a different program for incentive purposes with the guidance of PG&E's Program Manager. Note that taking this approach will require that the incentive applicant also construct a separate baseline model consistent with T-24 as defined in Appendix A.

Mixed use buildings should similarly be modeled as they would be for compliance, if possible, although they may be modeled in other software tools as well. The computer room portions of mixed use buildings should not be split out and used for separate incentive applications; mixed used buildings will be considered in their entirety for incentive purposes.

3.1.2. Savings Calculation with Compliance Tools

(a) IT Load Profile Energy Savings Basis

California Public Utilities Commission (CPUC) Energy Division (ED) rules mandate that utilities base incentives on savings generated using the computer room load profile observed at the time of project Measurement and Verification (M&V). To establish this load profile, new construction projects shall be subject to a (1) month post-installation trending period during which average post-installation IT load is established. Refer to Section 5.1.2 for details regarding appropriate methods and requirements for trend data collection.

Non-standard model true-up methods may be required to incorporate the M&V load data into the estimated project savings. Per Title 24 modeling rules, compliance tools estimate savings based on a built-in lifecycle IT load profile. These tools calculate savings using a computer room load profile that cycles monthly between 4 fixed loads: 100% in January, 75% in February, 50% in March, 25% in April, 100% in May, etc.

These savings effectively correspond to a lifecycle average of 62.5% of design computer room load. Unless the chosen simulation tool allows a separate performance run—which uses the compliance baseline but calculates savings with a user specified load profile—the outputs of the compliance run must be scaled to estimate savings at the M&V verified load level. Calculated compliance energy savings shall be scaled as follows for dedicated new construction data centers, but not for mixed use buildings:

$$Calibrated\ Energy\ Savings = T24\ Lifecycle\ Savings \times \frac{Average\ Verified\ IT\ Load}{.625\ \times Design\ IT\ Load}$$

(b) IT Load Profile Peak Demand Savings Basis

Peak demand savings must be calculated in a manner slightly inconsistent with the Database of Energy Efficiency Resources (DEER) peak period definition due to the nature of the life cycle load profile implemented in the compliance tools. The DEER peak month varies between July, August, and September based on the CEC CZ2010 climate zone. As such, climate zones with a July peak would yield peak savings calculated based on 75% of design load, while climate zones with August and September peaks would yield savings based on 100% of design load and 25% of design load respectively. Scaling of results (as is done for energy savings) would therefore yield significantly different results depending upon climate zone and the efficiency of the installed and baseline systems at the varying load points.

To make the approach consistent across climate zones, demand savings shall be calculated based on the average modeled demand reduction during the 2 P.M. to 5 P.M. period from June 1st through September 30th so as to include all modeled IT load levels. These data may be obtained from the hourly outputs of the baseline and proposed compliance model runs. The demand reduction calculated using this approach shall then be scaled based on the average IT load measured during the post-construction monitoring period as follows:

$$Calibrated\ Peak\ Demand\ Savings = Modeled\ Average\ Summer\ Peak\ Savings\ x\ \frac{Average\ Verified\ IT\ Load}{.625\ \times Design\ IT\ Load}$$

This approach ensures that the calculated peak demand savings are consistent with the calibrated energy savings, both in terms of the part load equipment efficiencies from the compliance calculations and the load profile gathered from post-installation monitoring.

(c) Considerations for Mixed Use Buildings

If computer rooms are located within a mixed use building, then two model runs are necessary. First, the whole building, inclusive of the computer rooms, should be modeled using a compliance run. Next, the building without the computer rooms should be modeled with a second compliance run. The difference between the energy and demand savings estimated using the two runs is effectively the computer room specific savings; only this portion of the total project savings should be scaled in accordance with the equations above.

3.1.3. Alternate Energy and Peak Demand Savings Calculation Approach

If the applicant chooses to modify their compliance model in a separate tool that allows user input of custom load schedules, or the applicant simulates the project in something other than a compliance tool, then the special considerations above for both mixed use buildings and dedicated data centers are not applicable. The average IT load observed during the (1) month post-installation trending period may be directly input in the model and utilized to estimate project savings. Peak demand savings may similarly be estimated according to the climate zone specific DEER peak period definition. No post-processing of results is necessary.

3.1.4. Special Requirements for Additions and Campus Plant Served Buildings

Additions and buildings served by campus primary systems shall primarily be modeled identically to other new construction projects. Customarily, additions may be modeled either stand-alone (i.e. without also modeling the existing building) or with the existing building in compliance calculations. When the existing building is also modeled, the existing plant, whether unchanged or expanded, must be modeled in its entirety.

If only the addition is modeled, then a scaled version of the existing plant should be modeled in the proposed case; the baseline primary system shall be allowed to default by the compliance software. Scaling should be done in proportion to the fraction of the plant's total design load that the addition accounts for. Refer to the example provided in Section 7.1 for guidance on implementing plant scaling.

New construction buildings served by campus plants shall be handled identically to addition projects for which only the addition is modeled.

Table 1: Addition and Campus Plant Served Building Primary Equipment Modeling Requirements

	Addition – Existing building & addition modeled	**Addition –** Only addition modeled	**New Bldg. Served by Campus Central Plant**
Plant not changing	Model the existing plant in its entirety.	Model a version of the existing plant scaled in proportion to the expansion's fraction of campus design load.	Model a version of the existing plant scaled in proportion to the expansion's fraction of campus design load.

Plant being expanded	Model the expanded plant in its entirety.	Model a version of the expanded plant scaled in proportion to the expansion's fraction of campus design load.	Model a version of the expanded plant scaled in proportion to the expansion's fraction of campus design load.

3.2. Electrical Equipment not Covered by Title 24

Efficient electrical systems in many cases have the potential to save as much energy as efficient mechanical systems serving computer rooms. Baselines are therefore specified below for three of the most critical electrical systems serving computer rooms:

- **Uninterruptible Power Supplies (UPS):** These systems protect critical IT equipment from out-of-tolerance utility power conditions (i.e. outage). Often they backup energy storage devices (i.e. high capacity chemical batteries, mechanical flywheels, etc.) to continuously supply energy to critical IT equipment during an out-of-tolerance utility event. To provide their critical function, UPS units must be in-line with utility power with their backup energy storage devices available. Since UPS units are less than 100% efficient, maximizing their efficiency offers a critical data center savings opportunity.
- **Rectifiers:** In the context of this document rectifiers are DC-output UPS systems. They are used to protect critical DC system loads most commonly found in telecommunication central offices and RBSs.
- **Transformers:** Stepdown distribution transformers are needed to reduce utility line voltage to levels usable within data centers. Since all data center utility power flows through transformers, increasing transformer efficiency can yield substantial energy savings.

UPS units, rectifiers, and transformers are not covered under the California Energy Code. Therefore, the baseline for these measures is unique from that applied to mechanical systems in computer rooms. The following sections define baseline requirements for each of these equipment categories.

3.2.1. UPS Units

(a) New Construction UPS Efficiency

The federal ENERGY STAR® standard, as defined in "ENERGY STAR® Program Requirements for Uninterruptible Power Supplies", forms the basis of the new construction UPS efficiency baseline[2].

[2] http://www.energystar.gov/sites/default/files/specs/private/ES_UPS_V1_Specification.pdf

ENERGY STAR® defines the efficiency threshold for ENERGY STAR® rating according to the following equation:

$$Eff_{avg} = \mathrm{t}_{25\%} * Eff_{25\%} + \mathrm{t}_{50\%} * Eff_{50\%} + \mathrm{t}_{75\%} * Eff_{75\%} + \mathrm{t}_{100\%}\mathrm{Eff}_{100\%}$$

Where,

$Eff_{xx\%}$ = UPS Efficiency at *xx*% load

$\mathrm{t}_{xx\%}$ = Proportion of time spent at *xx*% Load

This average efficiency threshold varies as a function of the UPS classification, UPS size, and communication capability. The three UPS classifications referenced in the standard are as follows:

- **Voltage and Frequency Dependent (VFD) –** These UPSs cannot respond to, or correct for, continuous under- or over-voltage input to the unit or variations in input frequency. Typical "offline/standby" UPSs fall into this category.
- **Voltage Independent (VI) –** These UPSs can respond to, and correct for, continuous under- or over-voltage input to the unit but cannot correct for variations in input frequency. Line-interactive UPS units fall into this category.
- **Voltage and Frequency Independent (VFI) –** These UPSs can respond to, and correct for, continuous under- or over-voltage input to the unit and variations in input frequency. Double conversion UPS units fall into this category.

UPSs are additionally classified based on whether they have the ability to meter output energy and communicate those measurements over a network via a standardized communication protocol. Refer to the ENERGY STAR® standard for additional details on this requirement.

The baseline Eff_{avg} for each category of UPS unit is defined as follows:

Rated Output Power (W)	VFD	VI	VFI
1,500 < P ≤ 10,000 irrespective of communication capabilities	0.970	0.967	$0.0099 * \ln(P) + 0.815$
P > 10,000 without communication capabilities	0.970	0.950	$0.0099 * \ln(P) + 0.805$
P > 10,000 with communication capabilities	0.960	0.940	$0.0099 * \ln(P) + 0.795$

The runtime fraction at each load condition used to define average efficiency varies by UPS as follows:

Rated Output Power (W)	25% Load	50% Load	75% Load	100% Load
1,500 < P ≤ 10,000	0.0	0.3	0.4	0.3
P > 10,000	0.25	0.5	0.25	0

Installed UPS units shall be compared to baseline UPSs of the same type (classification, size class, and communication category). A variable baseline recognizes that factors such as redundancy tier, uptime requirements, and variability in local power quality affect UPS selection. UPS units with an Eff_{avg} (as calculated from manufacturer's data) that does not exceed the corresponding threshold for a UPS of its type, size, and communication categorization shall not be eligible for incentives. UPS units with the ability to function in two modes depending upon power quality (most commonly units with both VFI and VI modes) shall be compared to a baseline unit of the less efficient type. UPS units smaller than 1,500 W shall not be eligible for incentives.

Though eligibility is determined based on Eff_{avg}, savings shall be assessed based on the *as-operated* performance of the installed and baseline UPS units. Baseline UPS system part load efficiency is therefore characterized by the following equation:

$$Eff(LF) = Eff_{avg}(a * LF^3 + b * LF^2 + c * LF + d)$$

Where,

$Eff(LF)$ = Efficiency at a load factor, *LF*

LF = Load Factor (% of full output capacity)

Eff_{avg} = Baseline Efficiency per the ENERGY STAR® definition

The regression coefficients in the above equation shall be defined as follows based on UPS size:

Rated Output Power (W)	a	b	c	d
1,500 < P ≤ 10,000	0.1698	-0.4203	0.3574	0.8982
P > 10,000	0.1719	-0.4256	0.3618	0.9092

Prior to applying for an incentive, customers should first determine whether the efficiency of the proposed UPS unit(s) exceed the applicable baseline Eff_{avg} value. Once the expected post-installation load profile is known, customers are additionally encouraged to estimate whether *savings will result using the baseline and proposed efficiency curves so as to confirm that the project will in fact yield savings relative to the baseline.*

(b) Quantity and Sizing

The baseline UPS system is specified as follows:

1. Using a maximum UPS size of 750 kVA, determine the quantity of UPS units required to just meet the design load with a safety factor of 1.2. Assume a power factor equal to that utilized to size the proposed UPS units. Calculate this value as follows:
2.

$$UPS_{req} = ROUNDUP\left(\frac{kW_{design} \times 1.2}{PF \times 750kVA}\right)$$

kW_{design} = Design Protected Data Center Load (kW)
PF = Design Facility Power Factor

For facilities with a protected load (including safety factor) that *does not* exceed 750 kVA, the baseline UPS shall be sized equal to the protected load rounded up to the nearest 50 kVA increment for protected loads greater than 100 tons and to the nearest 10 kVA for protected loads less than 100 tons (a 327 kVA load will utilize a 350 kVA UPS, while a 82 kVA load will utilize a 90 kVA UPS, e.g.).

3. Scale the quantity of installed UPS units based on facility redundancy requirements. For instance, in a 2N facility, the baseline UPS quantity is $2 \times UPS_{req}$.

All baseline units are identically sized and operated in parallel. All units, including redundant units, run at all times and serve an equal portion of the load.

3.2.2. Rectifiers

The federal ENERGY STAR® UPS Standard, which covers rectifiers in addition to AC-to-AC UPS units, forms the basis of the rectifier baseline in both new construction and retrofit contexts. ENERGY STAR® requires that rectifiers have an efficiency that exceeds a weighted average threshold defined as follows:

$$Eff_{avg} = \frac{Eff_{30\%_{load}} + Eff_{40\%_{load}} + Eff_{50\%_{load}} + Eff_{60\%_{load}} + Eff_{70\%_{load}} + Eff_{80\%_{load}}}{6}$$

$Eff_{30\%_{load}}$ = UPS Efficiency at 30% Load
$Eff_{40\%_{load}}$ = UPS Efficiency at 40% Load
$Eff_{50\%_{load}}$ = UPS Efficiency at 50% Load
$Eff_{60\%_{load}}$ = UPS Efficiency at 60% Load
$Eff_{70\%_{load}}$ = UPS Efficiency at 70% Load
$Eff_{80\%_{load}}$ = UPS Efficiency at 80% Load

ENERGY STAR® requires a minimum Eff_{avg} of 0.955 for all rectifiers, regardless of type or size, that lack metering and communication capabilities; rectifiers with metering and communication capabilities require an Eff_{avg} of 0.945. Rectifiers with an Eff_{avg} (as calculated from manufacturer's data) that does not exceed the applicable threshold shall not be eligible for an incentive.

Though eligibility is determined based on Eff_{avg}, savings shall be assessed based on the *as-operated* performance of the installed and baseline rectifiers. Baseline rectifier system part load efficiency is therefore characterized by the following equation:

$$Eff(LF) = Eff_{avg}(a * LF^4 + b * LF^3 + c * LF^2 + d * LF + e)$$

$Eff(LF)$ = Efficiency at a load factor, LF

LF = Load Factor (% of full output capacity)

Eff_{avg} = Baseline Efficiency per the ENERGY STAR® definition

The regression coefficients in the above equation shall be defined as follows:

	a	**b**	**c**	**d**	**e**
All Sizes	-0.5155	1.7065	-2.0770	1.0833	0.8022

3.2.3. Transformers

On April 18, 2013, DOE published a new rule mandating higher efficiencies for low and medium voltage dry and liquid-immersed transformers[3]. The rule took effect on June 17, 2013 and requires compliance nationally by January 1, 2016 for all new transformers. This revised standard shall form the baseline for efficient transformer incentives. For transformers sized between the values listed in the tables below, baseline efficiency shall be determined by linear interpolation. Transformers either smaller or larger than those specified in the tables below shall not be eligible for incentives. Low voltage power distribution units (PDUs) are not included within any of these classifications. Only transformers on the customer size of the utility meter shall be program eligible.

Tab: Liquid-Immersion Transformer Efficiency Baseline (All Voltages)

Single Phase		Three Phase	
Size (kVA)	Efficiency	Size (kVA)	Efficiency
10	98.70	15	98.65
15	98.82	30	98.83
25	98.95	45	98.92
37.5	99.05	75	99.03
50	99.11	113	99.11
75	99.19	150	99.16
100	99.25	225	99.23
167	99.33	300	99.27
250	99.39	500	99.35
333	99.43	750	99.40
500	99.49	1,000	99.43
667	99.52	1,500	99.48
833	99.55	2,000	99.51
		2,500	99.53

Table 2: Dry-Type Transformer Efficiency Baseline

[3] "2013-04-18 Energy Conservation Program: Energy Conservation Standards for Distribution Transformers, Final Rule", http://www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0048-0762

Single Phase					Three Phase				
		Medium Voltage					Medium Voltage		
Size (kVA)	Low Voltage	20-45 kV	46-95 kV	>=96 kV	Size (kVA)	Low Voltage	20-45 kV	46-95 kV	>=96 kV
15	97.70	98.10	97.86		15	97.89	97.50	97.18	
25	98.00	98.33	98.12		30	98.23	97.90	97.63	
37.5	98.20	98.49	98.30		45	98.40	98.10	97.86	
50	98.30	98.60	98.42		75	98.60	98.33	98.13	
75	98.50	98.73	98.57	98.53	113	98.74	98.52	98.36	
100	98.60	98.82	98.67	98.63	150	98.83	98.65	98.51	
167	98.70	98.96	98.83	98.80	225	98.94	98.82	98.69	98.57
250	98.80	99.07	98.95	98.91	300	99.02	98.93	98.81	98.69
333	98.90	99.14	99.03	98.99	500	99.14	99.09	98.99	98.89
500		99.22	99.12	99.09	750	99.23	99.21	99.12	99.02
667		99.27	99.18	99.15	1,000	99.28	99.28	99.20	99.11
833		99.31	99.23	99.20	1,500		99.37	99.30	99.21
					2,000		99.43	99.36	99.28
					2,500		99.47	99.41	99.33

3.3. Incremental Cost Analysis

New construction programs require that the incremental cost of the proposed system relative to the baseline system be established. The table below outlines the major components comprising the baseline systems types specified in the Title 24 Alternative Calculation Method (ACM) Reference Manual and assigns them to applicable cooling load categories. The ACM modeling rules, which are discussed in detail in Section 6.1, dictate which baseline is chosen. Of course, the baseline system component sizes, quantities, and performance metrics will be project-specific and must be accounted for.

The cost of each piece of equipment (e.g. chiller, AHU) relevant to each energy efficiency measure analyzed should be included in the calculation of incremental implementation cost. The incremental implementation cost is calculated as the difference in installed cost between proposed system equipment and baseline system equipment specific to each measure. Installed cost includes equipment cost, labor, and any additional engineering costs required because of innovative approaches taken in design. Equipment that is the same in the baseline and proposed systems should not be included in the incremental implementation cost calculation. For example, if minimally code compliant cooling towers are used in the proposed design for a new construction project, then the incremental implementation cost would not include the cost of the cooling tower. Alternatively, if the proposed cooling towers are oversized for a closer approach and less fan energy, then the incremental cost of the larger tower over the baseline tower must be included.

The source for each line item cost should be listed in the incremental implementation cost calculations. Contractor quotes and RS Means are two commonly acceptable sources for incremental cost data, although others will be accepted at the discretion of program implementers.

Table 3: Baseline System Component Matrix by Load Range

Component	Computer Room with <5 HVAC Load[4]	>= 5 and< 250 Ton HVAC Load	>=250 and <600 Ton HVAC Load	>= 600 Ton HVAC Load
DX CRACs with constant fan speed control, SAT reset, airside economizer[5]	Yes	-	-	-
DX CRACs with variable fan speed control, SAT reset, airside economizer	-	Yes	-	-
CRAH with variable fan speed control, SAT reset, airside economizer	-	-	Yes	Yes
Variable speed screw chillers	-	-	Yes	-
Variable speed centrifugal chillers	-	-	-	Yes
Axial fan, counterflow cooling towers with variable speed drive fans	-	-	Yes	Yes
Close-coupled, variable speed chilled water pumps	-	-	Yes	Yes
Close-coupled, constant speed condenser water pumps	-	-	Yes	Yes
Hot Aisle/Cold Aisle Containment	-	YES in any room where the IT load exceeds 175 kW	YES in any room where the IT load exceeds 175 kW	YES in any room where the IT load exceeds 175 kW
DDC Controls	-	Yes	Yes	Yes
UPS	-	Yes	Yes	Yes

[4] Applies to small computer rooms in facilities of any type. If a room's IT load exceeds 5 tons, then the system type dictated by the total facility IT load applies. Note that if a facility only has small IT rooms less than 5 tons in size, then their total IT load must exceed 30 kW for this baseline document to apply.

[5] The economizer requirement for rooms serving less than 5 tons is waived in buildings that do not have any economizers.

4. Retrofit Projects

Retrofit projects are distinct from new construction projects in many ways. The appropriate baselines, M&V methods, and cost analysis bases are unique. Retrofit projects can either use an existing equipment baseline for Retrofit Add-on (REA) and Early Retirement (ER) projects, or a Title 24 baseline for Replace on Burnout (ROB), Normal Replacement (NR), and New Load/New Added Equipment (NEW) projects. M&V for existing equipment baseline projects requires a means of assessing savings relative to pre-retrofit conditions. M&V for Title 24 baseline projects requires determination of savings relative to a code, as well as verification that actual savings relative to the pre-existing condition have occurred in the case of NR projects.

Cost analyses for REA and ER projects account for total project costs, while cost analyses for ROB, NR, and NEW projects account for incremental costs.

4.1. Baseline Determination: Existing Equipment or Code?

The appropriate baseline for a retrofit project can be existing conditions, code or standard practice conditions, or a combination of the two. The central concept which determines the appropriate baseline for retrofit projects is program influence. Baselines by PG&E project type are presented below. Further guidance can be found in the "Early Retirement Using Preponderance of Evidence" Guideline provided by the CPUC.

- **Early Retirement (ER):** Existing equipment forms the baseline when the utility program, under burden of proof, can be shown to have directly led to the replacement of the existing equipment.
- **Retrofit Add-On (REA):** Add-on measures, such as the installation of variable speed drives on existing pumps or the addition of a waterside economizer, shall utilize the existing condition of the facility as the baseline.
- **Normal Replacement (NR):** If the utility program cannot be shown to have led to the replacement of the existing equipment, then a code baseline applies.
- **Replace on Burnout (ROB):** Equipment that theoretically has many years of Remaining Useful Life (RUL), but has failed repeatedly or is being replaced out of necessity shall be considered to have exceeded its Effective Useful Life (EUL) and a code or standard practice baseline will apply.
- **New Load/New Added Equipment (NEW):** If a customer increases the load density of their data center or computer rooms and the existing cooling systems must be replaced because they are no longer sufficient to meet the load, then code shall form the baseline. If, however, the existing cooling systems are added to instead of replaced (e.g. additional CRACs are added to an existing computer room), then code baseline shall apply only to the new units and the remaining existing units shall be considered energy neutral (identical in both the baseline and proposed scenarios).
- **Mixed Baselines:** In instances where multiple pieces of equipment are replaced, but the program can only be shown to have induced the replacement of certain pieces of equipment, a mixed baseline applies: equipment that was replaced under direct program

influence shall use an existing equipment baseline, and other equipment shall use a code or standard practice baseline.

4.2. Unique Standard Practice Considerations for Retrofit Projects

4.2.1. UPS Units

(a) Retrofit UPS Efficiency

While ENERGY STAR® represents standard practice in the new construction market, PG&E experience indicates that ENERGY STAR® forms a prohibitively high bar in the retrofit context. As such, the baseline for UPS efficiency in normal replacement retrofit projects shall remain largely unchanged from the 2013 version of the Data Center Baseline document until completion of a future industry standard practice study. Definitions from the 2013 baseline document have been adjusted slightly for consistency with the new construction baseline above, but otherwise remain largely unchanged. Regardless of communication ability or type, the efficiency baseline shall be as follows for retrofit projects:

Rated Output Power (W)	Eff_{avg}
1,500 < P ≤ 10,000	0.898
10,000 < P ≤ 100,000	0.902
P>100,000	0.923

Part load efficiency shall be calculated used the equation and size dependent curve coefficients specified in the new construction efficiency baseline.

4.3. Effective Useful Life (EUL) Definitions for Covered Equipment

Table 4 below provides a summary of EUL values for many of the core systems used in data centers and computer rooms. The values below are taken from DEER. In some instances, equipment to be replaced may not fall within the categories listed below; in these cases, EUL shall be determined at the discretion of the program implementer and PG&E, not to exceed the CPUC maximum EUL of 20 years. EUL values are instrumental in determining the number of years of remaining useful life to be used in the “acceleration period” for the purposes of lifecycle cost savings analysis. This topic is beyond the scope of this document but discussed further in the CPUC’s “Early Retirement Using Preponderance of Evidence” Guideline.

Table 4: EUL Values for Data Center Equipment

Equipment	EUL
Chiller	20
Cooling Tower	15
Pump/Pump Motor	15
Fan/Fan Motor	15
Waterside Economizer	15
CRAH	15
CRAC (air or water cooled)	15
Airside Economizer	10
Evaporative Coolers (Indirect or Direct)	15
Variable Speed Drive	15
DDC Control System	15

4.4. Utilizing the Retrofit Baseline: Appropriate Analysis Methods

The methods required for project M&V vary with project baseline type. Regardless of M&V approach, all projects shall assess energy savings based on the loads observed during the post-retrofit monitoring period. Savings shall be calculated using a CEC CZ2010 weather file for the city nearest the site. Peak demand savings shall be estimated based on the average demand savings calculated for the DEER peak period specific to the California climate zone of the site. Since the DEER peak period definitions correspond to a 2009 weather year, savings analyses shall be conducted based on a 2009 calendar schedule (i.e. a year beginning on a Thursday).

All retrofit project analyses shall be supported by the collection of trend data. Unless otherwise noted in the subsequent project type specific sections, retrofit projects shall be subject to (4) months of pre-retrofit monitoring and (4) months of post-retrofit monitoring for weather dependent measures and (1) month of pre-retrofit monitoring and (1) month of post-retrofit monitoring for non-weather dependent measures. Details regarding required monitoring by project type are provided in Section 5.2.

A measure is weather dependent if the energy use of the incentivized equipment or any related systems is directly impacted by ambient conditions. Chiller replacements, waterside and airside economizer installations, cooling tower replacements, and CRAC retrofits are all examples of weather dependent measures. Non-weather dependent measures include all electrical Energy Efficiency Measures (EEMs) and any mechanical measures that can be shown under burden of proof from the applicant to be non-weather dependent. Examples of non-weather dependent mechanical measures include efficient (low kW/CFM) air handler installations and CRAH supply fan motor VFD retrofits.

The duration of monitoring either before or after the retrofit shall only be relaxed upon approval from the PG&E Program Manager. Reasons for deviating from the required monitoring periods must be documented in the project file.

4.4.1. Early Retirement (ER) & Retrofit Add-on (REA) Projects

In both of these scenarios the existing facility forms the baseline. Savings shall then be assessed using weather and load normalized regression models generated from pre- and post-retrofit period trend data. Detailed requirements for this M&V approach are provided in Section 5.2.1.

4.4.2. Normal Replacement (NR) Projects

Title 24 forms the baseline in this context for all covered systems. Standard practice forms the baseline for all electrical equipment measures. The difference between pre-retrofit and post-retrofit energy use will be assessed using weather and load normalized regression models generated from trend data. Savings calculated relative to the existing conditions will be used to (a) verify that actual project savings have been achieved and (b) set an upper bound on the savings claimed relative to Title 24.

The post-retrofit model will then be adjusted to represent Title 24 or standard practice baseline energy use. The annualized difference between the post-retrofit energy use and Title 24 or standard practice baseline energy use shall be the project savings used for incentive calculation purposes, subject to the limitation that claimed savings cannot exceed actual savings determined from pre-retrofit monitoring. Detailed requirements for this M&V approach are provided in Section 5.2.2.

4.4.3. Replace on Burnout (ROB) Projects

Title 24 (or standard practice for electrical measures) shall form the baseline in this scenario unless the rated efficiency of the failed equipment exceeds that stipulated by Title 24. In these instances, the failed equipment shall form the baseline.

Post-retrofit trend data shall be used to build a weather and load normalized regression model of the affected systems. The post-retrofit model will then be adjusted to represent Title 24 baseline energy use. The annualized difference between the post-retrofit energy use and Title 24 baseline energy use shall be the project savings used for incentive calculation purposes. Note that in contrast of NR projects, ROB projects *do not require pre-retrofit monitoring* since the existing equipment has failed or is near failure. Detailed requirements for this M&V approach are provided in Section 5.2.3.

4.4.4. New Load/New Added Equipment (NEW) Projects

NEW projects shall be treated similarly to new construction projects and thus require whole building energy simulation. Baseline and proposed case models shall be constructed in an energy simulation tool. For projects wherein Title 24 forms the entire baseline (i.e. all pre-existing mechanical systems will be replaced), the modeling should be done using a compliance tool if a compliance tool can accurately model the proposed systems; otherwise, a non-compliance tool may be used with the guidance of a PG&E Program Manager. In contrast to other retrofit project types, NEW projects shall only require (1) month of post-retrofit load trending to inform the baseline and proposed models. Refer to Section 5.2.4 for monitoring details.

4.4.5. Mixed Baseline Projects

M&V for mixed baseline projects, except those involving NEW measures, shall require pre- and post-retrofit monitoring for a duration of (4) months for weather dependent measures and (1) month for non-weather dependent measures as with other retrofit project types. Equipment subject to a Title 24 baseline shall require isolated monitoring during the pre-retrofit period. The energy use for these systems will be adjusted to represent Title 24 baseline efficiency levels in the pre-retrofit data set.

Weather and load normalized pre-retrofit and post-retrofit energy models will then be created to estimate project savings. Detailed requirements for this M&V approach are provided in Section 5.2.5.

For projects with any NEW measures, the analysis approach shall follow that specified in Section 4.4.4 above. For example, if a project involves adding a new chiller to handle increased load density in existing IT spaces (NEW measure) and installing a waterside economizer (REA measure), the project cannot be analyzed adequately using either a retrofit isolation approach or a whole building monitoring approach due to the change in loads. A whole building modeling approach allows construction of the appropriate baseline—the existing plant plus a Title 24 compliant chiller with a capacity equal to the newly installed chiller—as well as the proposed case—the existing plant, plus the new chiller and the waterside economizer.

4.5. Measure Cost Analysis

Retrofit projects are distinct from new construction projects in that total project cost, instead of incremental cost, applies in some contexts. REA and ER shall use a total project cost basis because replacement of the existing systems is not required. ROB, NR, and NEW projects shall use an incremental cost basis because equipment replacement or an addition is necessary. Mixed baseline projects shall use an incremental cost basis for any ROB, NR, or NEW components and a total cost basis for other components.

5. Addendum: Required Program M&V Approaches

This addendum describes in detail standardized M&V approaches—including field data collection, monitoring, and analysis—for both new construction and retrofit projects. These M&V requirements aim to standardize the M&V process to ensure a consistent level of analytical quality across programs and associated implementation teams utilizing the data center baseline. Requirements are broken up first by fundamental project type: new construction and retrofit projects. Retrofit project requirements are subdivided further by baseline type.

5.1. New Construction & Additions

5.1.1. Field Verification Requirements

New construction projects shall require one verification site visit that takes places after construction, commissioning, and building occupancy. During this site visit, the M&V contractor must confirm installation of all claimed energy efficiency measures. Nameplate data (model and serial numbers at a minimum) should be collected for all equipment related to the measures. M&V personnel should also obtain a final copy of the sequence of operations for the plant and airside systems. The Energy Management Systems (EMS) operator should also be interviewed regarding the programmed sequences to confirm that the written sequence of operation (SOO) reflects as-built operations. In addition to reviewing core sequences for the air and water side systems during this interview, the M&V contractor should additionally confirm all set points used to populate the model (e.g. minimum SAT, high limit economizer lockout temperature, CHWST set point and reset range, CWST set point, space relative humidity range, etc.).

Any discrepancies identified between the installed conditions, and those included in the model built from as-built drawings, must be addressed such that the model reflects as operated site conditions.

5.1.2. Monitoring Requirements

New construction projects shall require collection of (1) month of post-start up IT load data to support a true-up of the energy model estimated savings. These data should take the form of UPS kW output trends for the UPS units serving the computer room IT loads, but not the facility infrastructure. UPS output should be trended in 5 minute or 15 minute intervals if possible; hourly data is the minimum requirement. Trending of integrated averages is preferably to instantaneous readings whenever possible.

If the facility utilizes UPS units *without* kW output trending capabilities, then facility staff shall be required to keep a daily log of totalized kWh output for each UPS serving IT loads. These data can be read directly from the onboard display of most enterprise UPS units.

For projects claiming UPS, rectifier, and/or transformer savings, either the output or input power to these devices *must* be monitored for a full month (logs are unacceptable) in intervals no less frequent than every 15 minutes.

Trend data shall be provided by the utility customer for any (1) month period within four years of the incentive application approval date. Allowing an extended monitoring window provides the customer with an opportunity to report computer room loads at a reasonably built-out state following facility occupancy.

5.1.3. Analysis Requirements

The average IT load determined from the trend data or UPS logs shall be used to adjust the claimed energy savings according to the approach described in Section 3.1.2.

Savings from electrical measures *not* included in the simulation analysis (all EEMs discussed in Section 3.2) shall be assessed using the following generalized formula:

$$\boldsymbol{kWh_{saved} = \frac{8760}{n}\sum_{i}^{n} Load_i * \left(\frac{1}{\eta_{BL}(LF_{BL\_i})} - \frac{1}{\eta_{IS}(LF_{IS\_i})}\right)}$$

kWh_{saved}	= Annual energy savings
n	= Number of hours in the metered data set
$Load_i$	= Average output load during hour *i* of the metered data set
$\eta_{BL}(LF_{BL\_i})$	= Baseline efficiency during hour *i* at the baseline system load factor, LF_{BL_i}, for the hour.
$\eta_{IS}(LF_{IS\_i})$	= Installed efficiency during hour *i* at the installed system load factor, LF_{IS_i}, for the hour.

The part load efficiency curve for the installed equipment shall be taken from manufacturer's data whenever available. For UPS units and rectifiers, if a part load efficiency curve is not available from the manufacturer, then the normalized baseline curves provided in Section 3.2 shall be used instead. For UPS measures only wherein either the baseline or proposed units operate at less than 25% load, the efficiency at less than 25% load shall be fixed at the 25% load efficiency since most manufacturers do not provide test data for points below this load. In contrast to UPS units and rectifiers, transformers may use static efficiency values in the above analysis.

Interactive effects savings for electrical measures shall be estimated based on the nominal rated efficiency of the HVAC systems (primary and airside) serving the rooms housing the electrical equipment to simplify the analysis.

Peak demand savings for electrical measures shall be the maximum savings calculated for any hour *i* using the above energy savings equation.

5.1.4. New Construction M&V Process Flow

The diagram below schematically presents the savings analysis and measurement and verification process flow required for all new construction projects.

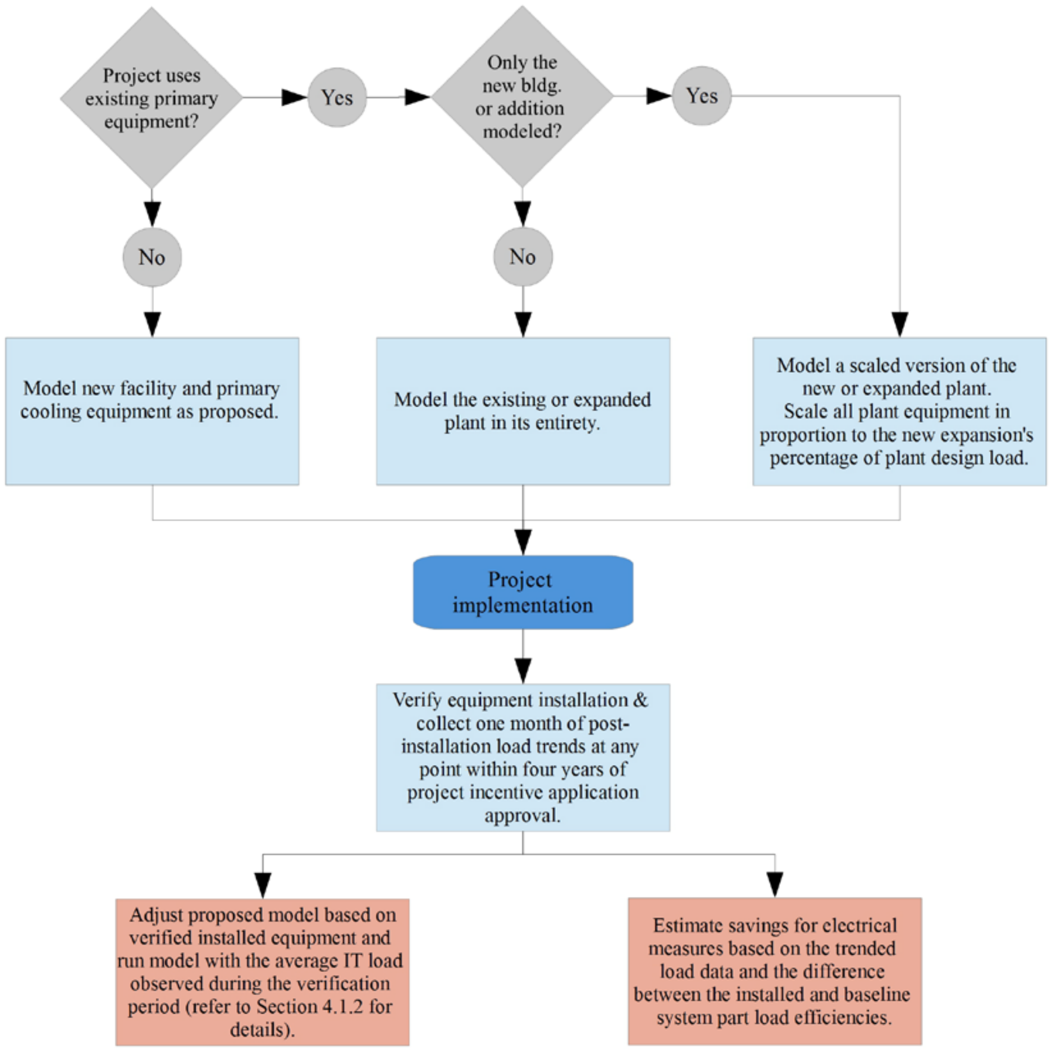

Figure 1: New Construction Savings Analysis Process Flow Chart

5.2. Retrofits

5.2.1. Early Retirement (ER) and Retrofit Add-On (REA) Projects

Two approaches are available for M&V of ER and REA projects: whole building monitoring and retrofit isolation. Whole building M&V entails measuring whole facility infrastructure energy use (total building energy use less IT loads) before and after a retrofit and using the difference to determine savings. Retrofit isolation M&V entails monitoring only the sub-systems directly related to the project and using those data to calculate savings.

Whole building monitoring based M&V is recommended any time project savings are anticipated to be greater than or equal to 10% of the existing infrastructure energy use. A retrofit isolation approach is otherwise recommended. Although recommendations are provided, either approach is acceptable as long as the results are shown to be statistically significant according to the metrics provided in the subsequent sections.

In the event that IT loads are expected to change by more than +/- 25% from the pre-monitoring period to the post-monitoring period, then only post-retrofit monitoring is required and the analysis requirements provided in this section do not apply. Instead, analysis should be conducted per Section 5.2.3(b) below, albeit with baselines determined based on the rated efficiencies of the equipment to be replaced (ER) or modified (REA). To waive the pre-retrofit monitoring requirement, the implementer must provide documentation from the customer proving that an IT load change of more than 25% following measure implementation is expected.

(a) Whole Building

(i) Monitoring Requirements

Monitoring shall include the following parameters as a minimum for a duration of at least (4) months both prior to and following project implementation. All parameters shall be sampled at a rate of at least once every 15 minutes and trended as averaged values at a frequency of at least once per hour.

- Total building load, inclusive of HVAC equipment, electrical equipment, and IT loads.
- Total IT load as registered on the downstream side of the UPS units
- Ambient dry bulb and wet bulb temperatures from sensors on site or from a nearby NOAA weather station, as applicable.

(ii) Regression Modeling Requirements

Metered data shall be utilized to estimate facility infrastructure energy use as a function of IT load and ambient weather conditions both before and after the retrofit *on an hourly basis*. Pre- and post-retrofit models shall be applied to CEC CZ2010 weather files from the nearest weather station to estimate annualized energy savings using the load profile determined during post-retrofit monitoring.

Pre- and post-retrofit regression models generated to characterize energy use shall be held to the following set of calibration targets:

- **Mean Bias Error (MBE):** Quantifies the deviation of modeled average energy use from actual energy use over the period from which the model was derived. ***Model mean bias error shall be limited to a maximum of 10%.***

$$MBE(\%) = \frac{\sum_{period}(S - M)}{\sum_{period} M} * 100$$

S = Modeled Energy Use for an hour during the monitoring period
M = Measured Energy Use for an hour during the monitoring period

- **Coefficient of Variation of Root Mean Square Error (CV-RMSE):** Quantifies the standard deviation of the differences between the measured and modeled hourly energy use, normalized to the average metered hourly energy use. For instance, a CV-RMSE of 15% indicates that the standard deviation of the differences between measured and modeled energy use is 15% of the average metered energy use. ***Model CV-RMSE shall be limited to a maximum of 30%.***

$$RMSE_{period} = \sqrt{\sum_{period} \frac{(S - M)^2}{N}}$$

$$CV(RMSE) = \frac{RMSE_{period}}{A_{period}} * 100$$

S = Modeled energy use for an hour during the monitoring period
M = Measured energy use for an hour during the monitoring period
N = Number of hours in the monitoring period
A_{period} = Average measured energy use during the monitoring period

- **Coefficient of Determination (R^2):** Measures the proportion of the total variation in energy use observed in the metered data set that is accounted for by the model. ***Model R^2 must be at least 0.7.***

$$SS_{tot} = \sum_{period} \left(M - A_{period}\right)^2$$

$$SS_{reg} = \sum_{period} (S - M)^2$$

$$R^2 = 1 - \frac{SS_{reg}}{SS_{tot}}$$

S = Modeled energy use for an hour during the monitoring period
M = Measured energy use for an hour during the monitoring period
A_{period} = Average measured energy use during the monitoring period
SS_{tot} = Total sum of squares
SS_{reg} = Regression sum of squares

The statistical requirements above shall only be relaxed upon approval from the PG&E Program Manager. Reasons for failure to meet the required statistical significance targets must be clearly documented when applying for an exception with the Program Manager. The DOE's "Measurement and Verification Protocol for Industry" document provides guidance on statistics to monitor when assessing model fit[6] for M&V purposes.

(b) Retrofit Isolation

(i) Monitoring Requirements

Equipment monitoring requirements shall vary depending on the equipment to be replaced. Monitoring durations shall be (4) months prior to and following project implementation for weather dependent measures and (1) month prior to and following project implementation for non-weather dependent measures. All trends should be collected in 5 minute intervals if possible, but no less frequently than every 15 minutes. Whenever possible, integrated average trends should be collected instead of instantaneous values; if 15-minute trends are used, they must be integrated averages.

Monitoring and/or EMS point trending requirements are provided below for a few of the equipment categories most likely to be subject to replacement measures. Monitoring shall include not only the equipment to be replaced, but also any equipment that it interacts with. Note that the example suggested monitoring for chillers and cooling towers below include the measure specific equipment and connected plant equipment.

All monitoring requirements apply to both the pre- and post-retrofit periods:

[6] http://www.energy.gov/sites/prod/files/2014/07/f17/sep_mv_protocol.pdf

(a) Chillers

- Chiller kW
- Cooling tower fan kW (as applicable for water cooled plants)
- Condenser water pump kW (as applicable for water cooled plants)
- Chilled water pump kW
- Water treatment kW (e.g. sidestream filtration pump)
- Ambient wet bulb temperature
- Ambient dry bulb temperature
- Chiller load via a BTU meter or calculated from:
    - Chilled water flow
    - Chilled water supply temperature
    - Chilled water return temperature

(b) CRAC units

- CRAC kW (all CRACs in any space for which savings are claimed)
- IT Load for spaces served by CRACs (prorated as necessary from UPS load in proportion to floor area, served rack quantity, or some other metric)
- Ambient dry bulb temperature

(c) Cooling Towers

- Identical to chiller replacement

(d) UPS Units

- Input Power (kW)
- Output Power (kW)

(ii) Analysis Requirements

Regression analysis shall be used to estimate project savings. Regression models shall be created to predict both pre- and post-retrofit equipment energy use as a function of load (e.g. cooling tons for chillers, kW output for UPS units, etc.) and ambient conditions (as applicable to weather dependent measures) on *an hourly basis*.

For plant measures, analyzing the replaced equipment alone is insufficient because of equipment interactions. For example, installing a more efficient cooling tower allows a customer to operate at a reduced approach, lowering condenser water supply temperatures and affecting chiller efficiency as a result. For this reason, plant related measures shall require whole plant models, including chillers, tower fans, CHWPs, and CWPs.

Pre- and post-retrofit models for weather dependent EEMs shall be applied to CEC CZ2010 weather files from the nearest weather station to estimate annualized energy savings at post-retrofit load levels.

Regression models generated to characterize pre- and post-retrofit energy use shall be held to the same set of validation targets as whole building models (see Section 5.2.1(a)(ii) for details):

- **Mean Bias Error (MBE):** 10% or less.
- **Coefficient of Variation of Root Mean Square Error (CV-RMSE):** 30% or less.
- **Coefficient of Determination (R^2):** 0.7 or better.

The statistical requirements above shall be relaxed only upon approval from the PG&E Program Manager.

For non-weather dependent EEMs (i.e. all electrical measures—UPS, rectifiers, and transformers), savings shall be determined based on the difference between the pre-retrofit and post-retrofit system efficiencies at the post-retrofit load levels. For UPS units and rectifiers, it may be possible to characterize efficiency based on actual input and output power trends (if available). For UPS units and rectifiers without *both* input and output trending capabilities, manufacturer's rating data will be used to determine part load efficiency whenever available. If part load efficiency curves of the existing and/or post-retrofit units are not available from the manufacturer, then the part load curves defined in Section 3.2 shall be used in their place. For UPS measures only wherein either the baseline or proposed units operate at less than 25% load, the efficiency at less than 25% load shall be fixed at the 25% load efficiency since most manufacturers do not provide test data for points below this load. Full load efficiency values may be used in transformer savings analyses unless part load efficiency curves for both the baseline and proposed transformers are available.

Interactive effects savings for electrical measures shall be estimated based on the nominal rated efficiency of the HVAC systems (primary and airside) serving the equipment to simplify the analysis.

(c) Early Retirement and Retrofit Add-On M&V Process Flow

The figure below schematically presents the M&V process for early retirement and retrofit add-on projects.

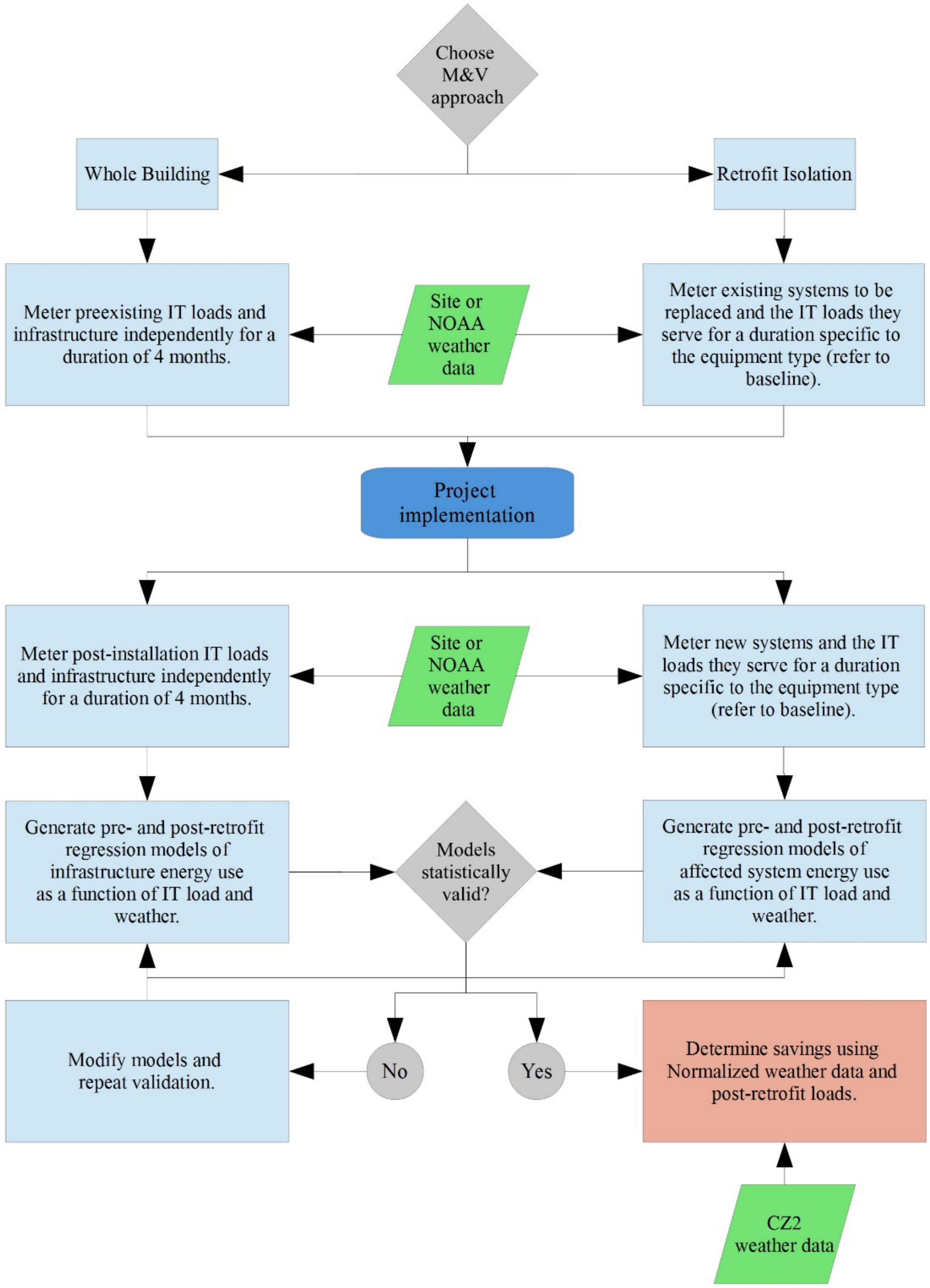

Figure 2: Early Retirement and Add-on Measure Retrofit M&V Process Flowchart

5.2.2. Normal Replacement (NR) Projects

Title 24 (or standard practice for electrical measures) shall form the baseline in this scenario unless the rated efficiency of the replaced equipment exceeds that stipulated by Title 24. In these instances, the existing equipment shall form the baseline. For Title 24 baseline projects, pre-monitoring shall still be required for all measures except electrical EEMs (UPSs, rectifiers, transformers) to verify that actual savings have been realized. Real savings must be shown using the retrofit isolation approach specified in Section 5.2.1(b). Annualized energy savings calculated relative to the pre-retrofit period shall form an upper-bound on the energy savings claimed for incentive purposes. Put another way, savings calculated relative to a Title 24 baseline using the methodology subsequently discussed for NR projects shall be capped at 100% of the pre- to post-retrofit annualized energy savings.

The PG&E Program Manager may waive the pre-monitoring requirements for NR projects if suitable evidence is provided indicating that the existing systems definitively operate at a lower efficiency than stipulated by Title 24. Suitable evidence may include service records indicating equipment defects; proof that a piece of equipment has been operating in “hand” or bypass due to failing VFD controls; or pre-existing data from a previous study indicating system performance. Manufacturer’s data showing that the equipment is rated less efficiently than Title 24 is alone insufficient.

NR projects subject to a Title 24 baseline shall use a retrofit isolation approach to estimate savings as described in Section 5.2.2(a). In NR projects where the existing equipment forms the baseline, the project may use either a retrofit isolation or whole building approach consistent with the methodologies discussed in Section 5.2.1.

(a) Projects Subject to Title 24 Baselines

(i) Monitoring Requirements

The requirements of Section 5.2.1(b)(i) shall be followed for both the pre- and post-retrofit periods for all EEMs except electrical EEMs. Electrical EEMs shall only require post-retrofit monitoring.

(ii) Analysis Requirements

In order to verify that actual savings have been realized, an analysis comparing the pre- and post-retrofit periods shall be conducted in accordance with the guidelines provided in 5.2.1(b)(ii).

For measures subject to a Title 24 baseline, an additional analysis will be conducted using the post-retrofit model constructed in the preceding analysis. The post-retrofit annual energy use, as determined by applying the post-retrofit regression model to a CEC CZ2010 file, will be scaled based on the differing efficiencies of the installed and Title 24 baseline equipment to estimate baseline energy use as follows:

$$Annual\ kWh_{T-24} = Annual\ kWh_{post} * \frac{\eta_{post}}{\eta_{T-24}}$$

$Annual\ kWh_{T-24}$	= Title 24 Baseline Annual Energy Use
$Annual\ kWh_{post}$	= Modeled Post-Retrofit Annual Energy Use
η_{T-24}	= Title 24 Baseline System Efficiency
η_{post}	= Post-Retrofit System Efficiency

Note that depending on the efficiency metric used (e.g. IEER or IPLV), the terms in the efficiency ratio will flip. The efficiency metric used in the above equation shall be a load-weighted average metric such as IEER or IPLV whenever possible. When load-weighted average efficiencies are not available, the efficiencies used in the above equation will be *rated values* determined from manufacturer's data for the post-retrofit period and Title-24 stipulated values for the baseline. Rated values are required for *both* the baseline and installed equipment in order to provide a normalized basis for scaling post-retrofit energy use. By contrast, using efficiency values determined based on metered data to determine efficiency for the installed case, while using rated values for the base case, would not provide a normalized basis for adjusting the post-retrofit metered data.

Static efficiency metrics—as opposed to dynamic terms that vary each hour based on load and additional efficiency drivers specific to the equipment—are required to simplify the analysis procedure for engineers and minimize analytical errors. Table 5 below provides a summary of integrated efficiency metrics for the most common direct-replacement measure equipment in data center and computer room applications. Refer to Title 24 for test procedures for the efficiency metrics.

Table 5: Integrated (Load Averaged) Equipment Efficiency Metrics

Equipment	Efficiency Metric
Chiller	Integrated Part Load Value (IPLV)
	Non-Standard Part Load Value (NPLV)
Unitary DX AC (Water or Air Cooled)	Integrated Energy Efficiency Ratio (IEER)

Annual energy savings are simply the difference between the installed and Title 24 baseline annual energy use values.

For all electrical measures not covered by code (see Section 3.2), savings shall be estimated using the methodology provided in Section 5.1.3 for new construction projects. The only distinction is that the baseline efficiencies used in UPS measure analyses shall not be based on ENERGY STAR®, but rather as defined in Section 4.2.1(a).

(b) Projects Subject to Existing Equipment Baselines

NR projects subject to an existing equipment baseline shall follow monitoring and analysis requirements consistent with Section 5.2.1.

(c) Normal Replacement Project M&V Process Flow

The figure below schematically presents the M&V process for NR projects subject to a Title 24 baseline.

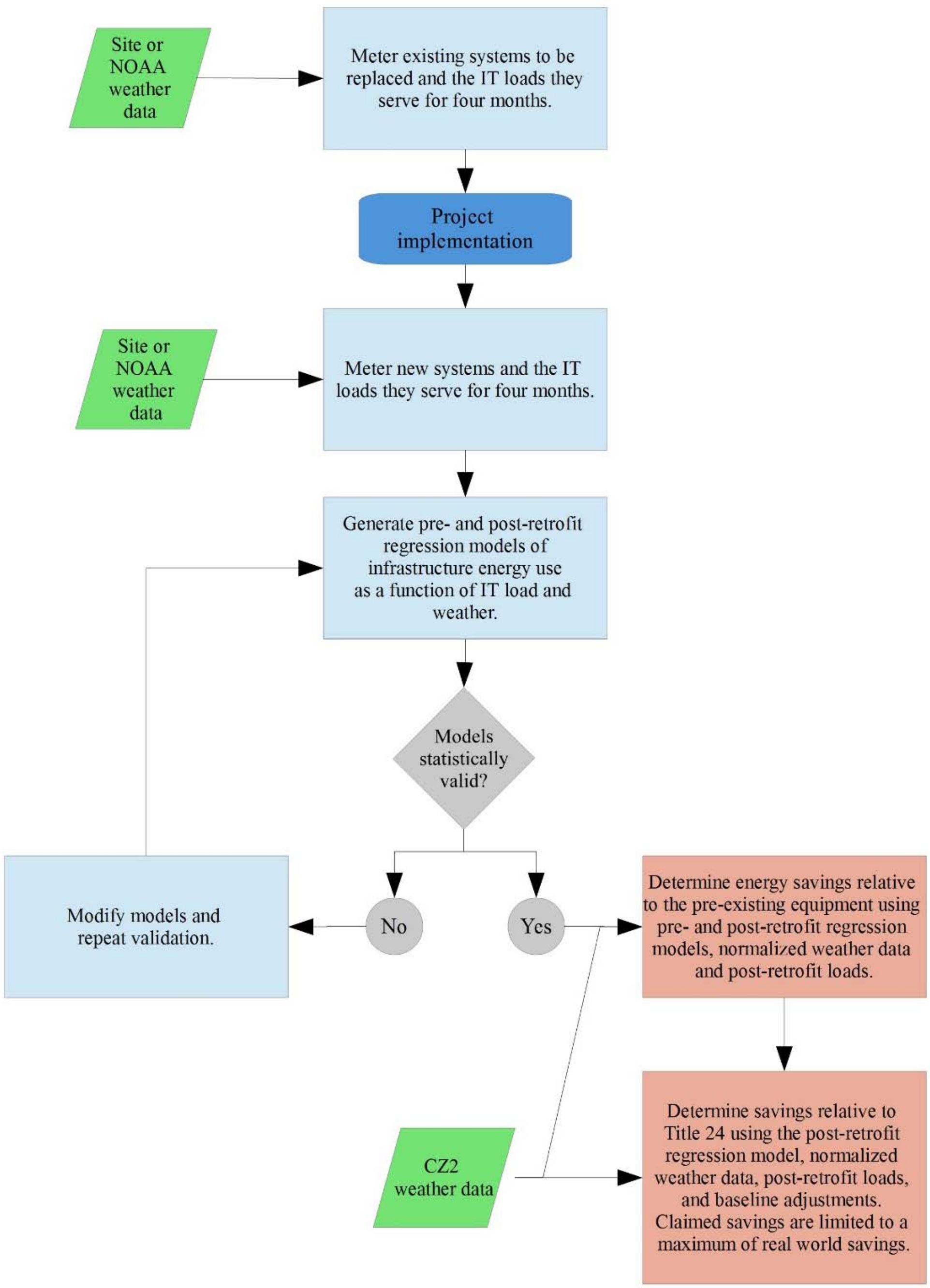

Figure 3**: Normal Replacement M&V Process Flow Chart**

5.2.3. Replace on Burnout (ROB) Projects

Title 24 (or standard practice for electrical measures) shall form the baseline in this scenario unless the rated efficiency of the failed equipment exceeds that stipulated by Title 24. In these instances, the failed equipment shall form the baseline. ROB projects are not subject to pre-monitoring requirements. ROB projects shall use a retrofit isolation approach to estimate savings as described in Sections 5.2.3(a) and 5.2.3(b) below.

(a) Monitoring Requirements

Equipment monitoring requirements shall vary depending on the equipment to be replaced. Monitoring durations shall be (4) months following project implementation for weather dependent measures and (1) month following project implementation for non-weather dependent measures. All trends should be collected in 5 minute intervals if possible, but no less frequently than every 15 minutes. Whenever possible, integrated average trends should be collected instead of instantaneous values; if 15 minutes trends are used, they must be integrated averages.

(b) Analysis Requirements

Post-retrofit equipment regression modeling requirements will be identical to those stipulated in Section 5.2.1(b)(ii); the analysis procedure shall otherwise be unique.

To estimate Title 24 baseline energy use, the post-retrofit annual energy use, as determined by applying the post-retrofit regression model to a CEC CZ2010 file, will be scaled based on the differing efficiencies of the installed and Title 24 baseline equipment to estimate baseline energy use as follows:

$$Annual\ kWh_{T-24} = Annual\ kWh_{post} * \frac{\eta_{post}}{\eta_{T-24}}$$

Where,

$Annual\ kWh_{T-24}$	= Title 24 Baseline Annual Energy Use
$Annual\ kWh_{post}$	= Modeled Post-Retrofit Annual Energy Use
η_{T-24}	= Title 24 Baseline System Efficiency
η_{post}	= Post-Retrofit System Efficiency

Note that depending on the efficiency metric used (e.g. IEER or IPLV), the terms in the efficiency ratio will flip. The efficiency metric used in the above equation shall be a load-weighted average metric such as IEER, IPLV, or ENERGY STAR® Eff_{avg} (for UPS units and rectifiers) whenever possible. When load-weighted average efficiencies are not available, the efficiencies used in the above equation will be *rated values* determined from manufacturer's data for the post-retrofit period and Title-24 stipulated values for the baseline. Rated values are required for *both* the baseline and installed equipment in order to provide a normalized basis for scaling post-retrofit energy use. By contrast, using efficiency values determined based on metered data to determine efficiency for the installed case, while using rated values for the base case, would not provide a normalized basis for adjusting the post-retrofit metered data.

Static efficiency metrics—as opposed to dynamic terms that vary each hour based on load and additional efficiency drivers specific to the equipment—are required to simplify the analysis procedure for engineers and minimize analytical errors. Table 5 in Section 5.2.2(a)(ii) provides a summary of integrated efficiency metrics for the most common direct-replacement measure equipment in data center and computer room applications. Refer to Title 24 for test procedures for the efficiency metrics.

Annual energy savings are simply the difference between the installed and Title 24 baseline annual energy use values.

For all electrical measures not covered by code (see Section 3.2), savings shall be estimated using the methodology provided in Section 5.1.3 for new construction projects. The only distinction is that the baseline efficiencies used in UPS measure analyses shall not be based on ENERGY STAR®, but rather as defined in Section 0.

(c) Replace on Burnout Project M&V Process Flow

The figure below schematically presents the M&V process for ROB projects.

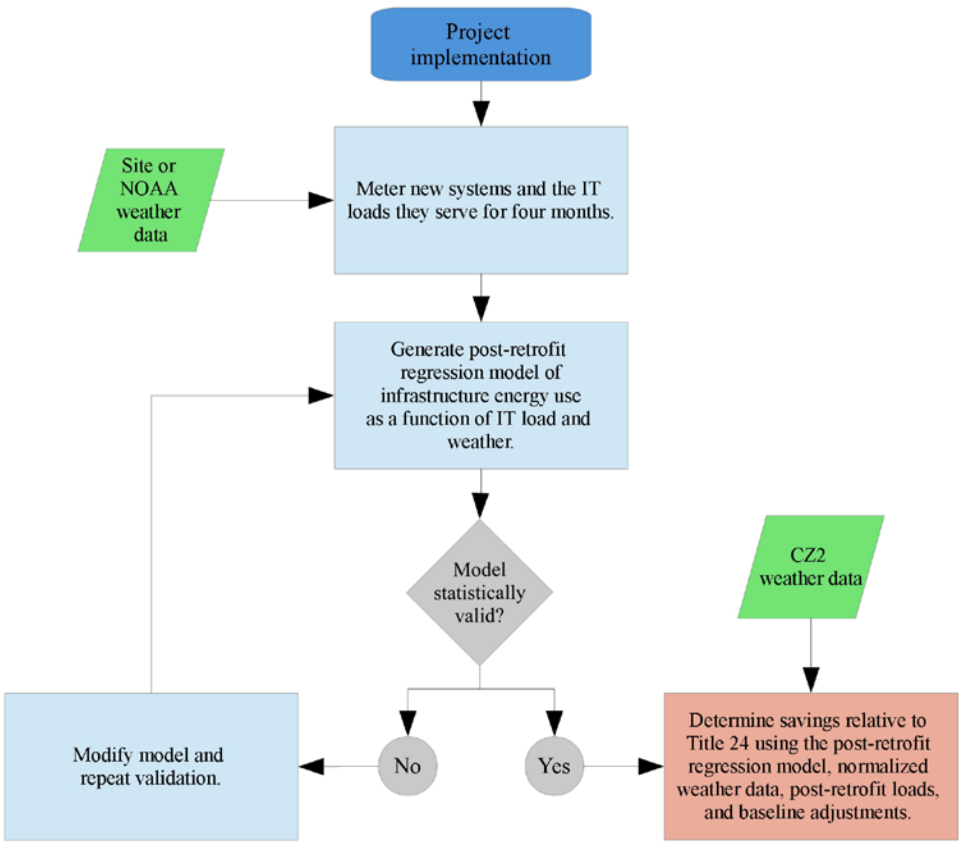

Figure 4: Replace on Burnout M&V Process Flow Chart

5.2.4. New Load/New Added Equipment (NEW) Projects

M&V requirements for NEW projects mirror the requirements for new construction projects. The only distinction in analysis approach is that NEW projects may require a custom baseline model if some or all of the existing mechanical systems are retained as part of a project. As an example, if a customer were to install 4 additional efficient CRACs in a data room with 8 existing CRACs, the baseline for the project would include the eight existing CRACs operating at their rated efficiency and 4 added CRACs operating at Title 24 baseline efficiency. This baseline would have to be modeled in a custom fashion using either compliance or non-compliance software.

Aside from this unique baseline consideration, M&V would be conducted as described in Section 5.1.

5.2.5. Mixed Baseline: Projects with Existing Equipment and Title 24 Baseline Components

A unique situation arises when a project has either ER or REA measures; and NR, ROB, or NEW measures. For instance, a data center owner may simultaneously replace chillers that have exceeded their EUL (NR measure) and install a waterside economizer (REA measure). The chiller replacement would require a T-24 baseline (assuming T-24 efficiency exceeds the existing chiller's rated efficiency), while the waterside economizer would require an existing equipment baseline. This scenario shall be addressed using the hybrid monitoring and analysis approach discussed below. If, however, a project has NEW measures and measures of any other type, then the NEW M&V approach from Section 5.2.4 shall apply since it is flexible enough to allow definition of any baseline conditions.

(a) Monitoring Requirements

During the pre-retrofit period, the project shall be monitored using either a whole building or retrofit isolation approach consistent with either Section 5.2.1(a)(i) or Section 5.2.1(b)(i) above. If a whole building approach is utilized, then any equipment subject to a Title 24 baseline must also be metered during the pre-retrofit period (presumably this equipment would already be metered using a retrofit isolation approach).

During the post-retrofit period, the monitoring requirements shall be identical to those stipulated in Sections 5.2.1(a)(i) and 5.2.1(b)(i) for whole building and retrofit isolation approaches respectively, albeit the whole building approach *will not* additionally require monitoring of the new equipment subject to the Title 24 baseline. Note that this is in contrast to the pre-retrofit period when monitoring of the equipment subject to a Title 24 baseline is required under the whole building approach.

(b) Analysis Requirements

The hourly metered data for the end-of-life equipment subject to a Title 24 baseline shall be adjusted to represent Title-24 equipment as follows:

$$kWh_{T24_i} = kWh_{pre_i} * \frac{\eta_{T24}}{\eta_{pre}}$$

Where,

kWh_{T24_i}	= Title 24 baseline equipment energy use for metered hour *i*
kWh_{pre_i}	= Monitored end-of-life equipment energy use for metered hour *i*
η_{T24}	= Title 24 Baseline System Efficiency
η_{pre}	= End-of-Life System Rated Efficiency

Note that depending on the efficiency metric used (e.g. IEER or IPLV), the terms in the efficiency ratio will flip. The efficiency metric used in the above equation shall be a load-weighted average metric such as IEER, IPLV, or NPLV whenever possible. When the load-weighted average efficiencies are not available, the efficiencies used in the above equation will be *rated values* determined from manufacturer's data for the pre-retrofit period, and Title 24 stipulated values for the baseline. See Section 5.2.2(a)(ii) for a discussion of the rationale for using static theoretical values in the analysis.

The scaled energy use for this pre-retrofit equipment will directly replace the metered energy use in retrofit isolation analyses. In a whole building analyses, the difference between the hourly Title 24 energy use and the metered energy use ($kWh_{pre_i} - kWh_{T24_i}$) will be deducted from the metered pre-retrofit infrastructure energy use.

After adjusting the baseline energy use, the remainder of the analysis shall be conducted as stipulated in Sections 5.2.1(a)(ii) and 5.2.1(b)(ii) for Whole Building and Retrofit Isolation analyses respectively.

(c) Mixed Baseline Retrofit Project M&V Process Flow

The figure below schematically presents the M&V process for projects having both end-of-life and early retirement or add-on measure components.

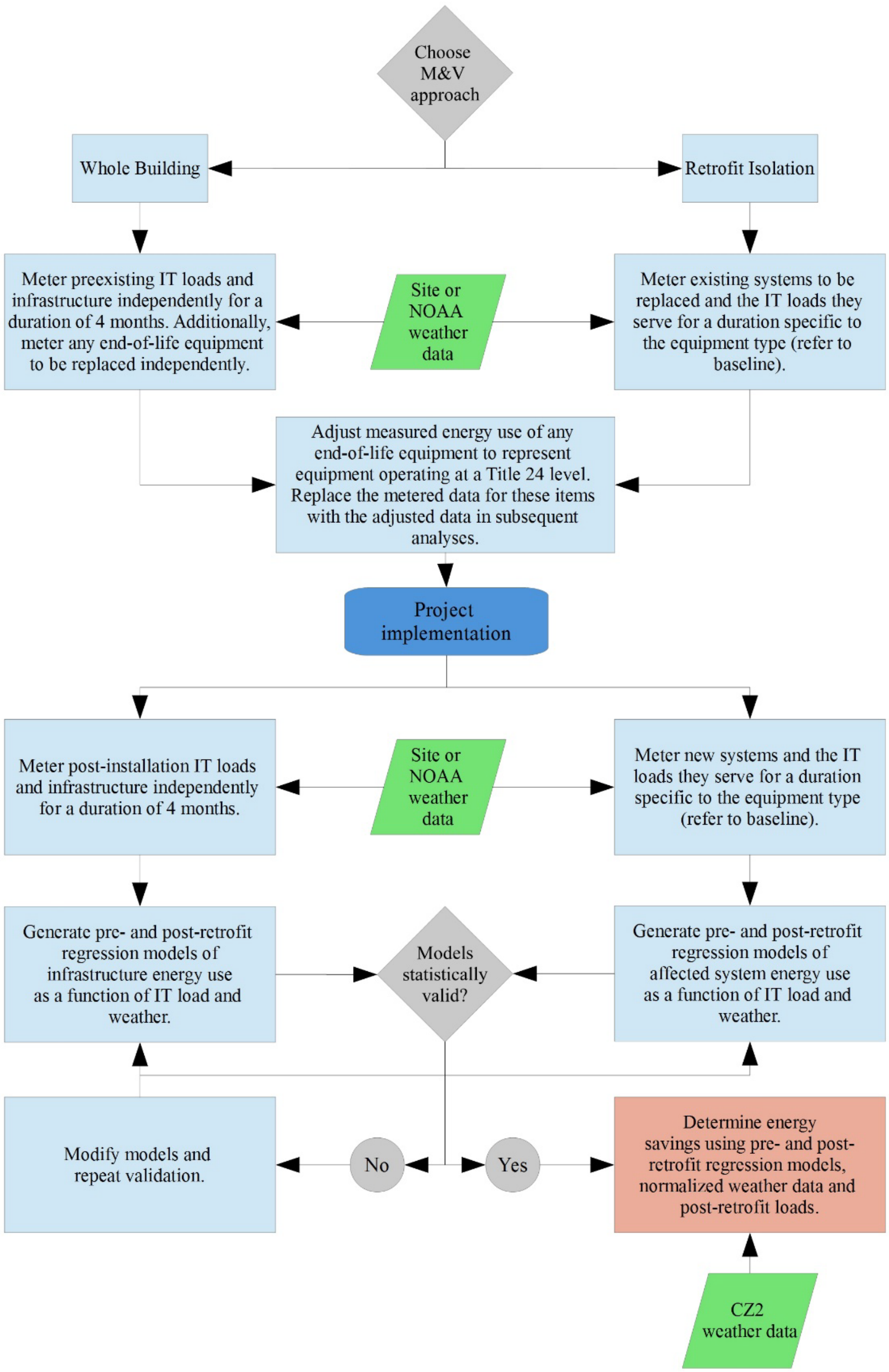

Figure 5: Mixed Baseline Retrofit M&V Process Flowchart

6. Appendix: Title 24 Baseline Modeling Specification

The Title 24 baseline must be applied manually in the context of retrofit projects with end-of-life and mixed baselines. All data center and computer room applicable ACM baseline requirements for mechanical systems are provided below. These requirements should be used to define the baseline for all retrofit projects requiring a Title 24 baseline. Note that this baseline is automatically applied in compliance tools for new construction projects and requires no additional work on the part of the incentive applicant.

6.1. Load Categories & Corresponding Baseline System Types

Title 24 specifies two baseline systems types: chilled water CRAH units and DX CRAC units. For any building with a total computer room cooling load of less than 3,000,000 Btu/h (250 tons), DX CRAC systems form the baseline for the computer rooms. Otherwise, chilled water CRAHs form the baseline.

Modeling requirements for both system types are specified in the subsequent sections.

6.2. Computer Room Airside Design Requirements

New construction baseline airside systems shall be sized for a 20^{o} F delta-T between the supply and return air at design load conditions; retrofit baseline airside systems shall be sized for the facility's actual airside delta-T. All baseline airside systems shall be specified with a minimum supply air temperature of 60^{o}F. All baseline computer room systems shall be designed to maintain an 80^{o}F room temperature (hot aisle temperature for facilities with containment). Baseline computer rooms shall *not* have humidity control.

New construction projects shall be simulated with a room temperature of 80°F as required per California Title 24 ACM modeling rules. For retrofit projects wherein the design room temperature exceeds 80^{o}F, both the baseline and proposed systems shall be modeled to operate at the design room temperature. For retrofit projects wherein the design room temperature is less than or equal to 80°F, both the baseline and proposed systems shall be modeled to operate at an 80°F room temperature. This approach disallows inflated savings claimed for operating at unnecessarily cold room temperatures as well as savings claimed for operating at higher room or cold aisle temperatures than baseline.

6.3. Secondary (Airside) System Definition

6.3.1. Coil Sizing

CRAH and CRAC coils shall be sized to provide 120% of design load at the 0.5% design dry-bulb temperature and its corresponding mean coincident wet-bulb temperature.

6.3.2. Fan Sizing and Efficiency

(a) Supply Airflow Sizing

Airflow shall be sized to meet 120% of the design cooling load with a 20^{o}F delta-T between the supply and return air.

(b) Supply Fan Efficiency Metric (CFM/kW)

(i) CRAC Systems

Baseline CRAC systems shall be specified with a supply fan efficiency of 0.49 W/CFM when the baseline includes an airside economizer. When the baseline does not include an airside economizer, an efficiency of 0.39 W/CFM shall be required.

(ii) CRAH Systems

Baseline CRAH systems shall be specified with a supply fan efficiency of 0.39 W/CFM under all circumstances.

(c) Supply Fan and Motor Placement

Baseline fan systems shall utilize draw through fans with supply fan motors located in the air stream.

(d) Supply Fan Power vs. Flow Performance Curve

Baseline variable flow supply fans shall utilize a fan power versus flow curve defined as follows:

$$PLR = a + b * FanRatio + c * FanRatio^2 + d * FanRatio\hat{}3$$

Where,

PLR	= Ratio of fan power at part load conditions to full load fan power
$FanRatio$	= Ratio of cfm at part-load to full-load CFM
a	= 0.027827882
b	= 0.026583195
c	= -0.0870687
d	= 1.03091975

PLR shall be limited to a minimum of 10%.

(e) Relief Fan Specification

Relief fans shall be modeled for all systems utilizing an outdoor air economizer. Baseline relief airflow shall be sized equal to the supply airflow less 0.05 cfm per ft^2 of space served by the system for pressurization. Relief fan design total static pressure shall be 0.75” for relief fans with a design airflow less than 10,000 CFM, and 1.00” for fans with a design airflow greater than or equal to 10,000 CFM. Relief fan efficiency shall be 40% for relief fans with a design airflow less than 10,000 CFM, and 50% for relief fans with a design airflow greater than or equal to 10,000 CFM.

Relief fan motor efficiency shall be specified based on the motor efficiency corresponding to the smallest standard motor size that exceeds the fan’s design break horsepower. See Section 6.5 for the baseline motor efficiency table. Fan break horsepower shall be calculated from the design airflow, static pressure, and fan efficiency specified above as follows:

$$BHP = \frac{CFM * SP}{6356 * eff_{fan}}$$

BHP = Fan break horsepower
CFM = Design relief fan airflow
SP = Design total static pressure
eff_{fan} = Fan efficiency

6.3.3. Airside Controls

(a) Fan Speed Control Methods

(i) CRAC Systems

CRAC units cooling a room with less than 5 tons of design load shall utilize a constant speed supply fan. CRAC units cooling a space with 5 or more tons of design load shall utilize a variable flow supply fan. The part load performance of the variable flow fan shall be defined by the curve in Section 6.3.2(d).

(ii) CRAH Systems

Baseline CRAH systems shall use a variable flow supply fan. The part load performance of the variable flow fan shall be defined by the curve in Section 6.3.2(d).

(b) SAT and Airflow Reset Sequencing

(i) CRAC Systems

Constant volume CRAC units shall modulate supply air temperature between a minimum of 60 F and 80 F to meet the zone load.

VAV CRAC units shall reset airflow linearly from 100% of design airflow at 100% cooling load to a minimum of 50% of design airflow at 50% cooling load. SAT shall be reset from a minimum of 60 F at 50% of design cooling load to 80 F at 0% cooling load. This reset strategy is effectively an “airflow first” sequence.

(ii) CRAH Systems

CRAH units shall reset airflow linearly from 100% of design airflow at 100% cooling load to a minimum of 50% of design airflow at 50% cooling load. SAT shall be reset from a minimum of 60 F at 50% of design cooling load to 80 F at 0% cooling load.

(c) Economizer Control

All baseline CRAHs shall have differential dry-bulb integrated economizers. Baseline CRACs shall utilize differential dry bulb economizers unless they are <= 54,000 Btu/h in size.

(d) Relief Fan Control

Relief fans shall be assumed to operate anytime the outdoor airflow exceeds the airflow required for normal building pressurization as determined based on the proposed design. Relief airflow shall be equal to outdoor airflow less the pressurization airflow. Relief fan power shall vary with flow according to the part load curve specified in Section 6.3.2(d).

6.4. Primary System Definition

6.4.1. DX Systems

(a) Sizing

CRAC units shall be sized such that one unit serves each individual room. Individual CRACs shall be sized per the coil and airflow requirements provided in Sections 6.3.1 and 6.3.2 respectively.

(b) Efficiency

For rooms with greater than or equal to 20 tons of load, CRAC efficiency shall be 9.8 EER at AHRI 340/360 test conditions. For rooms with less than 20 tons of load, CRAC efficiency shall correspond to the Title 24 efficiency for air-cooled packaged HVAC units sized equal to 50% of the room load. Refer to Title 24 Table 100.2-A for these efficiency requirements.

6.4.2. Chilled Water Systems

(a) Chillers

(i) Type & Quantity

The baseline plant shall be sized to satisfy 115% of design plant cooling load. Chiller quantity and type shall be assigned based on the table below:

Sizing Load	Number and Type of Chiller(s)
<= 300 tons	1 water-cooled screw chiller
>300 tons, < 600 tons	2 water-cooled screw chillers, sized equally
>= 600 tons	A minimum of two (2) water-cooled centrifugal chillers, sized to keep the unit size below 800 tons

(ii) Efficiency

Baseline chiller efficiency shall be determined based on the Title 24 Table 110.2-D excerpt below:

Chiller Type	Size Classification	Efficiency Requirements
Water Cooled, Electrically Operated Positive Displacement (Screw/Scroll)	<75 tons	≤ 0.800 kW/ton ≤ 0.600 IPLV
	≥ 75 tons and < 150 tons	≤ 0.790 kW/ton ≤ 0.586 IPLV
	≥ 150 tons and < 300 tons	≤ 0.718 kW/ton ≤ 0.540 IPLV
	≥ 300 Tons	≤ 0.639 kW/ton ≤ 0.490 IPLV
Water Cooled, Centrifugal	< 150 Tons	≤ 0.639 kW/ton ≤ 0.450 IPLV

	≥ 150 tons and < 300 tons	≤ 0.639 kW/ton ≤ 0.450 IPLV
	≥ 300 tons and < 600 tons	≤ 0.600 kW/ton ≤ 0.400 IPLV
	≥ 600 Tons	≤ 0.590 kW/ton ≤ 0.400 IPLV

Baseline screw/scroll chillers shall allow capacity modulation down to 15% of design; baseline centrifugal chillers shall allow capacity modulation down to 10% of design.

Baseline chiller capacity and efficiency shall vary with load, entering condenser water temperature, and leaving chilled water temperature according to the DOE2.2 chiller formulations specified in the ACM manual. The applicable curves are the "Chiller Cooling Capacity Adjustment Curve", the "Electric Chiller Cooling Efficiency Adjustment Curves". Curve coefficients are specified in ACM Appendix 5.7. *This information is provided for reference only. The M&V methodology specified in Section 5.2 allows static efficiency metrics to be used in retrofit analyses. New construction analyses will apply these curves by default when evaluating compliance and estimating savings relative to baseline conditions.*

(b) Cooling Towers

Baseline cooling towers shall be open towers equipped with variable speed axial fans. One single cell, single fan tower shall pair with each baseline chiller. Each baseline tower shall be sized to meet the design heat rejection load of a baseline chiller at the design wet bulb temperature, subject to the following constraints:

- **Entering Condenser (Leaving Tower) Water Temperature:** 85 ^{o}F or 10 degrees more than the design wet bulb temperature, whichever is less.
- **Tower Range:** 10 F

Each tower fan shall be sized at 1 HP per 60 gallons of tower flow. For example, if the tower serves a 600 ton load at design conditions, the baseline tower flow shall be:

$$\frac{600\ tons * 12000 \frac{Btu}{ton - h}}{500\ \frac{Btu}{h - GPM - F} * 10F} = 1440\ GPM$$

The tower baseline fan shall therefore require 24 BHP.

(c) Pumps

(i) Chilled Water Pumps

- **System Type:** The baseline chilled water pumping system shall be a variable primary flow system. Chilled water flow may decrease to a minimum of 30% of design flow. Refer to Section 6.4.2(d)(ii) for the baseline relationship between pump power and flow rate.
- **Quantity:** One baseline chilled water pump shall be provided for each baseline chiller.

- **Design Flow:** Pumps shall be sized to provide 1.2 GPM per ton of chiller capacity, corresponding to a 20 F delta-T across the evaporator.
- **Design Head:** Chilled water pump head shall equal 40 ft plus an additional allowance of .03 ft per ton served, capped at a maximum of 100 ft.
- **Design Pump Efficiency** Chilled water pumps shall be 70% efficient.
- **Design Motor Size & Efficiency:** Pump motors shall be sized based on the smallest standard size motor that can achieve the design BHP. Motor efficiency shall be determined from Section 6.5. BHP shall be calculated as follows:

$$BHP = \frac{Head * GPM}{3960 * eff_{pump}}$$

Where,

BHP	= Pump break horsepower
GPM	= Design water flow
$Head$	= Design pump head (ft)
eff_{pump}	= Pump efficiency

(ii) Condenser Water Pumps

- **System Type:** The baseline condenser water pumping system shall be constant flow.
- **Quantity:** One baseline condenser water pump shall be provided for each baseline chiller.
- **Design Flow:** Pumps shall be sized to provide 2 GPM per ton of chiller capacity, corresponding to a 12 F DT across the condenser.
- **Design Head:** Condenser water pump head shall equal 45 ft.
- **Design Pump Efficiency:** Condenser water pumps shall be 70% efficient.
- **Design Motor Size & Efficiency:** Pump motors shall be sized based on the smallest standard size motor that can achieve the design BHP. Motor efficiency shall be determined from Section 6.5. BHP shall be calculated as follows:

$$BHP = \frac{Head * GPM}{3960 * eff_{pump}}$$

Where,

BHP	= Pump break horsepower
GPM	= Design water flow
$Head$	= Design pump head (ft)
eff_{pump}	= Pump efficiency

(d) Plant Controls

(i) Chilled Water Supply Temperature (CHWST) Set Point and Reset

Baseline design chilled water supply temperature shall be 44 F. CHWST will reset from 44 F up to a maximum of 54 F based on demand.

(ii) Chilled Water Differential Pressure Reset

Baseline CHW systems shall reset DP based on demand. Compliance tools do not directly model DP reset. The impact of DP reset is implicitly accounted for the pump power versus flow equation below.

$$PLR = a + b * FlowRatio + c * FlowRatio^2 + d * FlowRatio\^3$$

PLR = Ratio of pump power at part load conditions to full load fan power

$FlowRatio$ = Ratio of GPM at part-load to full-load GPM

a = 0.0

b = 0.0205

c = 0.4101

d = 0.5753

(iii) Condenser Water Supply Temperature (CWST) Set Point Control

The CWST set point shall be fixed at the design wet bulb temperature for the site. Cooling tower fans shall maintain CWST at set point using variable speed fan control.

6.5. Motor Efficiency Tables

Title 24 utilizes the following nominal motor efficiencies for fan and pump motors irrespective of type enclosure type (TEFC or ODP) or motor speed.

HP	Efficiency
1	85.5%
1.5	86.5%
2	86.5%
3	89.5%
5	89.5%
7.5	91.7%
10	91.7%
15	92.4%
20	93.0%
25	93.6%
30	93.6%
40	94.1%
50	94.5%
60	95.0%
75	95.4%
100	95.4%
125	95.4%
150	95.8%
200	96.2%
250	96.2%
300	96.2%
350	96.2%
400	96.2%
450	96.2%
500	96.2%

7. Appendix: Analysis Examples

7.1. New Construction

7.1.1. Scenario

A large tech customer with an existing data center campus has decided to build a new high density data center building with an 800-ton design load. The existing buildings on campus have 1,200 tons of design load. To meet the cooling needs of the data center, while maintaining the campus' 2N redundancy requirement, the customer is adding two 800-ton chillers, as well as cooling towers, chilled water pumps and condenser water pumps, to their existing 2400-ton plant.

In addition to installing efficient air and water side equipment, the customer is installing efficient UPS units.

7.1.2. M&V Solution

Since the customer is expanding an existing plant, this scenario is slightly more complicated than a typical new construction project. The M&V process begins with developing an initial Title 24 model of the new facility. The new building's shell and airside systems should be modeled per the as-built design in a CEC approved compliance tool (CBECC-COM, IES, EnergyPro). The IT loads input in the model should be based on the expected full build-out design load (the compliance run will adjust the loads to generate a lifecycle average annual energy use estimate).

Since only the expanded part of the data center is being modeled, the expanded plant should be modeled as a scaled version of the actual plant. Scaling should be done in proportion to the fraction of campus design load that the new building accounts for. In this instance, the existing campus design load is 1200 tons, and the new addition's design load is 800 tons. Therefore, the entire plant—inclusive of the existing and new equipment—should be modeled and scaled to 40% of its actual size (800/(1200+800)). *Note that redundant mechanical equipment that does not run in normal operation is not modeled for savings calculation purposes.*

The table below presents a simplified example of this scaling process. Notice that only capacities for chillers and cooling towers have been scaled. Efficiency metrics have not been adjusted. Similarly, for condenser and chilled water pumps, the flow rates have been modified, but the design head and pump and motor efficiencies have not been changed.

Table 6: Scaled Plant Model Information

Plant Equipment	**Actual**	**Scaled**	
Chillers			
Type A - Existing			
Capacity @ Design Conditions	600	240	tons
Efficiency	0.5	0.5	IPLV
Quantity	2	2	
Type B - New			
Capacity @ Design Conditions	800	320	tons
Efficiency	0.38	0.38	IPLV
Quantity	1	1	
Cooling Towers			
Type A - Existing			
Capacity @ Design Conditions	750	300	tons
GPM per Fan HP	60	60	
Quantity	2	2	
Type B - New			
Capacity @ Design Conditions	1000	400	tons
GPM per Fan HP	75	75	
Quantity	1	1	
Condenser Water Pumps			
Type A - Existing			
Flow @ Design Conditions	1440	576	GPM
Head @ Design Conditions	40	40	ft
Pump Efficiency	72%	72%	
Motor Efficiency	94%	94%	
Quantity	2	2	
Type B - New			
Flow @ Design Conditions	1920	768	GPM
Head @ Design Conditions	40	40	ft
Pump Efficiency	70%	70%	
Motor Efficiency	95%	95%	
Quantity	1	1	
Chilled Water Pumps			
Type A - Existing			
Flow @ Design Conditions	900	360	GPM
Head @ Design Conditions	100	100	ft
Pump Efficiency	69%	69%	
Motor Efficiency	95%	95%	
Quantity	2	2	
Type B - New			
Flow @ Design Conditions	1500	600	GPM
Head @ Design Conditions	100	100	ft
Pump Efficiency	73%	73%	
Motor Efficiency	95%	95%	
Quantity	1	1	

In addition to creating an energy model, a preliminary UPS savings estimate should be generated based on the expected post-start up load, and the difference between proposed and baseline UPS efficiencies at that load. This analysis should be done in a spreadsheet.

After initial savings estimates are made, M&V activities will stop until project implementation is complete. At that point a verification site visit will be conducted to confirm that equipment has been installed as proposed and that plant and airside control sequences have been implemented as specified. This process entails verifying equipment nameplate data for all plant and airside equipment, and obtaining as-built controls sequences from the site. IT load (kW), as measured at the UPS output, should be trended for (1) month in 15 minute intervals or less to support a true-up of claimed savings.

After site work, the energy model should be modified to address any discrepancies identified between the claimed systems and control sequences and those identified during the verification site visit. The energy model should then be run with CEC CZ2010 weather data for city nearest to the project site. Savings should be adjusted using the methodology discussed in Section 3.1.2 based on the average IT load determined from (4) months of trend data.

UPS savings should be assessed according to Section 5.1.3 using the trended IT load and the differing efficiencies of the installed and baseline UPS units at the observed load conditions. Savings from both the modeled measures and the UPS measure should then be summed to estimate total project savings.

7.2. Retrofit – Early Retirement (ER) and Retrofit Add-On (REA) – Whole Building Analysis

7.2.1. Scenario

The customer operates an existing data center with four ten year old, 700-ton centrifugal chillers. These chillers serve custom AHUs located on the roof of the building. The customer has decided to overhaul their facility. They will replace the existing chillers, add an integrated waterside economizer, and install hot aisle containment within the data center. PG&E has gathered proof documenting the fact that the aforementioned changes would not have been made without the influence of the utility program.

7.2.2. M&V Solution

This project falls into the early retirement category because PG&E has gathered documentation that the project would not have moved forward without program influence. The existing condition therefore constitutes the baseline. Note that the project also includes retrofit add-on (REA) measures that also use the existing equipment baseline. Since the proposed measures represent a dramatic change in the existing HVAC infrastructure, they will likely produce savings that result in at least a 10% reduction in infrastructure energy use. As such, a Whole Building M&V approach is advisable in this instance rather than a Retrofit Isolation Approach. Prior to facility overhaul, (4) months of trends should be collected including the parameters identified in Section 5.2.1(a)(i) in 5 or 15 minute intervals, if available:

- Total facility electric meter load, inclusive of HVAC equipment, electrical equipment, and IT loads.
- Total IT load as registered on the downstream side of the UPS units
- Ambient dry bulb and wet bulb temperatures from sensors on site or from a nearby NOAA weather station if local sensors are not available.

These data will be used to develop a regression model of facility infrastructure energy use (total facility energy use less IT loads) as a function of IT load and ambient weather. As an example, the model may take a form such as:

$$kW_{facility} = a + b * T_{amb} + c * kW_{IT} + d * kW_{IT}^2 + e * T_{amb} * kW_{IT}$$

Where,

$kW_{facility}$ = Total facility electric load
kW_{IT}^2 = IT Load
T_{amb} = Ambient drybulb temperature (F)

This model will be evaluated and modified as necessary to achieve statistical validity based on MBE, CV-RMSE, and R^2 as specified in Section 5.2.1(a)(ii). Following project implementation, a post-retrofit model will be constructed in a similar fashion. Savings will be estimated based on the difference between these two models when they are applied to a CEC CZ2010 weather file and average post-retrofit load data.

7.3. Retrofit – Early Retirement (ER) – Retrofit Isolation Analysis

7.3.1. Scenario

The customer owns a large 2 story, 150,000 square foot office building. The building includes one 5,000 square foot data room currently served by 9 year old CRAC units located on the top floor of the building. The customer would like to improve the efficiency of their data room, so they plan to remove the existing CRAC units and install indirect/direct evaporatively cooled units above the space and isolate servers into a hot aisle/cold aisle arrangement. Because the data room is small, the customer had not previously invested in EMS trending for the space, nor do they intend to follow project implementation. PG&E has gathered proof showing that the project would not have moved forward without program influence.

7.3.2. M&V Solution

This situation falls into the early retirement category because PG&E's influence directly led to measure implementation. Since the data room only represents a small fraction of the total facility energy use, utilizing a whole building based savings analysis may yield results that are not statistically significant. Instead, a retrofit isolation approach is the best solution in this case. Since the data room is not monitored with EMS trends, it will be necessary to install kW data loggers on the CRAC units, their associated condensing units, and the circuits serving the IT loads in the data room. These data loggers should record values in 5 minute intervals and be left in place for a period of (4) months. To reduce monitoring costs, amperage data loggers may be used on the server room circuits in lieu of kW loggers so long as spot measurements are taken to verify power factor, which is typically relatively stable for IT loads.

Data collected using the data loggers will be used with weather data (collected either from the site or from a NOAA or CIMIS weather station nearby) to model existing HVAC energy use as a function of IT load and weather.

After project implementation, an identical procedure will be followed to generate a post-retrofit energy model. Savings will be estimated based on the difference between the two models when they are applied to a CEC CZ2010 weather file and average post-retrofit load data.

7.4. Retrofit – Normal Replacement (NR) – Retrofit Isolation Analysis

7.4.1. Scenario

A small data center customer has decided to replace 5 CRACs. Although the CRACs are only 10 years old, all have required compressor rebuilds and maintenance issues are recurring. As such, even though the CRACs technically have 5 years of RUL remaining, the project is deemed an end-of-life replacement. The facility will be replacing the CRACs with new CRACs.

7.4.2. M&V Solution

Since this is an end-of-life project, savings will be determined relative to a Title 24 baseline. However, to confirm that actual savings are generated by the project, the existing CRACs will still be metered with kW loggers prior to removal. The IT loads served by the CRACs will also be trended using kW or amperage loggers. These data will be used with local weather data to generate a pre-retrofit regression model of CRAC energy use as a function of load and weather data.

An identical monitoring and modeling procedure will be followed after project implementation. The pre-existing and installed models will be compared using CEC CZ2010 weather and post-retrofit load data to confirm that actual savings have been realized as a result of the project.

If savings have been realized, the methodology outlined in 5.2.2(a)(ii) will be used to estimate CRAC savings relative to Title 24. If these savings are determined to exceed actual savings, then project savings shall be capped at the actual savings.

7.5. Retrofit – Mixed Early Retirement (ER)/Retrofit Add-On (REA) and Normal Replacement (NR) – Hybrid Analysis

7.5.1. Scenario

The situation is identical to the scenario presented in Section 7.2.1, but two of the four chillers are deemed to be at the end of their effective useful life because of repeated maintenance issues.

7.5.2. M&V Solution

This project now contains both early retirement and end-of-life replacement components. Since this project is best analyzed with a whole building approach, the baseline metered data must be adjusted to reflect the energy use that would have been observed if the two end-of-life chillers had operated at a Title 24 minimum level. This adjustment is accomplished by monitoring the existing chillers to be replaced in addition to the existing monitoring discussed in Section 7.2.2. These monitored data are then scaled in proportion to the ratio between the existing chillers' IPLV and the Title 24 baseline IPLV. The difference between this scaled energy use and the actual chiller energy use for each time interval is then deducted from the facility infrastructure energy use used to develop the baseline regression model. The remainder of the analysis is conducted as specified in Section 7.2.2.