Energy Efficiency Baselines for

DATA CENTERS

Statewide Customized New Construction and Customized Retrofit Incentive Programs

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(Rectifier Efficiency Added)

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Incentive Programs

The California Customized incentive programs are designed to help California utility customers save energy by implementing energy efficiency measures. Many market sectors, such as residential and commercial, are served by well-established calculation methods. The industrial sector –in particular, high tech industrial facilities such as laboratories, cleanrooms and data centers – are large consumers of energy, yet are poorly targeted by standard incentive calculations.

Customized incentive programs for high tech customers are designed to help the customer go beyond selection of incrementally more efficient components, and push designers and owners to consider new design strategies not normally offered in lowest-first-cost situations. Historically, data centers have not received the same level of attention as commercial projects. This leaves ample opportunity to significantly reduce the energy budget for data center facilities by incorporating non-standard but well proven design strategies.

High Tech Industrial Facilities

Data centers, laboratories, and cleanrooms are referred to as "high tech industrial" spaces. These spaces are largely exempt from Title 24 compliance. California Title 24, Part 6 applies to Occupancy Groups A (assembly), B (office), E (K-12 education), F (factory), H (high hazard), M (mercantile), R (residential), S (storage), and U (agricultural). High tech industrial spaces do not fall into any of these Occupancy Groups and are therefore exempt from Title 24 required compliance. For more definition of the term "data center", refer to Data Center Definition section. California Title 24, Part 6 also excludes process loads and the fan system energy serving them when considering if a proposed building is compliant.

Note: Starting on January 1, 2014, Title 24 will be expanded to include data centers.

The typical high tech industrial facility (i.e., the industrial space and the HVAC systems serving it) operates continuously – 24 hours/day, 7 days/week, 365 days/year – even if the space is not occupied by staff continuously.

Offices, conference rooms, auditoriums, cafeterias, restrooms and so forth are referred to as "commercial" space, and are governed by Title 24.

Buildings that contain industrial space often contain commercial space as well. Such buildings are referred to as "hybrid".

Modeling Approach

Energy calculations for commercial space are typically performed using EnergyPro or an equivalent Title 24 performance compliance program. These programs take into account the construction of the building envelope (roof, walls, glazing), solar orientation, and shading to determine the extent of HVAC loads due to outside conditions. These "envelope loads" are often comparable to or even exceed the internal loads (people, lights, and office equipment).

The internal and process loads in high tech industrial spaces are typically far greater than any HVAC loads caused by heat transfer through the building envelope. Additionally, the HVAC systems serving high tech industrial spaces are often not easily modeled in software programs designed for commercial spaces. As a result, the energy calculations for high tech industrial facilities typically ignore envelope loads. In these cases, envelope loads can be ignored in high tech energy models built with custom software packages or commercially-available software.

Modeling Tools

The currently dominant modeling tools are listed below with key notes about how they work and for what type of modeling they are best suited. Tools other than the ones listed here may be used for incentive calculations, but the calculation approach must be approved by the utility administering the customized incentive program prior to performing the incentive calculations.

Table 1: Energy Modeling Tool Comparison

	Energy Modeling Tool			
	EnergyPro	*eQuest*	*EnergyPlus*	*Custom Spreadsheets*
Developer	EnergySoft	James J. Hirsch & Associates	U.S. Dept. of Energy	Microsoft Excel (typically)
Calculation Engine	DOE 2.1e	DOE 2.2	EnergyPlus v7.1	2008 Alternative Calculation Method (ACM) if applicable
Types of Systems/ Spaces Able to be Modeled	Developed for modeling energy effects of building envelope, lighting, and simple HVAC systems in comfort conditioning- driven buildings.			Best suited for modeling systems energy, not building envelope or solar effects on load.
Ability to Model Spaces that CA Title 24 Does Not Address	Limited	Some	Adequate	Strong
Models CA Title 24 Compliance?	Yes	Yes	Not Automatically	No
Baseline System Type	CA Title 24	CA Title 24 or Custom	Custom	Custom
Development Status	Complete	Complete, with continuous updates	Under development, no publicly available graphic user interface yet	Ongoing

Whole Building vs Systems Approach

The Savings By Design incentive program defines two performance-based design approaches, the Whole Building Approach and the Systems Approach, to identify and quantify energy-efficient design improvements. When envelope loads are not modeled, the Systems calculation method is typically used to calculate the incentive. The Systems approach can also be used when the energy savings are attributable to a single system (e.g. supply fans). This is the case for most high tech and industrial projects. The high tech space is typically a subset of the building, often with its own dedicated mechanical support systems. The Systems approach isolates the energy use of a specific system and ignores the energy use of other systems. In contrast, the Whole Building calculation method encompasses the entire building, including the envelope, in the energy model. The Whole Building approach is typically used for New Construction commercial projects.

Hybrid Buildings

Hybrid buildings consist of both commercial and high tech space. Performing an energy analysis for a hybrid building usually requires a two-pronged modeling approach (EnergyPro or similar for the commercial space and custom software for the high tech space). Care must be taken to integrate the two analyses properly to avoid double-counting energy use between the commercial and high tech spaces. For energy-using equipment serving both commercial and high tech spaces, the following methodology should be used to split the energy use between the two space types:

> The shared equipment should be modeled using the entire load. The final energy savings and incentive for the high tech space, however, are determined by pro-rating the proposed whole-building shared equipment energy use by the ratio of the high tech load to the whole-building load.

Baselines

To determine the energy savings due to a particular energy efficiency measure, the proposed situation is compared to a baseline situation.

For commercial spaces, the baseline is defined by California's Title 24 Non-Residential Building Energy Efficiency Standard.

This Title 24 standard does not apply to HVAC systems that serve "process loads[1]":

> 3. **Energy excluded**. The following energy shall be excluded:
> A. Process loads; and
> B. Loads of redundant or backup equipment, if the plans submitted under Section 10-103 of Title 24, Part 1, show controls that will allow the redundant or backup equipment to operate only when the primary equipment is not operating, and if such controls are installed; and
> C. Recovered energy other than from space conditioning equipment; and
> D. Additional energy use caused solely by outside air filtration and treatment for the reduction and treatment of unusual outdoor contaminants with final pressure drops more than one-inch water column. Only the energy accounted for by the amount of the pressure drop that is over one inch may be excluded.

There is some debate as to what constitutes a process load, and as to how far "downstream" in the HVAC system the exemption from the Title 24 standard applies.

[1] 2008 Title 24 Standard, Section 141 (c) 3. A. (page 92).

High tech industrial spaces are currently interpreted to be those spaces and associated infrastructure where the dominant design criteria are to satisfy the needs of processes rather than human comfort.

Some portions of the HVAC systems that serve industrial spaces, and are therefore exempt from Title 24, must still adhere to the American Society of Heating, Refrigerating, and Air Conditioning Engineers' (ASHRAE) Standard 90.1. For example, a chilled water plant delivering chilled water at a standard temperature must meet minimum performance criteria, regardless of the activity in the space being cooled.

This document does not intend to establish new baselines in any case where Title 24 and/or ASHRAE 90.1 have already defined them. Although Title 24 and ASHRAE 90.1 do not cover process load HVAC systems as a whole, both standards may have baselines that are appropriate to any individual component, such as equipment selection. In that case, designers are expected to abide by the relevant Title 24 or ASHRAE 90.1 baseline. This document only aims to provide baselines for which neither Title 24 nor ASHRAE 90.1 gives guidance.

The starting point for defining high tech industrial baselines is to determine what is current standard design and operating practice for these types of facilities in California. These practices are a moving target, particularly in the high tech industry. Periodic research is needed to update the descriptions of standard practice.

Integral Group has conducted much of this research. In some instances direct benchmarking measurements in the field were undertaken. It is indicated where this is the case. In other instances literature searches, phone surveys, or on-line surveys of industry experts were conducted. Finally, Integral Group relied on extensive experience as mechanical designers in the high tech industrial field to assess current standard practice.

The second step in defining industrial baselines is to set the bar slightly higher than current typical practice (in the same way that the Title 24 standard pushes the envelope of typical commercial construction.) This is intended to encourage adoption of new technologies and operating strategies in addition to selecting more energy efficient system components. In general, the incentive programs are designed to reflect trends in design practice and recognize those designs that are above the norm in terms of energy performance.

Energy savings for a given measure are determined by comparing the estimated energy use of the proposed new system to the estimated energy use of a baseline system that serves the same load.

HVAC equipment operating efficiencies depend not only on technology and load factor of the devices used in their construction but also the fluid temperatures and flow rates involved in the heat transfer process. For instance a water-cooled chiller, regardless of compressor technology, will tend to transfer heat more efficiently as the difference between the chilled water temperature and the condenser water temperature decreases. Air Conditioning and Refrigeration Institute (ARI) Standards prescribe test conditions under which HVAC equipment efficiencies are determined. The standard test conditions allow for equipment to be rated uniformly, enabling fair comparisons.

California Title 24 and ASHRAE 90.1 energy efficiency standards both mandate minimum non-residential air conditioner and electric water chiller efficiencies with respect to ARI Standards 340/360 and 550/590, respectively. The test conditions under these ARI standards, however, do not necessarily coincide with typical operating conditions for HVAC equipment in most territory in California serving high-tech and bio-tech facilities. When there is a difference between ARI standard test conditions and typical operating conditions for air conditioners or electric chillers, the minimum equipment efficiency mandated by California Title 24 is used to establish one point on the equipment efficiency performance map. This map is then extended, via DOE-2.2 default efficiency formulas, to construct the baseline efficiency curve at typical operating conditions within California.

This document describes the design expectations for an industry standard practice data center. A facility built to the baseline values will likely have a PUE[2] in the range of approximately 1.5-1.8. A data center built to exceed these PUE values (i.e. a lower PUE) suggests the use of better than typical data center design practices. Utilities currently are not providing incentives based on realized PUE performance.

The modeled baseline PUE is lower (1.5) for a large facility with a dense IT load served by a chilled water plant.

The modeled baseline PUE is higher (1.8) for a small facility with less dense IT load served by air-cooled DX CRACs.

A well-designed large data center utilizing free cooling, low power fan systems, and effective air containment may achieve a PUE value as low as 1.1.-1.2.

Metrics

Baselines are defined not just for equipment efficiency, but overall system efficiency. Incentives are based on the degree to which the entire proposed system (the air delivery system, the cooling system, humidity control system, etc.) out-performs its baseline counterpart. The United States Environmental Protection Agency (USEPA) is currently working to develop metrics for data center energy usage. Meanwhile, this baseline document serves to encourage data center energy efficiency improvement on a project-by-project basis.

[2] Power Usage Effectiveness (PUE) = total data center power draw divided by total IT power draw.

IT Equipment Efficiency

This document does not address the energy efficiency of IT equipment.

Title 24 Equipment

Unless otherwise stated, this document recommends Title 24 standards for the efficiency requirements of individual pieces of equipment (DX cooling units, chillers, boilers, etc.) High tech industrial spaces generally have stringent requirements for safety, redundancy, control of space temperature & humidity, and so forth, but these requirements can usually be met with off-the-shelf HVAC equipment.

Retrofit Program

In the baseline case for Retrofit projects, all equipment should be assigned a baseline efficiency as defined by this document, with two exceptions:

1. The existing equipment has a better annual average efficiency than the baseline defined in this document. In these cases, the existing equipment efficiency is used in the baseline case.

2. The equipment meets the Early Retirement criteria as defined by the Customized Retrofit (CR) Procedures Manual. The Early Retirement Program feature is intended to accelerate the retirement of less efficient equipment by offering increased incentives (see CR Procedures Manual).

For equipment that meets Early Retirement criteria:

> The baseline case should incorporate the equipment's existing efficiency for the accelerated replacement period of the dual-baseline method.
>
> If the existing equipment efficiency is better than baseline efficiency recommended in this document, savings for the period after the accelerated replacement period (typically, EUL-RUL period), should be calculated using the difference between the efficiency of the existing equipment and new equipment. When the existing equipment efficiency is inferior to the baseline efficiency recommended in this document, savings beyond the accelerated replacement period should be calculated using the differential between the recommended baseline efficiency and the efficiency of the new equipment.

In the baseline case for Retrofit projects, all equipment should be modeled with the existing operating setpoints (temperatures, flow rates, etc.) and configurations (quantity and capacity of equipment). Only modified system operating parameters and equipment must meet or exceed current Baseline standards as described in this document.

Under the Retrofit Program, the baseline system and technology type are matched to the existing system.

In some cases, a retrofit project may include installing additional capacity and support equipment to serve additional IT load. There are three types of data center expansion projects:

- Floor Area Expansion – In this case, the floor area of the data center is expanded to accommodate the additional load. The new area shares the same air handlers, plenums, or duct network with the existing space. The baseline system type for new equipment in a Floor Area Expansion project is matched to the existing system type and is treated as an expansion of the existing system. The baseline efficiency for the new equipment is defined in this document.

  Exception: If the proposed project increases the total data center IT capacity by greater than 50% and the total IT capacity after the expansion exceeds 1 MW, then the baseline system type is defined by this document.

- New Build-Out – In this case, a new space in the same building is build-out to accommodate the new IT load. The new space is separated by a wall or barrier and does not share the same air distribution system, plenums, or duct network as the existing data center (although they may share a common chilled water plant and electrical distribution system). New Build-Out projects should follow the baseline outlined in this document for both system type and efficiency, the existing equipment is not considered.

In the above two scenarios, the baseline Air Management Scheme and Technology Type are determined by the final IT load and IT load density. Whether a project is considered a Floor Area Expansion or a New Build-Out project is determined by the program implementer in accordance with these rules.

- Load Expansion in Existing Footprint – In this case, new IT load is added to an existing data center, and the data center floor area remains the same. The baseline system type for the new total IT load is matched to the existing system type.

  If the new total IT does not exceed the limitations of the existing Air Management Scheme (see Table 5) and the existing equipment has enough capacity to serve the new total IT load, then the project can be addressed as Retrofit project with the existing equipment used as baseline.

  If the new total IT load falls into a higher Air Management Scheme (due to load density, see Table 5) or if the existing equipment capacity is insufficient to serve the new total IT load, then the baseline system efficiency for the new total IT load is defined in this document. See Examples 1 and 2 below.

  - Example 1: The existing air delta-T is 6F, and the existing IT load density (67 W/sf) falls into Air Management Scheme I. The new total IT load density (133 W/sf) falls into Air Management Scheme II. The baseline air delta-T for the new total IT load is the baseline value for Air Management Scheme II (10F), per Table 5: Baseline Air Management Schemes. See the following table.

Table 2: Load Expansion in Same Footprint Example 1

	Existing	Baseline	Proposed (Existing + New)
Total IT Load (kW)	100	200	200
Total IT Load Density (W/sf)	67	133	133
Air Delta-T	6	10	18

- Example 2: An existing air-cooled chiller with a COP of 2.50 (worse than Title 24 2008) is replaced with a larger air-cooled chiller to accommodate the new total IT load. The baseline air-cooled chiller has Title 24 2008 efficiency (COP of 2.80).

Existing Equipment in New Construction Projects

In some cases, new construction projects can include equipment which interfaces with existing equipment; for example, building a new data center that is served from a campus chilled water plant. If the existing equipment performance or load is affected by the interface with the new construction, the existing equipment must be modeled in order to accurately reflect the savings for the project. In these situations, the existing system type and actual efficiencies for the existing equipment should be modeled for both the baseline and proposed case. If the circumstances do not make it possible to obtain the actual equipment efficiencies, the baseline efficiencies presented in this document should be used. All system setpoints should match the existing for both the baseline and proposed cases unless the effects of the new construction project require the setpoints to be changed.

For existing equipment that is replaced in a New Construction project, the baseline system type is matched to the existing system and the baseline efficiency is determined by the values in this document.

Format of this Document

This document is updated annually to reflect changes in technologies, and practices in the rapidly evolving data center industry.

Categories

The baselines presented in this document are arranged in the following categories:

- Loads
- Redundancy
- Space Design Conditions
- Air Delivery Systems
- Hydronic Systems
- Cooling Systems
- Heating Systems
- Humidity Control Systems
- Process Systems

Subcategories

Many of the categories are further divided as follows:

System Configuration
Description of the baseline system, what components it contains, how it is generally operated.

System Efficiency Metric
What is the baseline operating efficiency of the entire system?

Economizing & Heat Recovery
Are there any economizing or heat recovery schemes that are considered baseline?

Pressure Drop
Baseline pressure drops for air delivery and hydronic systems.

Component Efficiency
Baseline efficiencies for individual system components.

Thermal Storage
Are there any thermal storage components that are considered baseline?

Control Sequences
Baseline methods of system control.

Data Center Definition

Data centers are spaces specifically designed to accommodate dense arrangements of computer equipment and associate networking, telecommunications, storage and auxiliary equipment required to store, process, manage and disseminate data and information. A data center may include redundant power supplies, backup power equipment, and HVAC equipment. This document does not apply to data centers with a design IT load of less than 30kW.

The baseline for telephone company "central offices" or "telcos", computer labs, and mobile switching center (MSC) cellular telephone sites are currently described in this document. Radio base station (RBS) cellular telephone sites are also addressed. The baseline for these facility types is described in the pertinent section of this document.

Size Categories for Data Centers

Small Data Centers

These are facilities provided with up to and including 1 MW total design IT load.

Large Data Centers

These are facilities provided with more than 1 MW total design IT load.

Loads

Envelope Loads

Envelope loads are not typically modeled for data centers. However, when modeling building envelope load for data centers or telecom sites, a simplified model may be used that adds or removes heat (BTUs) from the building perimeter zone. A simplified model allows the entire energy model to be constructed in a single model and avoids having to construct two separate models to analyze both the envelope and internal loads. The simplified model is a linear curve fit based on the performance of a "typical" building in different climate zones determined by an eQuest® building energy model. The building was modeled to meet Title-24 minimum requirements for the envelope assembly. The simplified model outputs the hourly envelope load by inputting the outside air drybulb temperature and coefficients A and B from the following table. A different pair of coefficients is used for each climate zone. The model assumes only the perimeter zone, the area within 15 feet of an exterior wall, is affected by the envelope load. The area of the perimeter zone (perimeter square feet) is used to normalize the output to the building size. The simplified model is listed on the following page:

Envelope Load in BTU/hr = [A*(Outside Air Drybulb Temp (ºF) + B]*[Perimeter Floor Area (sq. ft.)]

Table 3: Envelope Load Coefficients

Climate Zone	A	B
2	0.317	-16.47
3	0.380	-20.75
4	0.340	-18.11
11	0.365	-19.76
12	0.377	-20.19

IT Loads

The full build-out IT load and load density are used to determine the baseline system type and capacity. The load measured at the time of the post-construction verification is used in the final incentive calculation.

Redundancy

- We use the Uptime Institute's definitions of redundancy Tiers. See the white paper "Tier Classifications Define Site Infrastructure Performance", by Turner, Seader, & Brill, 2006, available from http://www.greenserverroom.org/Tier%20Classifications%20Define%20Site%20Infrastructure.pdf
- The baseline data center is modeled at the same redundancy tier to which the proposed data center is designed.
- If the redundancy level of the proposed data center is not stated by the customer, it is modeled to be Tier II.
- For N+1 and N+2 redundancy, we apply the requirement to every 10 computer room air conditioners (CRACs) or computer room air handlers (CRAHs). For example, if an N+0 requirement resulted in 50 units, then N+1 would result in 55 units and N+2 would result in 60 units.
- For information on control of redundant fans and pumps, see Air Delivery Systems\Control Sequences and Hydronic Systems\Control Sequences, respectively.

Baseline Costs

The new construction program requires the incremental cost of the proposed vs. the baseline system be established. The table on the following page outlines the major systems included in the baseline design for guidance in the estimation of baseline costs. Not all systems in the list below will be included in the baseline cost for every project. The appropriate baseline systems to include will depend on the scope of the proposed measures.

The cost of each piece of equipment (e.g. chiller, ducting) 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 (as described in this document) that is used for each measure. Equipment that is the same in the baseline and proposed systems should not be included in the incremental implementation cost calculation. For example, if baseline supply air ducting and is used in the proposed design for a new construction project, then the incremental implementation cost does not include the cost of ducting. Alternatively, if the proposed ducting is oversized for a lower pressure drop (i.e. a fan energy savings measure), then the incremental cost of the larger ducting over baseline ducting can be included.

The source for each line item cost should be listed next to each line item in the incremental implementation cost calculations.

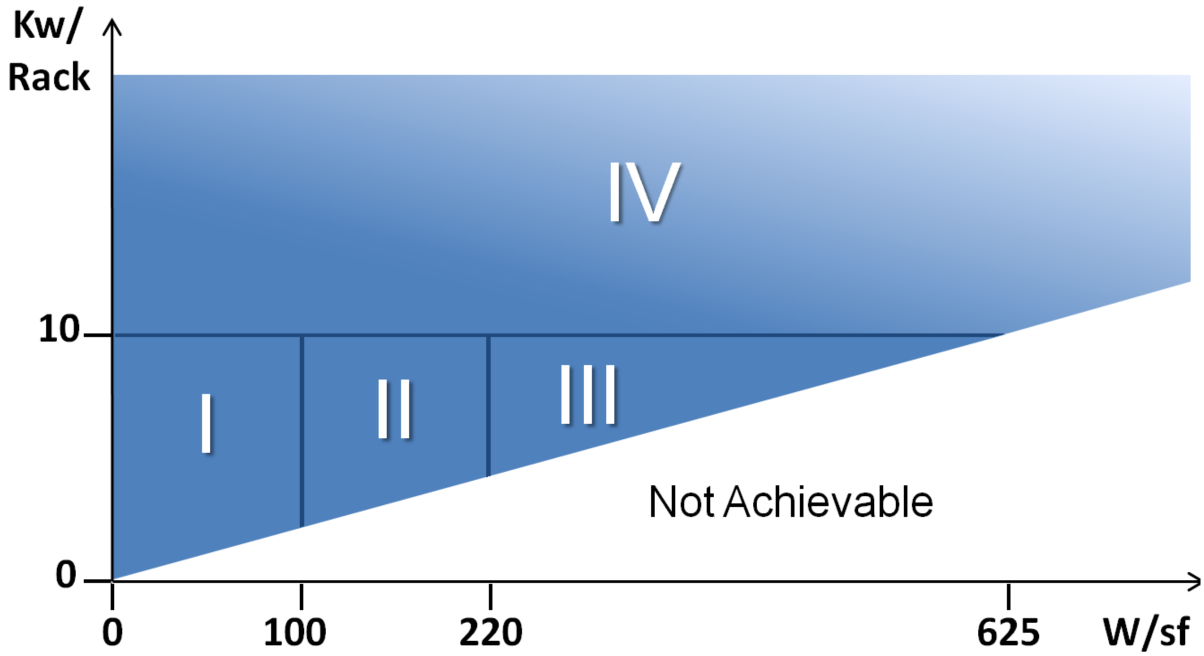
Table 4: Baseline System Equipment for Costing

	Design IT Load Up to 1 MW			Design IT Load Greater than 1 MW		
	Air Management Scheme			Air Management Scheme		
	I	II	III	I	II	III
Chilled water CRAHs with constant-speed, downflow fans, equipped with humidifiers				✓	✓	✓
DX CRACs with constant-speed, downflow fans, humidifiers, and remote, air-cooled condensers	✓	✓	✓			
On-board CRAC/H controls	✓	✓	✓	✓	✓	✓
Ductwork (From hot aisle to CRAC)		✓	✓		✓	✓
Aisle containment (strip curtains, doors)			✓			✓
Uninterruptible Power Supply	✓	✓	✓	✓	✓	✓
Water-cooled, centrifugal chillers				✓	✓	✓
Axial cooling towers with VFD				✓	✓	✓
90-degree, centrifugal, condenser water pumps				✓	✓	✓
90-degree, centrifugal, primary chilled water pumps with VFD				✓	✓	✓
Central plant connected to and controlled by building direct digital control system.				✓	✓	✓

Space Design Conditions

There are four baseline air management schemes for data centers, depending on the actual load density of the IT equipment. The appropriate air management scheme for a data center can be determined using the chart below.

Baseline Air Management Schemes



This diagram assumes a rack footprint of 2 ft x 3 ft. Therefore, certain power densities (W/sf) are not possible at some rack densities (kW/rack).

Data centers with rack load densities greater than 10 kW/rack require alternative cooling strategies. Air management scheme IV is described in more detail in the High Density Data Center section of this document.

Table 5: Baseline Air Management Schemes

ID	Name	IT Load Density at Full Build-Out[B]		Design IT Load Density at Full Build-Out		Return Air Drybulb Temp. Setpoint	Operating Supply Air Temp.	Operating Airside Delta-T[C]	RH Setpoint and Tolerance[D]	Fan Airflow Efficiency Metric[E]	Operating CRAC/H Airflow Capacity[G]	Cooling Coil Capacity per unit at Baseline Conditions[G]		Total Static Pressure
		Min	Max	Min	Max							CRAC	CRAH	
		W/sf	W/sf	kW/rack	kW/rack	F	F	F		cfm/kW[F]	cfm	Tons	Tons	in. w.g.
I	Hot Aisle/Cold Aisle, Open	0	100	0	10	74	64	10	50% +/- 10%	1,536	16,800	25	23	2.75
II	Hot Aisle/Cold Aisle, Ducted Return	101	220	0	10	78	65	13	50% +/- 10%	1,508	15,800	25	28	2.80
III	Hot Aisle/Cold Aisle, Fully Enclosed[A]	221	400	0	10	85	67	18	50% +/- 10%	1,482	13,875	30	39	2.85
IV	In-Row Cooling Solution			10	30									

Notes

[A]Air Management Scheme III: A fully enclosed cold aisle scheme is modeled to be identical to a fully enclosed hot aisle scheme, from the standpoint of temperatures, humidity, and total static pressure drop.

[B] Load Density is actual measurable load density at full build-out, not design density including a safety factor, and is based on total data center floor area.

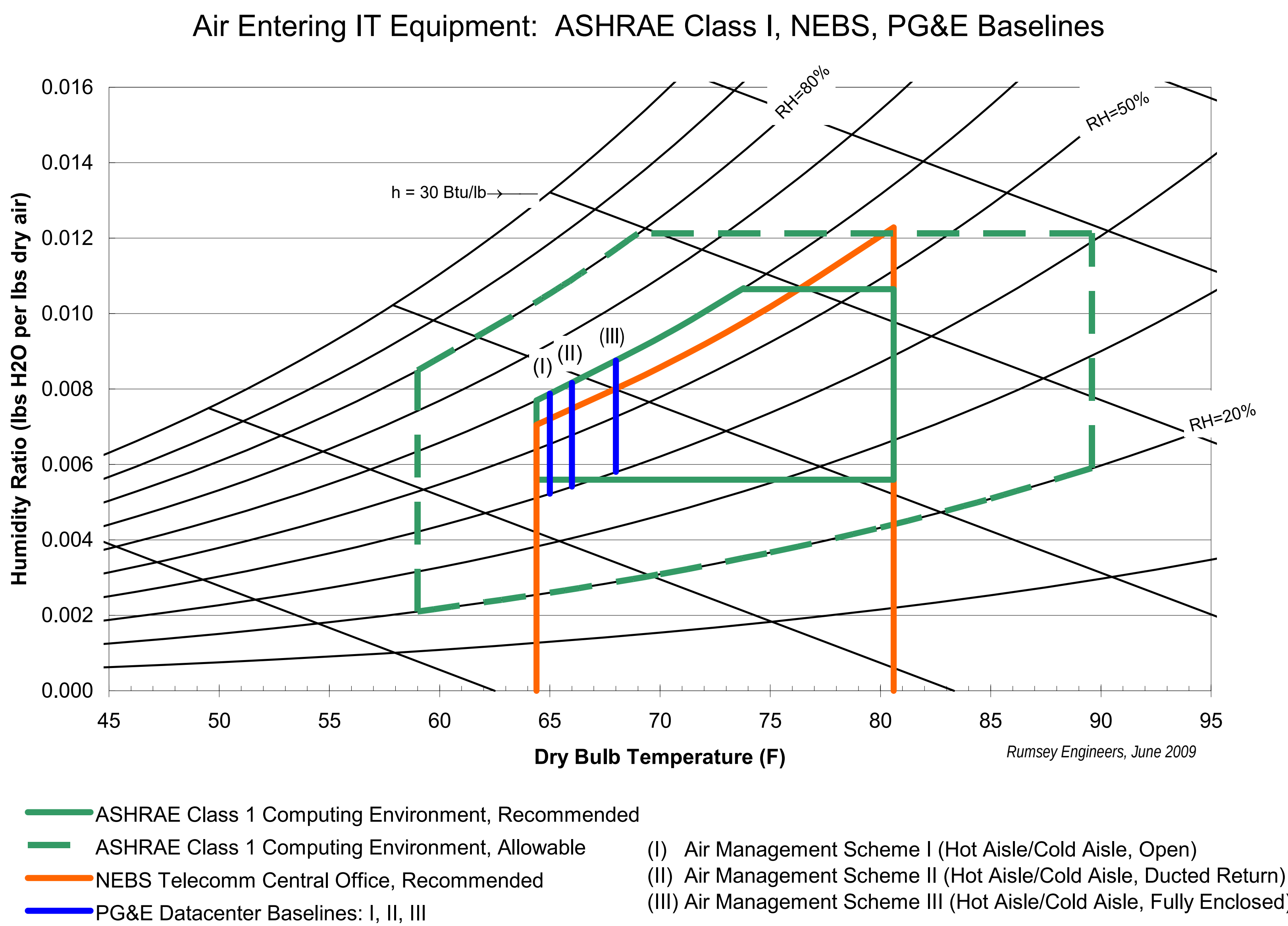
[C] Airside delta-T does not include fan motor heat. Delta-T is the temperature difference between the supply air leaving the CRAC/H and the air returning to the CRAC/H.

[D] Humidity Control Range: "Thermal Guidelines for Data Processing Environments, Second Edition", ASHRAE, 2009. The minimum dewpoint temperature and maximum relative humidity shown in this table is the "Recommended" range for Class 1 and 2 facilities. The values apply to the air entering the computer equipment. Baseline facilities employ RH sensors, not dewpoint sensors. The baseline relative humidity setpoint and tolerance are set as shown in the table. See the following psychrometric charts.

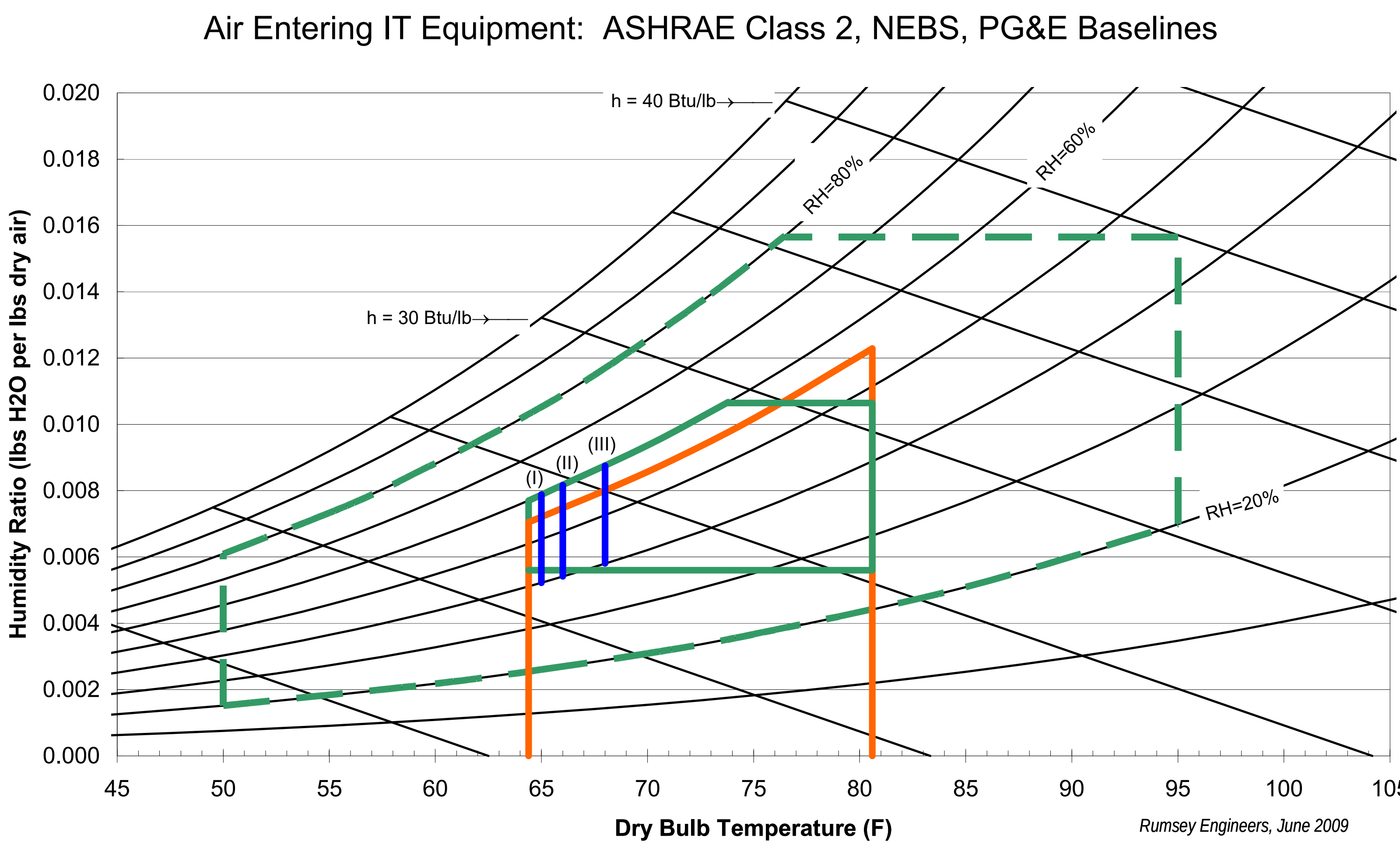
[E] Airflow Efficiency Metric was created based on baseline static pressure drop and baseline fan, drive, and motor efficiencies for a 15hp motor.

[F] The denominator kW value refers to fan power demand.

[G] Determined based on a survey of CRACs and CRAHs from prominent manufacturers operating at the baseline static pressure drop.



(I) Air Management Scheme I (Hot Aisle/Cold Aisle, Open)
(II) Air Management Scheme II (Hot Aisle/Cold Aisle, Ducted Return)
(III) Air Management Scheme III (Hot Aisle/Cold Aisle, Fully Enclosed)



ASHRAE Class 2 Computing Environment, Recommended

ASHRAE Class 2 Computing Environment, Allowable

NEBS Telecomm Central Office, Recommended

PG&E Datacenter Baselines: I, II, III

(I) Baseline AM Scheme I (Hot Aisle/Cold Aisle, Open)

(II) Baseline AM Scheme II (Hot Aisle/Cold Aisle, Ducted Return)

(III) Baseline AM Scheme III (Hot Aisle/Cold Aisle, Fully Enclosed)

Ventilation
The CA Title 24 Non-Residential Alternative Calculation Method (ACM) Manual lists minimum outside air ventilation rates for a variety of occupancy types but does not include data centers. Data centers are considered part of the "All Others" occupancy type, for which CA Title 24 requires 0.15 cfm/sf. Therefore, this ventilation rate is considered baseline.

Exhaust
Exhaust volume is the same as ventilation volume (no in/exfiltration in space).

Occupancy
Human occupancy adds a negligible load to the HVAC system that serves the data center. The IT equipment load is present 24/7/365.

Air Delivery Systems

System Configuration

Recirculation

Small Data Centers – Schemes I, II, and III
Recirculation is provided by air-cooled DX computer room air conditioner (CRAC) units equipped with constant-speed fans. Specifications for CRACs from prominent manufacturers were evaluated to determine the nominal airflow per unit at an external static pressure drop of 0.3, 0.6, and 1.1 in. for air management scheme I, II, and III, respectively.

Exception 1: For an existing or new small data center in an existing building served by a chilled water plant, and the plant has sufficient cooling and pumping capacity, and running new chilled water pipes to the data center is feasible, then the baseline consists of tapping in to the existing chilled water system to run chilled water computer room air handlers (CRAHs) with constant-speed fans.

Large Data Centers – Schemes I, II, and III
Recirculation is provided by chilled water CRAHs equipped with constant-speed fans. Specifications for CRAHs from prominent manufacturers were evaluated to determine the nominal airflow per unit at the baseline external static pressure drop of 0.3, 0.6, and 1.1 in. for air management scheme I, II, and III, respectively.

High Density Data Centers – Scheme IV
The baseline system for scheme IV is an in-row cooling solution. An in-row cooling solution is defined as a system which cools one rack or one aisle of equipment only and is physically located in the row. An in-row solution requires running chilled water or refrigerant to each rack or aisle.

The baseline system is described in terms of the energy consumption per ton of design cooling for the entire cooling system within the data center. The baseline performance is 170 watts/ton[3] at design conditions. There are two energy consuming components shared by all products considered to be in-row solutions: fans and pumps. The table below describes the baseline component efficiency metric at design conditions. Please note that a design which has one component performing better than the value listed in this table can still be considered below baseline if the sum of the fan and pump energy is greater than 170 watts/ton at design conditions.

Baseline in-row fans actively vary their speed relative to the data center load via a variable frequency drive (VFD). The fan speed reduction is proportional to the load reduction at partial loads. The fans on a baseline in-row unit do not turn down below 50% of their maximum. The fan power at part load is calculated using the fan affinity law and an exponent of 2.0. See the Affinity Law section for a more detailed description of the fan exponent.

Table 6: Baseline In-Row Cooling Equipment Efficiency

Fan Energy	130	Watts/ton
Pump Energy	40	Watts/ton

The baseline system performance above accounts for pumping specific to the in-row cooling solution. These pumps are generally located in the data center and act as booster pumps or are located on the secondary side of a heat exchanger (if present). The energy given in this table does not account for the presence of any central chilled water pumps, which are addressed in a subsequent section of this document. Baseline in-row unit pumps are constant speed.

Humidity control in high density data centers is performed by a CRAC in a small data center or by a CRAH in a large data center as defined in the previous Size Categories for Data Centers section. The CRAC/H provides dehumidification only and its supply fan runs continuously.

Ventilation

In hybrid facilities, ventilation for the data center is often provided by the "house air" system; i.e., the system that serves the commercial space. However, to simplify energy calculations we define the baseline ventilation air system as a dedicated make-up air handler (MUAH) equipped with a constant-speed fan. Excess air is removed from the space via a constant-speed exhaust fan.

The MUAH delivers 0.15 cfm/sf at a drybulb temperature of 55 ºF. Energy is required to temper the outside air, and this air provides a cooling effect that supplements the main cooling system. This tempering energy and the cooling effect are addressed in the Cooling Systems section.

[3] Determined based on a survey of available in-row cooling solutions.

Exhaust

The exhaust system is not equipped with any heat recovery devices.

System Efficiency Metric

The operative metric for air delivery systems is the volumetric flow rate of air being delivered divided by the fan motor power, in units of cubic feet per minute per kilowatt, or cfm/kW.

For a given volumetric air flow rate, the efficiency of the air delivery system is dictated both by the total static pressure drop (TSP) of the system, and by the efficiency of the fan system (the fan/drive/motor combination).

Baseline values for TSP and for the fan system are defined in this document, but exceeding baseline practice for one of these two aspects does not necessarily provide better-than-baseline overall system efficiency. It is the combination of the two aspects that determines the resulting value of cfm/kW.

Baseline cfm/kW values differ for each air management scheme and are presented Table 5: Baseline Air Management Schemes.

Pressure Drop

The total static pressure drop of the air delivery system is the sum of the pressure drops of the components that make up the system- the filters, coils, fans, duct system, silencers, dampers, grilles, and any other devices the air flows through - while under peak design airflow conditions.

Baseline pressure drops are defined below for many of these components, but it is the total static pressure drop that influences the efficiency of the air delivery system. In other words, reducing the pressure drop below the baseline value for just one or two components of the system does not necessarily provide a better-than-baseline TSP.   Note that the following values apply only at the peak design airflow.

Ventilation

<u>MUAH Face Velocity</u>
The baseline MUAH coil face velocity is 500 fpm. This is a long-standing design rule of thumb. Reducing the face velocity decreases the fan energy required to deliver a given air volume.

<u>MUAH Total Static Pressure Drop</u>
The total pressure drop is the sum of the internal and external pressure drop. The internal pressure drop includes all components inside of the MUAH (fans, coils, filters, etc). The external pressure drop includes the dampers, diffusers, and ducting.

The internal pressure drop of a baseline MUAH (total of all components) is 2.0" w.g. at nominal conditions.

The baseline external pressure drop for MUAH dampers and diffusers is 0.20" w.g. at nominal conditions.

The baseline duct static pressure drop is 0.10" w.g. per 100 ft at nominal conditions.

A baseline MUAH operates at nominal conditions.

Recirculation

The baseline total static pressure drop for the three baseline air management schemes involving DX CRACs and chilled water CRAHs are shown in the rightmost column of Table 5: Baseline Air Management Schemes.

Exhaust

The baseline exhaust path pressure drop is 1.0" w.g. for the exhaust duct, up to and including a vertical run of 3 floors. We add 0.5" for every additional floor beyond a vertical run of 3 floors.

Component Efficiency

Fans

The table below lists the baseline fan efficiency for common fan sizes.

Table 7: Baseline Fan Efficiencies

Nominal Fan Motor Horsepower	Baseline Efficiency
0.5	0.420
1	0.500
1.5	0.500
2	0.500
3	0.500
5	0.500
7.5	0.533
10	0.556
15	0.587
20	0.608
25	0.624
30	0.638
40	0.658
50	0.675
60	0.686
75	0.698
100	0.715
125	0.727
150	0.736
200	0.750

These fan efficiency values apply to all fans: MUAHs, CRACs, CRAHs, supply fans, and exhaust fans.

Fan Drives

Baseline CRACs and CRAHs have V-shaped belt drives, non-cogged with 95% average belt lifetime efficiency.

Table 8: Baseline Drive Efficiencies

Drive Type	*Average Lifetime Efficiency*
V-shaped belt drive, non-cogged	95% [4]
Direct drive	99.5%

[4] US Department of Energy Industrial Technologies Program (2008, September). *Motor Systems Tip Sheet #5.*

Control Sequences

Recirculation

Constant speed fans, balanced at startup, run 24/7.

Refer to the Table 5: Baseline Air Management Schemes.

- The baseline return air drybulb temperature is modeled to be successfully controlled to the setpoint shown in the table.
- The baseline air flow rate is constant for each CRAC or CRAH. CRAC and CRAH supply fans are constant speed.
- The baseline supply air drybulb temperature is therefore a resultant (not controlled to a setpoint) and is modeled to float with the cooling load.
- The number of CRACs or CRAHs running is constant over the year. The number of CRACs or CRAHs running is equal to the number of CRACs or CRAHs needed to serve the peak annual IT load and to achieve the target air delta-T per Table 5: Baseline Air Management Schemes.

Ventilation

Constant ventilation rate.

Exhaust

Constant exhaust rate.

Redundant Fans

For air delivery systems with redundant fans, the redundant fans are never needed and never run in the baseline model. The energy savings calculations do not model failure events of fans.

Hydronic Systems (Chilled Water, Condenser Water, Hot Water)

System Configuration

Chilled Water

The baseline chilled water pump configuration is a variable flow primary-only loop. The pump speed is varied by a VFD and is controlled to maintain a constant differential pressure set point of 30 ft across a CRAH two-thirds the distance down the chilled water supply pipe run. Primary chilled water pumps are piped in a parallel bank of pumps such that any primary chilled water pump can operate with any chiller and all primary chilled water pumps can run simultaneously. The pump speed is dependent on the demand for cooling but does not go below two-thirds of the design flow through the chiller.

Condenser Water

The baseline condenser water pump configuration is one constant speed condenser water pump per chiller, each pump dedicated to its respective chiller.

Hot Water

Hot water is not baseline for New Construction program data centers. Hot water pumping systems are primary-only with continuous variable flow. Hot water systems serving 120,000 sf or more have variable-speed drives, and systems serving less than 120,000 sf are modeled as riding the pump curve[5].

System Efficiency Metric

Condenser Water

New condenser water pumps operate at 19 W/gpm at design conditions[6], where the flow rate (gpm) is the total condenser water flow rate per pump and the power draw (Watts) is the power demand for each condenser water pump.

Heating Hot Water

The baseline total hot water pumping energy at peak design load is 19 W/gpm[7], where the flow rate (gpm) is the total hot water flow rate per pump and the power draw (Watts) is the power demand for each hot water pump.

Water Flow Rate

<u>Chilled Water Flow Rate</u>
The baseline chilled water flow rate is the ARI test standard flow rate of 2.4 gpm/ton of chiller capacity.

<u>Condenser Water Flow Rate</u>
The baseline condenser water flow rate is the ARI test standard flow rate of 3.0 gpm/ton capacity.

Exception: In Retrofit program projects and New Construction program projects using existing equipment, water flow rates should match existing conditions.

Pressure Drop

Baseline total head pressure is presented in Table 9: Baseline New Construction Chilled Water Pump Parameters.

[5] ASHRAE 90.1-2007, section G3.1.3.5.
[6] ASHRAE 90.1-2007, Appendix G3.1.3.11.
[7] ASHRAE 90.1-2007, Appendix G3.1.3.5.

Exception: In Retrofit program projects and New Construction program projects reusing existing equipment, the baseline total head pressure at the peak design condition is the same as the existing total head pressure at the peak design condition.

Component Efficiency

Chilled Water Pumps

The baseline primary chilled water pumping energy at peak design load is 22 W/gpm[8], where the flow rate (gpm) is the primary chilled water flow rate per pump and the power draw (Watts) is the power demand for each chilled water pump. Table 9: Baseline New Construction Chilled Water Pump Parameters below shows baseline chilled water pump component efficiency at design conditions. Chilled water flow rate is specified in the previous Chilled Water Flow Rate section. For baseline facilities, pump selections are tailored to the project via impeller trimming.

<u>New Construction Baseline Chilled Water Pump System Efficiency</u>

Table 9: Baseline New Construction Chilled Water Pump Parameters

Chilled Water Pumps		
Pressure Drop	Motor Efficiency	Pump Efficiency
75 ft	94.1%	68.0%

A different method is used to determine the baseline pump efficiency in Retrofit program projects. New pumps in Retrofits are specified based on fixed, existing conditions rather than more flexible design conditions in new construction projects. Baseline pump efficiency for Retrofit projects can be determined from Table 10: Baseline Retrofit Program Chilled Water Pump Efficiency.

[8] ASHRAE 90.1-2007, Appendix G3.1.3.10.

<u>Retrofit Program Baseline Chilled Water Pump Efficiency</u>

Table 10: Baseline Retrofit Program Chilled Water Pump Efficiencies

		Head (ft)									
		20		40		60		80		100	
		hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)	hp	eff (%)
GPM	100	1	58	2	69	5	59	5	51	7.5	56
	500	5	72	7.5	84	15	79	20	71	20	75
	1000	7.5	79	15	79	25	80	30	84	40	86
	1500	15	73	25	77	40	80	50	80	60	85
	2000	15	76	40	62	50	79	60	82	75	81
	2500			40	77	75	63	100	65	100	72
	3000			50	73	75	75	100	82	100	86
	3500			60	70	100	71	100	81	125	84
	4000			60	78	100	74	125	78	150	81
	4500			75	73	125	72	125	84	150	86
	5000			100	75	125	72	150	77	200	81

The above table is considered baseline practice for chilled water pump efficiency based on system pressure drop and flow rate. The table was derived by selecting the least expensive option for a given condition from prominent pump manufacturers' product selection software. All selections in the table are sized to not exceed 90% of the rated power at the given condition.

Pump Motors

Baseline motor efficiencies are tabulated in the Electrical section.
Baseline pump motors are not equipped with VFDs, except the primary chilled water pump motors as described elsewhere in this document.

Control Sequences

For hydronic systems with redundant pumps, the baseline redundant pumps are never needed and never run. The energy savings calculations do not model failure events of pumps.

It is baseline practice to stage the condenser water pumps on and off with the chiller they serve. Baseline condenser water pumps do not run when their associated chiller is off.

Cooling Systems

Baseline cooling system efficiency varies by system type (DX or water-cooled chiller), and design IT equipment power draw capacity. In all cases the efficiency is expressed in units of annual average kW/ton – the annual combined electric energy use (kWh/yr) of all fans, compressors, and other system components that help provide cooling, divided by the annual ton-hours of cooling delivered. Unless otherwise stated, the incentive for a cooling system energy efficiency measure (or suite of measures) is based on the degree to which the measure(s) improve upon the baseline.

There are many different aspects of cooling systems that can be addressed to improve efficiency. Baseline practice for many of these aspects are defined below, but exceeding baseline practice for one or more of these aspects does not necessarily provide better-than-baseline overall system efficiency. It is the resulting overall kW/ton efficiency of the cooling system that determines the resulting savings and incentive.

System Configuration

This section applies to projects that fall under the Customized New Construction (CNC) program. The baseline for Retrofit projects is determined by the existing system type (see Retrofit Program section).

Small Data Centers

The baseline cooling system for data centers up to and including 1 MW total design IT load is uniformly-sized air-cooled DX, constant-speed fan CRACs.

Exception 1: For an existing or new small data center in an existing building served by a chilled water plant, and the plant has sufficient cooling and pumping capacity, and running new chilled water pipes to the data center is feasible, then the baseline consists of tapping in to the existing chilled water system to run chilled water CRAHs (or chilled water air handler units for telecom facilities) with constant-speed fans.

Large Data Centers

The baseline cooling system for data centers above 1 MW total design IT load is a water-cooled chilled water plant serving uniformly-sized chilled water CRAHs equipped with constant-speed fans.

Air-Cooled DX CRAC Units

The baseline air-cooled DX CRAC configuration has:

- Redundancy = N+1, if not otherwise specified in the proposed design.
- Safety factor on capacity = design load * 1.20.
- All units are equally sized.
- Condensers are air-cooled. Add-on evaporative cooling devices for condenser coils are not baseline.

Water-Cooled Chilled Water Plant

The baseline chilled water plant has:

- No thermal storage.
- No water-side economizing (aka "free cooling")
- Redundancy = N+1 on chillers, cooling towers, and pumps, if not otherwise specified in the proposed design.
- Safety factor on capacity = design load * 1.20.
- All chillers are identical.
- Idle chillers are staged on after operating chillers exceed 80% load factor
- The cooling load is shared equally among all active chillers.
- Baseline chillers are electric (not absorption or adsorption).
- Baseline chiller performance is displayed in the Chiller section.

Electric chiller technology type (screw, scroll, centrifugal; constant-speed vs variable speed; etc.) tends to vary with capacity, but the Customized incentive program does not dictate technology type. If a chiller of any technology type can be shown to produce annual energy savings over the defined baseline chiller in its capacity class – and using the same fuel – then it is eligible for an incentive.

All CRACs and CRAHs

The baseline number of CRACs or CRAHs is determined by finding the maximum of:

- the number of CRAC/Hs needed to meet the airflow requirement
- the number of CRAC/Hs needed to meet the cooling requirement with a safety factor
- the number of CRAC/Hs needed to meet the cooling requirement with redundancy

(CRAC/H redundancy is not addressed in the Uptime Institute's definition of Tier II. The CRAC/H redundancy level discussed here is to address general mechanical reliability.) The baseline quantity and size of CRAC/Hs are calculated for the expected build-out load. Baseline CRAC/H nominal capacity is listed in the Baseline Air Management Scheme.

<u>Number of CRAC/Hs Needed to Meet Airflow Requirement</u>

This is determined by first establishing the baseline air management scheme based on the proposed build-out rack load density. This in turn determines the nominal baseline supply and return air temperatures. These temperatures and the proposed total load are used to calculate the needed cooling airflow. The nominal baseline CRAC/H size is selected based on the proposed load density. The air that the CRAC/H unit can deliver is dependent on the expected total static pressure drop it will see with the given air management scheme. Once the airflow per CRAC/H is determined, the number of CRAC/Hs needed to meet the airflow requirement is calculated by taking the total cooling air flow requirement divided by the airflow per CRAC/H and rounding up to the nearest integer.

Number of CRAC/Hs Needed to Meet Cooling Requirement
This is determined by first establishing the baseline air management scheme based on the proposed rack load density. This in turn determines the nominal baseline return air temperature and CRAC/H capacity at those conditions since the CRAC/H cooling capacity is dependent on the return air temperature. (The cooling capacity increases with the return air temperature, all other factors held equal.) Once the cooling capacity per CRAC/H is determined, two values are calculated:

1. The number of CRAC/Hs needed to meet the cooling requirement with a safety factor. This is calculated by dividing the expected maximum cooling load times a safety factor by the cooling capacity per CRAC/H and rounding up the result to the nearest integer.

2. The number of CRAC/Hs needed to meet the cooling requirement with redundancy. This is calculated by taking the number of CRAC/Hs needed to meet the cooling requirement *without* a safety factor, then applying the redundancy requirement to every ten CRAC/H units.

System Efficiency Metric

The operative metric for baseline data center cooling systems is annual average kW/ton, as defined at the beginning of this section. If the ventilation system provides cooling that supplements the main cooling system, it is included in the kW/ton calculation.

Air-Cooled DX CRAC Units

The cooling efficiency of baseline air-cooled DX CRAC units is described below under Component Efficiency.

Chilled Water Plant – Performance Calculation Method

If the entire chilled water plant (chillers, cooling towers, condenser water pumps, chilled water pumps) is being considered in the analysis but the proposed design does not include any changes to the chilled water system, then the chilled water plant performance metric can be used to calculate plant energy consumption. In order for this calculation method to be accepted, it must be used in both the baseline and proposed models. The plant performance at various load factors can be found in the tables below for a water-cooled and air-cooled chilled water plants.

Table 11: Baseline Water-Cooled Chilled Water Plant Performance (kW/ton) vs Load Factor

Load Factor	Chiller	CHW Pumps	Cooling Tower	CW Pumps	Chilled Water Plant (Total)
0.2	0.803	0.146	0.001	0.278	1.228
0.3	0.661	0.100	0.002	0.190	0.953
0.4	0.580	0.075	0.003	0.143	0.800
0.5	0.542	0.060	0.003	0.114	0.719
0.6	0.524	0.050	0.004	0.095	0.673
0.7	0.519	0.045	0.005	0.081	0.650
0.8	0.518	0.048	0.005	0.071	0.643
0.9	0.528	0.051	0.006	0.063	0.649
1.0	0.539	0.054	0.007	0.057	0.657

Table 12: Baseline Air-Cooled Chilled Water Plant Performance (kW/ton) vs Load Factor

Load Factor	Chiller	CHW Pumps	Chilled Water Plant (Total)
0.2	0.853	0.139	0.992
0.3	0.933	0.104	1.036
0.4	0.916	0.078	0.994
0.5	0.903	0.062	0.966
0.6	0.893	0.052	0.944
0.7	0.883	0.048	0.931
0.8	0.875	0.051	0.927
0.9	0.868	0.055	0.923
1.0	0.856	0.057	0.913

These curves are for plants consisting of one chiller. For plants with multiple chillers, the chillers stage on in series. Chilled water plants with multiple operating chillers cannot use this method and the entire plant must be modeled.

Economizing & Heat Recovery

Air-side economizing is not baseline practice for data centers. Because baseline CRAC and CRAH units typically have low static pressure drop, air delivery systems with economizing should be designed with as low pressure drop as possible in recirculation mode to avoid a summer peak demand spike with respect to the baseline.

Pressure Drop

The baseline pressure drop for CRAC and CRAH units is listed in Table 5: Baseline Air Management Schemes. Baseline pressure drops for pumping systems are discussed in the Hydronic Systems section.

Component Efficiency

Air-Cooled DX CRACs

DX CRAC unit specifications from prominent manufacturers at nominal conditions are used as the baseline, but the specifications do not address the efficiency of the on-board DX cooling system at part loads. To model the cooling system performance, the calculation method specified by the CA Title 24 2008 Alternative Calculation Method (ACM) Manual is used. This method relies on the DOE 2.1 modeling engine. The calculated efficiency depends on the effective air temperature at the condenser coil, the air condition (temperature and humidity) at the cooling coil, and the system's rated efficiency at the ARI standard condition. For the latter parameter, CRAC cooling efficiency is equivalent to a CA Title 20 CRAC or CA Title 24 minimally-compliant DX package unit of the same nominal capacity (see Table 13: Baseline Air-Cooled Package Unit Efficiencies in the Air-Cooled DX Package Units section below.)

Chilled Water CRAHs

For the cooling efficiency of chilled water CRAHs, refer to the water-cooled chilled water plant system efficiency metric, above.

Air-Cooled DX Package Units

The baseline efficiencies for air-cooled DX package units are taken from the 2008 California Non-Residential Title 24 Standards (Table 112-A) and 2009 California Appliance Efficiency Title 20 Regulations (Table C-9). High efficiency DX units with less than 63.3 tons of cooling capacity are not eligible for a Customized Incentive according to the 2011 Statewide Customized Offering Procedures Manual for Business. The values for such units are shown here for energy modeling purposes only.

Table 13: Baseline Air-Cooled Package Unit Efficiencies

kBTU/hr	*Tons*	*EER*	*kW/ton*
<65	<5.42	11.0	1.09
>=65 and <135	>=5.42 and <11.25	11.2	1.07
>=135 and <240	>=11.25and <20	11.0	1.09
>=240 and <760	>=20 and <63.3	10.0	1.20
>=760	>=63.3	9.7	1.24

These values are for air-cooled air conditioners with electric resistance heating or no heating.

Unlike chillers, part-load efficiency curves are typically not available from package unit manufacturers. Therefore, the calculation method specified by the CA Title 24 2008 Alternative Calculation Method (ACM) Manual is used as described in the previous section on DX CRACs. The efficiency values shown here include the supply fan energy as well as the condenser fan and compressor energy.

Chillers

Chiller Efficiency

As described in the Baselines section at the beginning of this document, the efficiency of a baseline chiller that is providing chilled water in a temperature range that is typical for space cooling needs (42 to 50 ºF) is expected to meet the CA Title 24 minimum efficiency standard. The efficiency of baseline chillers that provide chilled water temperatures lower than this (for example, making ice or maintaining low humidity levels) or higher than this (for example, serving water-cooled industrial tools), are currently not addressed by this document.

Chiller manufacturers typically describe the efficiency of their products with a single number (EER, COP, or kW/ton) that corresponds to full load operation at specific conditions. Some may offer a single efficiency number that is an average over a well-defined, limited number of operating conditions (SEER or IPLV). Title 24 follows suit, by assigning minimum allowable efficiencies to chillers that are grouped by their nominal, full-load capacity (and technology type).

However, the operating efficiency of virtually all chillers varies significantly with the load imposed on them, ambient air conditions, the chilled water supply temperature setpoint, and if water-cooled, the condenser water temperature setpoint. The efficiency typically decreases as the load decreases, decreases as the chilled water supply temperature decreases, and decreases as the ambient air temperature and/or the condenser water temperature increases. The shape of this efficiency-vs-load, (performance) curve also usually differs by chiller technology type.

Furthermore, chilled water systems for high tech facilities are typically and deliberately oversized by designers, to provide redundancy and increased safety factors. Therefore, chilled water systems for high tech facilities typically operate most of the time at something less than 100% capacity.

For these reasons, it is not accurate to compare a single baseline and proposed full-load chiller efficiency values at nominal conditions to model annual chiller energy use. To accurately estimate the energy use of a given chiller, part-load chiller efficiency data must be used. These efficiency curves with the estimated load imposed by the facility, a typical meteorological year of hourly weather data appropriate for the project site, and chilled water and condenser water temperature setpoints, to determine the chiller's annual energy use.

Because Title 24 does not address part-load chiller performance, or performance at other than standard ambient conditions, several baseline chiller performance curves have been created that match Title 24 minimum efficiencies at full load and have shapes that are characteristic of the given technology type. These curves run through the same type of analysis as described in the previous paragraph to estimate the annual energy use of a baseline chiller appropriate to the project at hand.

Baseline chiller curves are modeled using single-compressor chillers.

<u>Baseline Quantity and Size of Chillers</u>
All chillers in a baseline chilled water plant are identical and rotated equally. Baseline chillers have one compressor. Cooling load is shared equally among all active chillers. The baseline chiller redundancy requirement is N+1 for data centers, if not otherwise specified in the proposed design.

Baseline chillers are selected based on the following methodology (taken from the 2008 Non-Residential Alternative Calculation Manual, page 2-107):

> The baseline system uses a minimum of two water-cooled centrifugal chillers, machines are added as required to keep the maximum single unit size at or below 1,000 tons. The chiller capacity is rounded up to the nearest 50 tons.

<u>Air-Cooled Chillers</u>
Air-cooled chillers may be baseline only for existing equipment in Retrofit and New Construction program projects or for containerized data centers. Reference the Retrofit Program and Containerized Data Center sections of this document for guidance on when this baseline is acceptable.

> <u>Chilled Water Supply Temperature Setpoint</u>
> The baseline chilled water supply temperature setpoint is 44 ºF, constant.
>
> <u>Chilled Water Loop Delta-T</u>
> The baseline chilled water loop ΔT is 10 ºF.
>
> <u>Chilled Water Flow Rate</u>
> The baseline chilled water flow rate is the ARI test standard flow rate of 2.4 GPM/ton.
>
> <u>Minimum Chiller Load Factor</u>
> The baseline minimum operable chiller load factor is 20%.

<u>Air-Cooled Chiller Efficiency</u>
The full load efficiency of a baseline air-cooled chiller at ARI Standard 550/590 test procedure conditions equals the minimum full-load efficiency requirement from the 2008 California Non-Residential Title 24 Standards. A portion of the table in which the efficiency requirement appears is provided here.

Table 14: Baseline Air-Cooled Chiller Efficiency

Equipment Type	*COP*	*kW/ton*
Air-Cooled, With Condenser, Electric	2.80	1.256

The default chiller curve formulas defined in the CA Title 24 2008 Alternative Calculation Method (ACM) Manual are used to generate part-load chiller efficiency curves at varying outside air dry bulb temperatures. The minimum 2008 Title 24 chiller efficiency shown above is applied as the full load ARI standard condition to these formulas.

Water-Cooled Chillers

Chilled Water Supply Temperature Setpoint
The baseline chilled water supply temperature setpoint is 44 ºF, constant.

Chilled Water Loop Delta-T
The baseline chilled water loop ΔT is 10 ºF.

Cold Condenser Water Temperature Setpoint
The ARI test standard is a cold condenser water temperature of 85 ºF, but 80 ºF was determined to be the typical practice in data centers. A condenser water temperature reset is required by CA Title 24, but is typically not implemented in critical facilities. The baseline cold condenser water temperature setpoint is 80 ºF, constant.

Minimum Chiller Load Factor
The baseline minimum continuously-operating chiller load factor is 20%.

Water-Cooled Chiller Efficiency

Table 15: Baseline Water-Cooled Chiller Performance (kW/ton) vs Load Factor

Load Factor	*Chiller Efficiency (kW/ton)*[9]
20%	0.824
30%	0.648
40%	0.572
50%	0.537
60%	0.522
70%	0.518
80%	0.522
90%	0.530
100%	0.542

The above chiller efficiency curves were obtained by using default chiller curve formulas found in DOE 2.2. The minimum 2008 Title 24 chiller efficiency is applied at the ARI standard condition to these formulas. The efficiency curve outputs adjusted for cold condenser water temperature = 80 °F generate the values in the above table. Note that water-cooled chillers for data centers with design IT loads less than 1 MW are not baseline for New Construction projects.

The above efficiencies implicitly assume the ARI standard condition chilled water and condenser water flow rates of 2.4 gpm/ton and 3 gpm/ton of chiller capacity, respectively.

Open Loop Cooling Towers

Efficiency
The efficiency of a cooling tower plant (measured in kW of cooling tower fan energy divided by tons of cooling provided by the entire chilled water plant) varies with ambient conditions and the cooling tower specifications. Baseline cooling tower specifications are described below.

Cold Condenser Water Temperature
The baseline cold condenser water temperature setpoint is 80 ºF.

Approach Temperature
The baseline cooling tower approach temperature to the ambient wetbulb temperature at the "nominal condition" is 10 ºF.

[9] Values were obtained by using default chiller curve formulas defined in the CA Title 24 2008 Alternative Calculation Method (ACM) Manual for a centrifugal compressor chiller and DOE2.2 coefficients for chiller efficiency and capacity.

"Nominal condition" is defined as:

- A hot condenser water temperature of 95 ºF.
- An ambient wetbulb temperature of 75 ºF.
- A condenser water flow rate equal to the maximum design flow for the given tower. (This is not necessarily the same as the *chiller's* design condenser water flow rate.)
- Fan speed = 100%.

The actual approach temperature of a given tower at any given moment will vary depending on incoming condenser water temperature and flow rate, tower fan speed, and ambient wetbulb temperature.

Motor Size

The baseline cooling tower fan motor is sized based on a target of 60 gpm/hp. To determine the baseline cooling tower fan motor size, the total tower flow rate is divided by 60 gpm/hp and rounded up to the nearest common motor size (see the Electric Motors for Fans and Pumps section).

Fan Speed

- For cooling towers with a fan motor less than 7.5 hp, the baseline tower has a constant speed, single speed fan motor.
- Title 24 2008 requires 'speed control' on all cooling towers greater than 7.5 hp. For cooling towers with a fan motor greater than 7.5 hp, the baseline tower has a VFD on the fan motor and is controlled to a constant cold condenser water temperature.

Staging

There is one baseline cooling tower per chiller. The towers are staged sequentially, not in parallel.

Closed Loop Cooling Towers

Closed loop cooling towers may be baseline only for existing equipment in Retrofit and New Construction program projects. Closed loop cooling towers are modeled the same as open loop cooling towers with the exception that closed loop cooling towers have an additional 5 ºF approach to the ambient wetbulb temperature as an open loop cooling tower at the same conditions.

Dry Coolers

Dry coolers may be baseline only for existing equipment or expansion projects where existing heat rejection uses dry coolers; dry coolers are never baseline for New Construction Projects without existing equipment. Dry coolers serving water-cooled DX units are modeled the same as open loop cooling towers, with the exception that dry coolers have a 15 ºF[10] approach to the ambient drybulb temperature instead of an

[10] This nominal approach temperature is at the dry cooler manufacturer's nominal air flow rate, nominal water flow rate, and 95 ºF ambient temperature.

approach to the ambient wetbulb temperature. The operating approach temperature will vary with the ambient drybulb temperature and air and water flow rates.

Water-Cooled DX and CRAC Units

Water-cooled DX and CRAC units may be baseline only for existing equipment in Retrofit and New Construction program projects. Water-cooled DX units and water-cooled DX CRACs operate at 2008 California Non-Residential Title 24 Standards (see table below).

Table 16: Baseline Water-Cooled DX and CRAC Unit Efficiency

kBTU/hr	*Tons*	*EER*	*kW/ton*
>240	>20	11.0	1.09

Thermal Energy Storage (TES) Systems

TES systems are not baseline. They can be configured and applied in different ways. If a TES system will be used to occasionally shed electric demand upon request from the utility, the customer should inquire with their utilities Demand Response Program regarding incentives.

If a TES system will be used regularly as part of the cooling system, the difference in annual energy use between the proposed TES system and the baseline (no TES) must be examined. Ice storage systems typically use more total annual energy, even though they can save annual cost by avoiding high-rate peak demand periods. Such a system would not be eligible for an incentive under the Customized New Construction or Customized Retrofit programs. Chilled water storage systems can be designed to save both annual energy and cost, and can therefore earn an incentive.

Heating Systems

Data centers are cooling dominated. The only need for heat is in the MUA system for preheating cold outside air, or in the CRAC or CRAH units for humidifying.

System Configuration

The following configuration applies to small and large data centers alike.

Preheat

Preheat is provided by a natural gas-fired air furnace in a Title 24-compliant air-cooled DX MUAH.

Humidification

See next section on Humidity Control Systems.

System Efficiency Metric

<u>Natural Gas-Fired Hot Water Boiler</u>

Natural gas-fired hot water boilers are not typically used in data centers and are only considered baseline in special cases (e.g. existing equipment in a New Construction program project). A baseline boiler is considered to be non-condensing with a full fire thermal efficiency of 80[11]%. For detailed calculations, the following baseline boiler performance curve for a non-condensing boiler is used:

Table 17: Baseline Hot Water Boiler Efficiency

Load Factor	Baseline Boiler Efficiency
10%	72.1%
20%	77.5%
30%	79.2%
40%	80.0%
50%	80.3%
60%	80.4%
70%	80.4%
80%	80.3%
90%	80.2%
100%	80.0%

Economizing & Heat Recovery

The baseline data center in a hybrid building (a building containing both data center and office space) does not recover heat from the data center to heat office space.

Pressure Drop

The baseline hot water pump operating conditions are described in the Hydronic Systems section.

Component Efficiency

<u>Natural Gas-Fired Boiler</u>

See System Efficiency above.

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[11] 2009 Title 20 Appliance Efficiency Regulations, Table E-3 Standards for Gas- and Oil-Fired Central Boilers and Electric Residential Boilers.

Control Sequences

The hot water supply temperature setpoint is a constant 180 °F. The HW return temperature is 140 °F.

Humidity Control Systems

For baseline RH values, refer to the table below:

Table 18: Baseline Humidity Control Parameters

ID	Name	RH Setpoint and Tolerance	Location of RH Sensor	Drybulb Temp. at RH Sensor	Average Temp. of Air Entering IT Equip.	Temp. Rise of Supply Air Before Entering IT Equip.	Dewpoint Temp. at RH Sensor
				F	F	F	F
I	Hot Aisle/Cold Aisle, Open	50% +/- 10%	Return Air Opening of CRAC	70	65	3	51
II	Hot Aisle/Cold Aisle, Ducted Return	50% +/- 10%	Cold Aisle	66	66	2	47
III	Hot Aisle/Cold Aisle, Fully Enclosed	50% +/- 10%	Cold Aisle	68	68	1	49
IV	In Row Cooling Solution	50% +/- 10%	Cold Aisle	67			48

Notes

Location of RH Sensor: For CRAC and CRAH units with humidity control capability, the RH sensor is typically located in the return air opening of the CRAC or CRAH. In Scheme I, the RH sensor is left in this location. In Schemes II, III, and IV the RH sensor is relocated to the supply air stream.

CRAC or CRAH units with on-board humidity control systems typically have the temperature and humidity sensors factory-mounted in the return air opening of the CRAC or CRAH. For Scheme I (open aisles), the sensors are left in this position.

For Schemes II and III, baseline practice is to relocate the CRAC or CRAH temperature and humidity sensors to a cold aisle, or to install additional temperature and humidity sensors in the cold aisles and disable the original CRAC or CRAH sensors. The aisle-mounted sensors control the CRAC or CRAH humidity.

For Scheme IV, the humidity sensor is located in the supply air stream.

System Configuration

Dehumidification

In baseline data centers, the MUAH is assumed to not provide active humidity control. Only default latent cooling occurs, due to the temperature of the cooling coil in the MUAH. Humidity control is provided by the CRAC or CRAH units.

Dehumidification is accomplished by cooling the return air stream, not by desiccant systems.

Small Data Centers
Dehumidification is accomplished by condensation on the CRAC DX coil.

Large Data Centers
Dehumidification is accomplished by condensation on the CRAH chilled water coil.

A single chilled water plant provides the chilled water supply temperature necessary to accomplish dehumidification requirements; this chilled water supply temperature is served to all cooling coils in the facility, even if they are not called upon to perform dehumidification.

The chilled water supply temperature setpoint is constant, set at a value to ensure the relative humidity of the return air never exceeds the upper limit.

Reheat

The baseline data center does not employ reheat. The baseline RH upper limit is high enough that the temperature of the supply air after dehumidifying is close to the nominal supply air temperature when not dehumidifying.

Humidification

A humidifier is considered baseline equipment in both small and large data centers. It uses electric resistance heat to boil water. This includes infrared lamps.

Adiabatic humidifiers (evaporative, ultrasonic, etc) are not baseline.

System Efficiency Metrics

Dehumidification

The efficiency of this process is determined by the efficiency of the cooling system.

Reheat

No reheat – not applicable.

Humidification

The baseline humidifier uses 0.33 kWh to produce 1 pound of steam. This is the amount of energy required to isobarically bring one pound of 60 ºF liquid water at atmospheric pressure to 212 ºF saturated water vapor.

Economizing & Heat Recovery

Hot gas bypass is not used as a heat source for reheat or humidification in baseline DX CRAC units.

Component Efficiency

See System Efficiency Metrics, above.

Control Sequences

Each CRAC or CRAH unit controls RH independently. (In practice, there may be only a subset of CRAC or CRAH units programmed for active humidity control.) Independent RH control often leads to an energy-wasting struggle among the CRAC or CRAH units, but this does not occur in the analysis model of the baseline data center.

Electrical

Electric Motors for Fans and Pumps

Refer to the tables below for motor baseline efficiencies, given as a percentage. The tables below are from EISA 2007: NEMA MG-1, Table 12-11 and Table 12-12. Federal legislation on December10, 2010, specified the minimum efficiencies in the tables below. The baseline motor is Open Drip-Proof (ODP), 1200 rpm for motors located indoors and Totally Enclosed Fan-Cooled (TEFC), 1200 rpm for motors located outdoors.

Table 19: Baseline Subtype I Motor Efficiencies

Open Drip-Proof (ODP)				
460 V				
Nominal Motor hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
1	77.0	85.5	82.5	
1.5	84.0	86.5	86.5	
2	85.5	86.5	87.5	
3	85.5	89.5	88.5	
5	86.5	89.5	89.5	
7.5	88.5	91.0	90.2	
10	89.5	91.7	91.7	
15	90.2	93.0	91.7	
20	91.0	93.0	92.4	
25	91.7	93.6	93.0	
30	91.7	94.1	93.6	
40	92.4	94.1	94.1	
50	93.0	94.5	94.1	
60	93.6	95.0	94.5	
75	93.6	95.0	94.5	
100	93.6	95.4	95.0	
125	94.1	95.4	95.0	
150	94.1	95.8	95.4	
200	95.0	95.8	95.4	

Totally Enclosed Fan-Cooled (TEFC)				
460V				
Nominal Motor hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
1	77.0	85.5	82.5	
1.5	84.0	86.5	87.5	
2	85.5	86.5	88.5	
3	86.5	89.5	89.5	
5	88.5	89.5	89.5	
7.5	89.5	91.7	91.0	
10	90.2	91.7	91.0	
15	91.0	92.4	91.7	
20	91.0	93.0	91.7	
25	91.7	93.6	93.0	
30	91.7	93.6	93.0	
40	92.4	94.1	94.1	
50	93.0	94.5	94.1	
60	93.6	95.0	94.5	
75	93.6	95.4	94.5	
100	94.1	95.4	95.0	
125	95.0	95.4	95.0	
150	95.0	95.8	95.8	
200	95.4	96.2	95.8	

Table 20: Baseline Subtype II Motor Efficiencies

Open Drip-Proof (ODP)				
460 V				
Nominal Motor hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
1		82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5
2	84.0	84.0	85.5	85.5
3	84.0	86.5	86.5	86.5
5	85.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5
10	88.5	89.5	90.2	89.5
15	89.5	91.0	90.2	89.5
20	90.2	91.0	91.0	90.2
25	91.0	91.7	91.7	90.2
30	91.0	92.4	92.4	91.0
40	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4
75	93.0	94.1	93.6	93.6
100	93.0	94.1	94.1	93.6
125	93.6	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6
200	94.5	95.0	94.5	93.6
250	94.5	95.4	95.4	94.5
300	95.0	95.4	95.4	
350	95.0	95.4	95.4	
400	95.4	95.4		
450	95.8	95.8		
500	95.8	95.8		

Totally Enclosed Fan-Cooled (TEFC)				
460V				
Nominal Motor hp	3600 rpm	1800 rpm	1200 rpm	900 rpm
1	75.5	82.5	80.0	74.0
1.5	82.5	84.0	85.5	77.0
2	84.0	84.0	86.5	82.5
3	85.5	87.5	87.5	84.0
5	87.5	87.5	87.5	85.5
7.5	88.5	89.5	89.5	85.5
10	89.5	89.5	89.5	88.5
15	90.2	91.0	90.2	88.5
20	90.2	91.0	90.2	89.5
25	91.0	92.4	91.7	89.5
30	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.0
100	93.6	94.5	94.1	93.0
125	94.5	94.5	94.1	93.6
150	94.5	95.0	95.0	93.6
200	95.0	95.0	95.0	94.1
250	95.4	95.0	95.0	94.5
300	95.4	95.4	95.0	
350	95.4	95.4	95.0	
400	95.4	95.4		
450	95.4	95.4		
500	95.4	95.8		

VFDs

Efficiency

VFD efficiency is not constant over the operable speed range of the controlled fan or pump[12]. The table below is an adaptation of the chart published on page 43.13 in the 2008 ASHRAE Handbook and is considered baseline practice.

Table 21: VFD Efficiency vs Design Speed

Design Speed, %	Efficiency, %
10	88
20	91
30	93
40	94
50	96
60	97
70	98
80	98
90	98
100	98

Turndown Limit

For new VFD compatible motors with new VFDs, there is no practical turndown limit. For systems with older motors or older VFDs, the baseline VFD turndown limit is 12 Hz (20%).

Uninterruptible Power Supply (UPS)

The baseline UPS system is battery-based, double-conversion, non-switching (all power to the devices supported by the UPS flows through the UPS battery system.) Baseline loading depends on the redundancy requirement of the proposed system.

The baseline efficiency curve depends on the size of the UPS. The baseline efficiency criteria for each module of a UPS system are as follows:

[12] *2008 ASHRAE Handbook-HVAC Systems and Equipment, page 43.13.*

Table 22: Baseline UPS Efficiencies[13]

UPS Size	% Load			
	25%	50%	75%	100%
kVA < 20	86.3%	89.1%	90.1%	90.2%
20 <= kVA <= 100	88.5%	90.5%	91.3%	91.9%
kVA > 100	89.8%	93.0%	93.5%	93.8%

For UPS units running at less than 25% load factor, use the efficiency at 25% load factor in energy savings calculations. UPS efficiency is not linear. To interpolate UPS efficiency for load factors not shown in the table above. The following equation should be used:

$$\text{effic} = a + b*LF + c*LF^2 + d*LF^3$$

where
effic = UPS efficiency
LF = load factor
a, b, c, d = efficiency coefficients

Table 23: UPS Efficiency Curve Coefficients

UPS Size	Efficiency Coefficient			
	a	b	c	d
kVA < 20	0.808	0.286	-0.288	0.096
20 <= kVA <= 100	0.843	0.225	-0.256	0.107
kVA > 100	0.814	0.473	-0.616	0.267

Different data centers have different requirements for UPS run-time in the event of a power outage. The baseline run-time requirement is set to match the requirement of the proposed data center. In the baseline case, the run-time requirement is met by adjusting the number of storage batteries, not by changing the baseline power output capacity of the UPS inverter.

Baseline Quantity and Size of UPS Modules

For UPS systems with capacities greater than or equal to 100kVA, the baseline UPS system is determined as follows:

1. Determine the fewest number of UPS modules that meet the design load.
2. Apply the baseline safety factor (1.20) and the redundancy required by the proposed facility.

[13] Average values based on published UPS efficiency data compiled from prominent UPS manufacturers and Environmental Protection Agency data used in Energy Star performance criteria.

3. A power factor equal to the proposed power factor is used to size baseline UPS modules.

The largest baseline UPS capacity is 750kVA, based on commonly available UPS sizes.

Baseline UPS units are identically-sized and are operated in parallel; all UPS modules, including redundant units, run at all times and serve an equal portion of the load.

UPS Cooling

Baseline UPS systems are located in a separate electrical room served by the same cooling system type (CRAH/CRAC) as the data center. The UPS cooling system operates at the parameters shown in the table below.

Table 24: Baseline UPS Cooling Air System Parameters

Air Distribution Type	Return Air Drybulb Temp. Setpoint	Supply Air Temp.	Airside Delta-T	RH Setpoint and Tolerance	Airflow Efficiency Metric	Operating CRAC/H Airflow Capacity	Cooling Capacity per unit at Baseline Conditions		Total Static Pressure
							CRAC	CRAH	
	F	F	F		cfm/kW	cfm	Tons	Tons	in. w.g.
Open Supply/ Return	70	62	8	50% +/- 10%	1,536	16,800	25	23	2.75

Transformers

The baseline transformer efficiency is equivalent to the minimum efficiency allowed in the California Electrical Code Appliance Efficiency Regulations[14]. It should be noted that these standards hold for low-voltage, dry-type transformers manufactured on or after January 1, 2007, and for medium-voltage, dry-type and liquid-type transformers manufactured on or after January 1, 2010. The baseline efficiency criteria are as follows:

[14] This baseline document references Tables T-3, T-4, and T-5 in CEC 2009. Previous versions of this baselines document referenced NEMA as the baseline, but CEC 2009 requires slightly higher efficiencies for both dry- and liquid-type transformers.

Table 25: Baseline CEC Class 1 Efficiency Levels for Liquid-Type Distribution Transformers

Reference Condition		Temperature	Percent of Nameplate Load
Load Loss		55 C	50%
No Load Loss		20 C	50%
kVA	Single Phase Efficiency	kVA	Three Phase Efficiency
10	98.6	15	98.4
15	98.8	30	98.6
25	98.9	45	98.8
37.5	99.0	75	98.9
50	99.1	112.5	99.0
75	99.2	150	99.1
100	99.2	225	99.2
167	99.3	300	99.2
250	99.3	500	99.3
333	99.4	750	99.3
500	99.4	1000	99.4
667	99.5	1500	99.4
833	99.5	2000	99.5
		2500	99.5

Table 26: Baseline CEC Class I Efficiency Levels for Dry-Type Distribution Transformers

Single phase efficiency					Three phase efficiency				
BIL kVA	Low Voltage (35% Load)	Med Voltage (50% Load)			BIL kVA	Low Voltage (35% Load)	Med Voltage (50% Load)		
		20-45 kV	46-95 kV	>=96 kV			20-45 kV	46-95 kV	>=96 kV
15	97.7	98.1	97.9		15	97.0	97.5	97.2	
25	98.0	98.3	98.1		30	97.5	97.9	97.6	
38	98.2	98.5	98.3		45	97.7	98.1	97.9	
50	98.3	98.6	98.4		75	98.0	98.3	98.1	
75	98.5	98.7	98.6	98.5	113	98.2	98.5	98.3	
100	98.6	98.8	98.7	98.6	150	98.3	98.6	98.4	
167	98.7	99.0	98.8	98.8	225	98.5	98.7	98.6	98.5
250	98.8	99.1	99.0	98.9	300	98.6	98.8	98.7	98.6
333	98.9	99.1	99.0	99.0	500	98.7	99.0	98.8	98.8
500		99.2	99.1	99.1	750	98.8	99.1	99.0	98.9
667		99.3	99.2	99.2	1,000	98.9	99.1	99.0	99.0
833		99.3	99.2	99.2	1,500		99.2	99.1	99.1
					2,000		99.3	99.2	99.2
					2,500		99.3	99.2	99.2
Standards apply for low-voltage dry-type transformers manufactured on/after January 1, 2007, and for medium-voltage dry-type transformers manufactured on/after January 1, 2010.									

For transformers of capacities not covered in these tables, efficiency values can be linearly interpolated or extrapolated.

Servers

High Voltage Service to Server Power Supply

In the United States, the standard electric service to servers in data centers is 110-120V. Most servers are capable of operating in the range 100 – 240 V AC. Baseline servers operate at 120V.

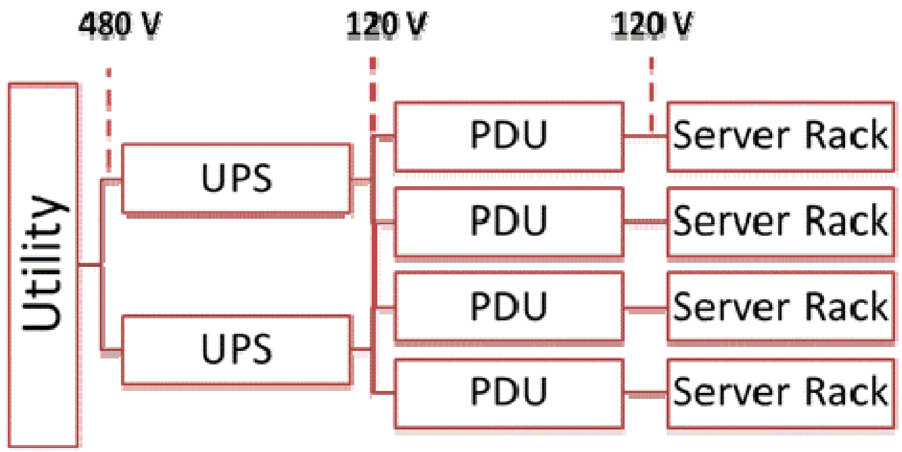

Figure 1: Data Center Typical Power Distribution

Telecom Facilities

Large telecom facilities, also known as Central Offices, predominantly contain IT equipment (e.g. switching gear) and are largely unoccupied. Small telecom facilities are typically referred to as Radio Base Station (RBS) remote cellular telephone sites. The previous information in this document applies to all telecom facilities, with the following **exceptions**.

Envelope Loads

Envelope loads may be significant in telecom and RBS cellular sites and may be included in the energy analysis. For a simplified envelope load model, refer to the Loads section in this document.

Humidity Control

For all telecom facilities, it is typical practice to have no active humidity control and no humidifier. The humidity control range in Table 5: Baseline Air Management Schemes does not apply to all telecom facilities.

Economizing & Heat Recovery

Air-side economizers for all telecom facilities are considered standard practice. If an existing telecom facility is not served by air side economizing, then energy savings due to adding an operable air side economizer is eligible for an incentive.

Small Telecom Facilities (RBS Cellular Telephone Sites)

Air Management Schemes
Baseline RBS cellular sites operating in Air Management Scheme I do not have equipment arranged in hot and cold aisles.

Recirculation Air and Cooling System
For RBS cellular sites with up to and including 20 kW total design IT load, air-cooled DX split systems or package units are baseline. Supply fans are single speed. Split system supply fans cycle with the compressor (i.e. split system supply fans are on when the compressor is on, and split system supply fans are off when the compressor is off).

RBS cellular sites do not have greater than 20 kW total design IT load. Telecom facilities with greater than 20 kW total design IT load are considered Large Telecom Facilities.

Ventilation Rate
RBS cellular sites do not provide ventilation air mechanically, unless the proposed site is occupied and requires ventilation air. If the proposed site is occupied and requires ventilation air, then the baseline RBS site mechanically provides 0.15 cfm/sf of outside air to the space.

Large Telecom Facilities (Central Offices)

Recirculation Air System
For all non-RBS cellular site telecom facilities, chilled water air handlers with constant speed supply fans are baseline.

Cooling System
For non-RBS cellular site telecom facilities with up to and including 1 MW total design IT load, air-cooled chillers are baseline.

For non-RBS cellular site telecom facilities with greater than 1 MW total design IT load, a water-cooled chilled water plant is baseline.

Rectifiers

Rectifiers serve a constant equipment load. Baseline rectifiers are identically-sized and are operated in parallel. All rectifiers, including redundant units, run at all times and serve an equal portion of the equipment load. The following table and graph show baseline rectifier efficiency values at various load factors. Efficiency values should be linearly interpolated for load factors not listed in the table below.

Table 27: Baseline Rectifier Efficiency

Load Factor	Efficiency
0%	74.50%
10%	81.60%
20%	88.06%
30%	91.35%
40%	92.34%
50%	92.75%
60%	92.87%
70%	92.91%
80%	92.81%
90%	92.62%
100%	92.35%

Containerized Data Centers

The baseline containerized data center is described below. Proposed containerized data center systems may be considered for incentives based on the incremental energy savings, demand reduction, and implementation cost as compared to the baseline containerized data center, on a case by case basis.

Air Management

Baseline containerized data centers contain server racks arranged in hot and cold aisles and in-row chilled water fan coils operating with the baseline parameters for Air Management Scheme IV: In-Row Cooling Solution described in Table 5: Baseline Air Management Schemes.

Cooling System

Baseline containerized data centers are served by chilled water plants subject to the efficiency requirements and operating parameters outlined in the Cooling Systems section of this document.

Exceptions:

- For containerized data center full build-out IT loads of 1 MW or less, the baseline chilled water plant uses air-cooled chillers.
- For containerized data center full build-out IT loads of more than 1 MW, the baseline chilled water plant uses water-cooled chillers.

Humidity Control

Baseline containerized data centers use electric humidifiers to control the lower humidity limit, and latent cooling at the cooling coils to control the upper humidity limit. Baseline containerized data centers use the baseline humidity limit values outlined for Air Management Scheme IV described in Table 18: Baseline Humidity Control Parameters. A baseline containerized data center humidifier uses 0.33 kWh to produce 1 pound of steam. This is the amount of energy required to isobarically bring one pound of 60 ºF liquid water at atmospheric pressure to 212 ºF saturated water vapor.

Calculation Assumptions

The following items are ***not*** baseline targets. Some of them are average values reflecting typical practice. Other items describe standard calculation procedures.

Commercial Space Load

To accurately model the performance of a chilled water plant that serves a hybrid building (or multiple buildings), it is necessary to account for the load imposed on the plant by the commercial space. If the commercial space is not being analyzed separately with EnergyPro or similar software, the following parameters are assumed:

Table 28: Commercial Space Parameters

Typical occupant density (floor area per person)	150 sf
Typical office occupancy	8 am to 6 pm, M-F
Typical supply air temperature in cooling mode	55 degF
Typical return air temperature	72 degF

Table 29: Commercial Space Loads

<table>
<tr><td rowspan="3"></td><td colspan="3">Loads</td><td colspan="2" rowspan="2">Rates</td><td colspan="2">Load Densities</td></tr>
<tr><td colspan="2">Per Person</td><td>Density</td><td colspan="2">Watts/sf</td></tr>
<tr><td>BTU</td><td>Watts</td><td>Watts/ sf</td><td>Occupied</td><td>Unoccupied</td><td>Occupied</td><td>Unoccupied</td></tr>
<tr><td>People</td><td>250</td><td>73</td><td>0.5</td><td>100%</td><td>0%</td><td>0.5</td><td>0.00</td></tr>
<tr><td>Office Equipment</td><td colspan="2"></td><td>0.5</td><td>100%</td><td>20%</td><td>0.5</td><td>0.10</td></tr>
<tr><td>Lights (incl. task lights)</td><td colspan="2"></td><td>1.2</td><td>100%</td><td>20%</td><td>1.2</td><td>0.24</td></tr>
<tr><td>Total</td><td colspan="5"></td><td>2.2</td><td>0.34</td></tr>
</table>

Cooling System Performance

Chiller Performance as a function of Chilled Water Supply Temperature, Condenser Water Supply Temperature

The efficiency of water-cooled chillers increases by 1.1% for every 1 ºF drop in condenser water temperature, and increases by 1.0% for every 1 ºF increase in chilled water supply temperature. This rule of thumb is used to modify chiller performance curves to match proposed operating conditions, in cases where the chiller manufacturer is unable to provide us with chiller performance data at those conditions.

Chiller Capacity as a function of Chilled Water Supply Temperature, Condenser Water Supply Temperature

The *capacity* of water-cooled chillers also increases, about 1.5% for every 1 ºF decrease in chiller lift, as compared to the chiller's capacity & lift at nominal conditions.
This can be seen in chiller selection software. There is of course a practical limit to this rule of thumb, as every chiller has a minimum allowed operating lift.

Performance at Part Load

Affinity Law

It is a common practice to use the Affinity Law to model the part-load power draw of a centrifugal pump or fan. The Affinity Law describes the relationship between flow rate and power demand as

$$\frac{kW_1}{kW_2} = \left(\frac{gpm_1}{gpm_2}\right)^n \quad \text{OR} \quad \frac{kW_1}{kW_2} = \left(\frac{cfm_1}{cfm_2}\right)^n$$

where kW = the shaft brake power of the pump or fan, and n = 3.0.

However, the Affinity Law is not a law, it is merely a calculation tool. It applies only in a narrow, theoretical case, because it assumes:

- Fully turbulent flow.
- An incompressible fluid.
- No "system effects".
- A closed loop that does not change shape (no modulating valves or dampers).
- When the flow goes to zero, the brake power goes to zero (no constant static head or pressure setpoint).
- Constant pump/fan efficiency.

Most real-world pump and fan systems do not meet all these criteria. The Affinity Law can still be applied in many cases, but it must be modified to better represent the situation. A common method is to reduce the exponent n. The recommended exponents to use are as follows.

For Systems of Fixed Geometry

	Air/Water Loop is:		
	Fully or Mostly Closed	Semi-Closed	Mostly or Fully Open
Fixed Geometry	2.4	2.2	2.0

For Systems of Variable Geometry

	The Pressure Setpoint is this percent of the Total Static Pressure at Maximum Flow			
	20% or Less	Greater than 20%, Less than 50%	Greater than 50%, Less than 80%	80% or More
Constant Pressure Setpoint	2.4	2.0	1.5	1.0
Variable Pressure Setpoint	2.4			

Explanation of Terms

Geometry	This refers to the shape and dimensions of the path the fluid moves through – pipes, ducts, valves, dampers, filters, grills, etc.
Fixed Geometry	A system of fixed geometry has no moving parts other than the pump or fan. A chilled water system with 3-way valves at the cooling coils is also treated as fixed geometry.
Closed vs Open Systems	In a closed system the working fluid is entirely contained by pipes/ducts and other fittings, all of which provide some significant resistance to flow. A completely open system consists of just the fan or pump, with no appreciable external resistance to flow.
Examples of Fully or Mostly Closed Systems	• Chilled water pumping system. • Contained, in-cabinet IT cooling systems.
Examples of Semi-Closed Systems	• Condenser water loop serving open cooling towers. • CRACs/CRAHs serving enclosed hot/cold aisles.
Examples of Mostly or Fully Open Systems	• CRACs/CRAHs serving an unobstructed underfloor plenum, open aisles, open returns.

Variable Geometry	A system of variable geometry has automatically-controlled components that modulate during operation and affect the resistance to flow. Examples: • A chilled water system serving cooling coils equipped with automatically controlled 2-way valves. • An air distribution system equipped with automatically controlled volume dampers.
Pressure Setpoint	This refers to a point in the system, remote from the pump or fan, that is maintained at a specific pressure during operation. In a pump system, this may be due simply to the physical configuration (for example, pumping water uphill to an open reservoir). More commonly, the setpoint is maintained by means of a pressure sensor and a control system.
Constant Pressure Setpoint	The pressure setpoint is maintained at a constant value during system operation.
Variable Pressure Setpoint	The pressure setpoint is automatically reset during system operation, such that the setpoint is lower when less flow is needed.

Abbreviations

ACH	Air changes per hour.
AHU	Air handling unit.
ASHRAE	American Society of Heating, Refrigeration, and Air-conditioning Engineers.
BTU	British Thermal Unit.
CCW	Cold condenser water.
CCWT	Cold condenser water temperature.
CFM	Cubic feet per minute.
CHW	Chilled water.
CHWR	Chilled water return.
CHWRT	Chilled water return temperature.
CHWS	Chilled water supply.
CHWST	Chilled water supply temperature.
CNC	Customized New Construction.
CR	Customized Retrofit.
CRAC	Computer room air conditioner.
CRAH	Computer room air handler.
CW	Condenser water.
dP	Delta-P (pressure difference).
dT	Delta-T (temperature difference).
DB	Drybulb.
DP	Dewpoint.
DX	Direct expansion.
EER	Energy efficiency ratio.
FFU	Fan filter unit.
HCW	Hot condenser water.
HCWT	Hot condenser water temperature.
HEPA filter	High efficiency particulate air filter.
HHW	Heating hot water.
HVAC	Heating, ventilation, and air conditioning.
HW	Hot water.
HX	Heat exchanger.
IPLV	Integrated part load value.
MUA	Makeup air.
MUAH	Makeup air handler.
OA	Outside air.
OAT	Outside air temperature.
ODP	Open drip-proof.
PUE	Power Utilization Effectiveness.
RAT	Return air temperature.
RH	Relative humidity.
SAT	Supply air temperature.
TSP	Total Static Pressure
UPS	Uninterruptible power supply.
VAV	Variable air volume.
VFD	Variable frequency drive.
WB	Wetbulb.
in. w.g.	Inches of water gauge.