“DC Pro” Data Center On-Line Profiling Tool

Calculation Reference Manual

This manual describes DC Pro v3.0.

July 28, 2014

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Contents

Appendices

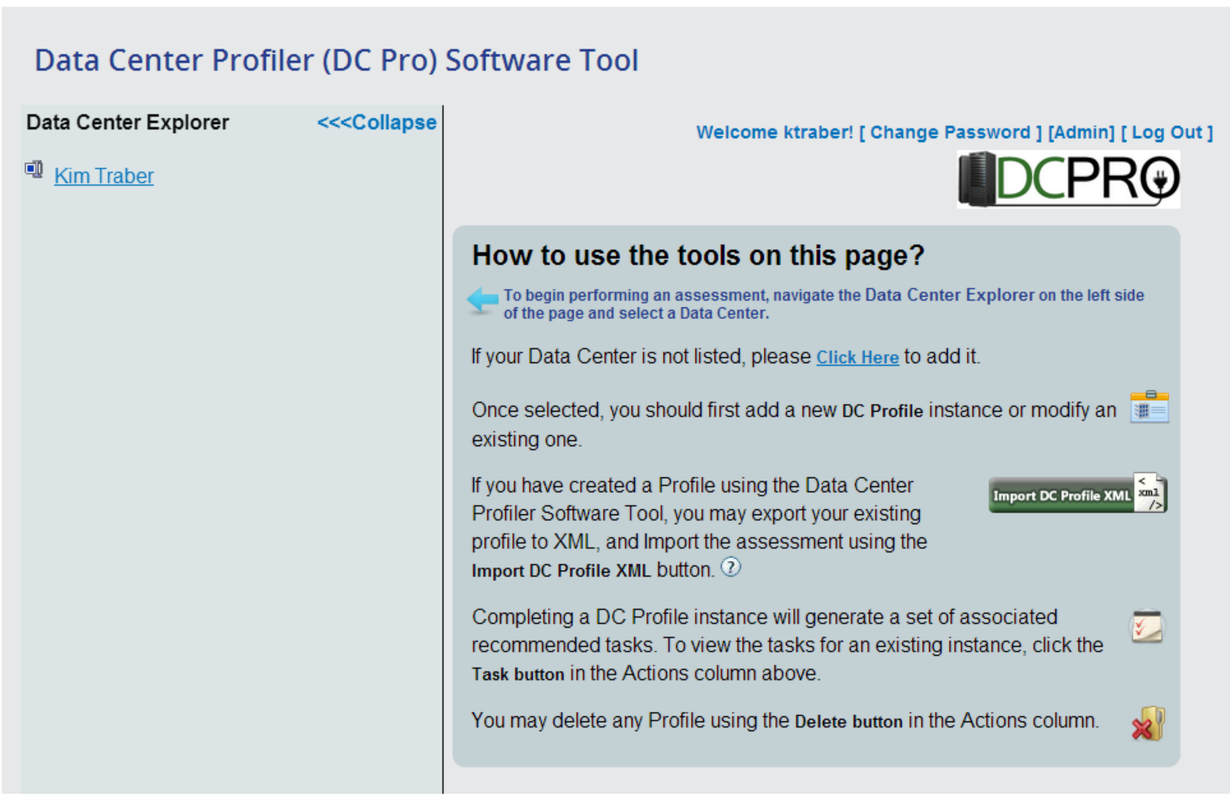
Purpose of This Manual

The intent of this manual is to give users of the Profiling Tool an understanding of how the Profiling Tool's results are generated.

Initial Screen

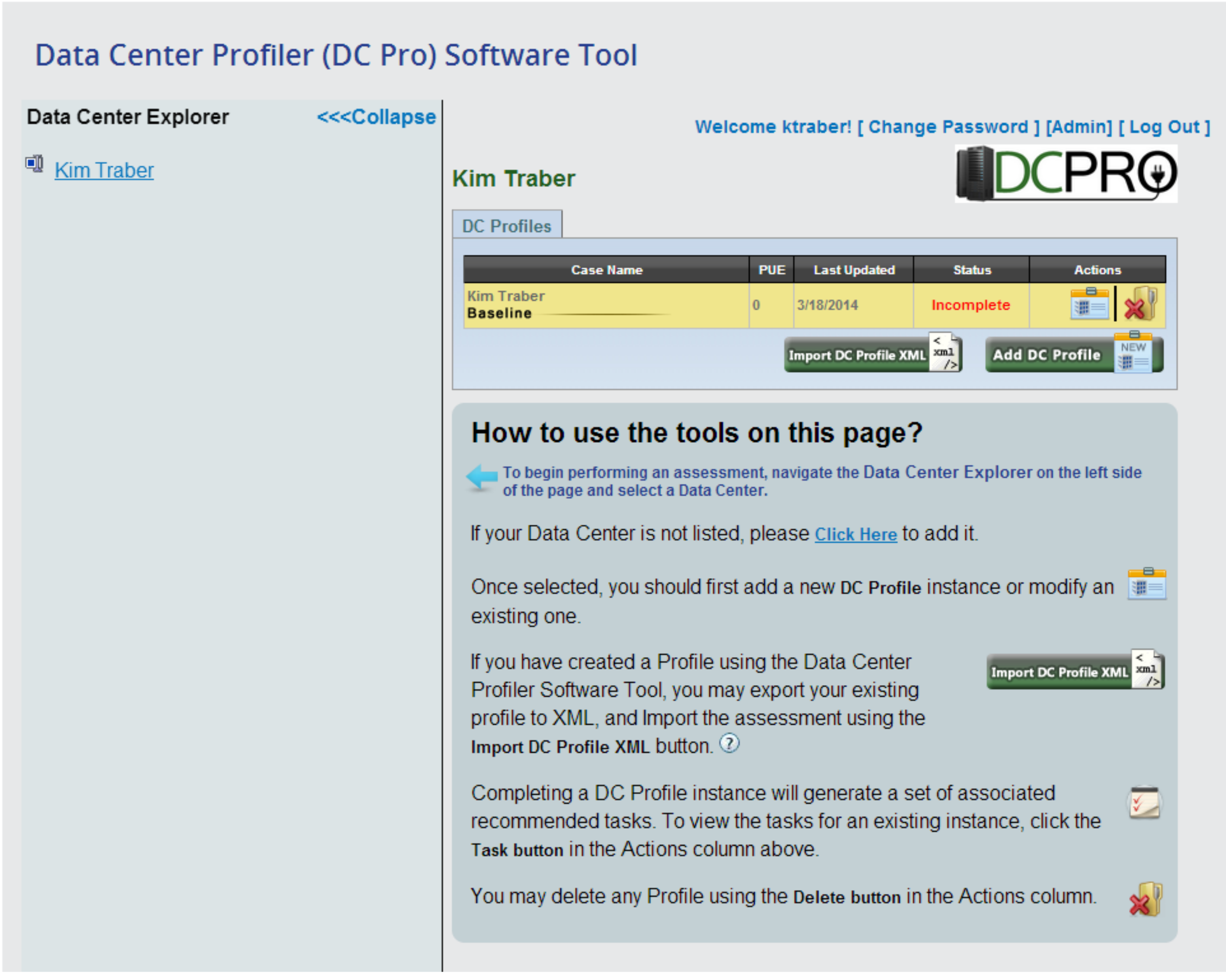
After signing on to DC Pro v3, the initial screen shown in Figure 1 is presented. The list of data centers will vary according to user.

Figure 1. Initial Screen



Click on the data center of interest from the list in the left column. The screen shown in Figure 2 is presented. The list of profiles will vary according to the data center selected. Select an existing profile to modify, or create a new profile.

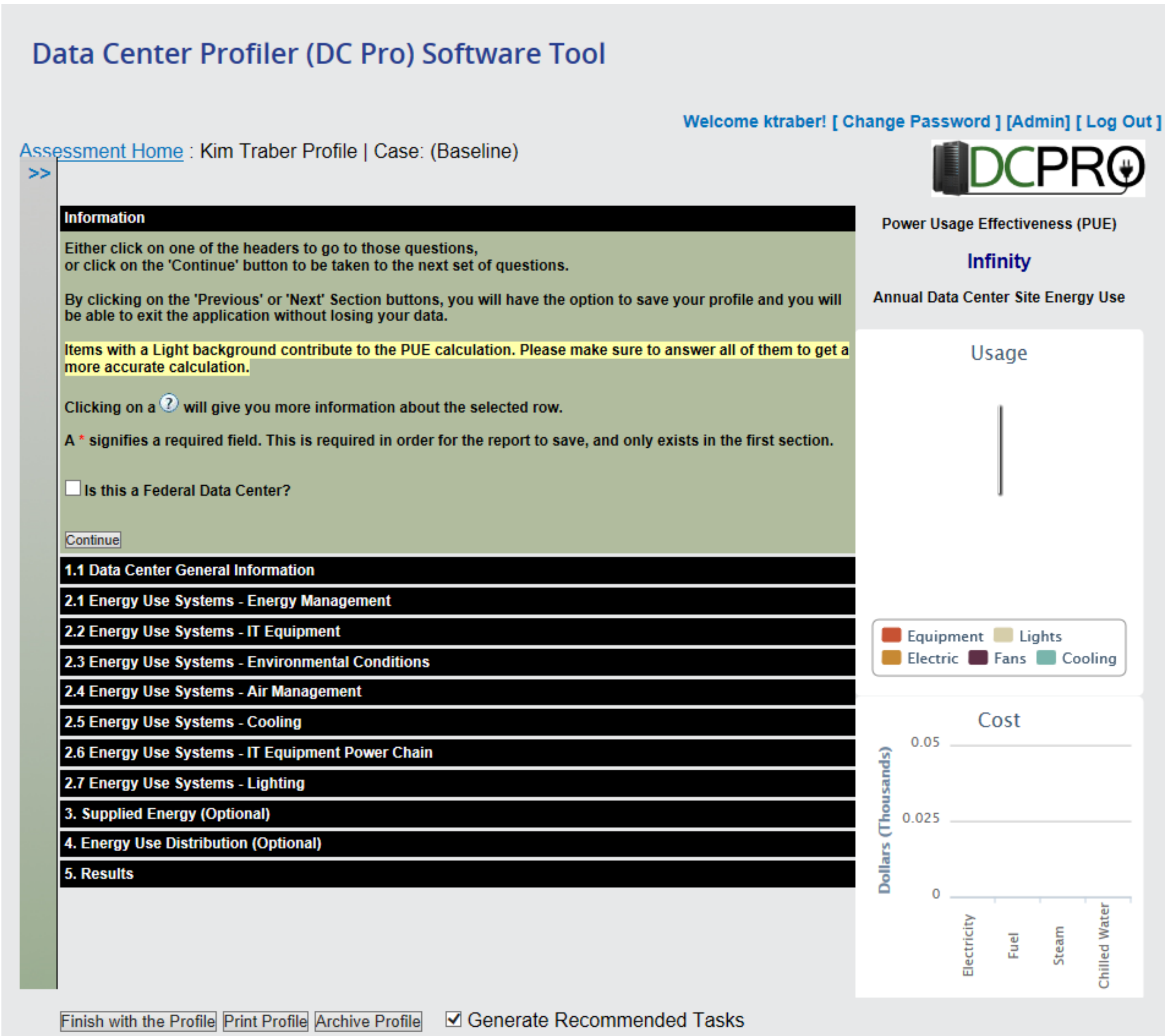
Figure 2. Create/Select the Profile



Main Screen

There are three elements on the main screen – a list of Profiler steps on the left, a performance summary on the right, and a row of options at the bottom.

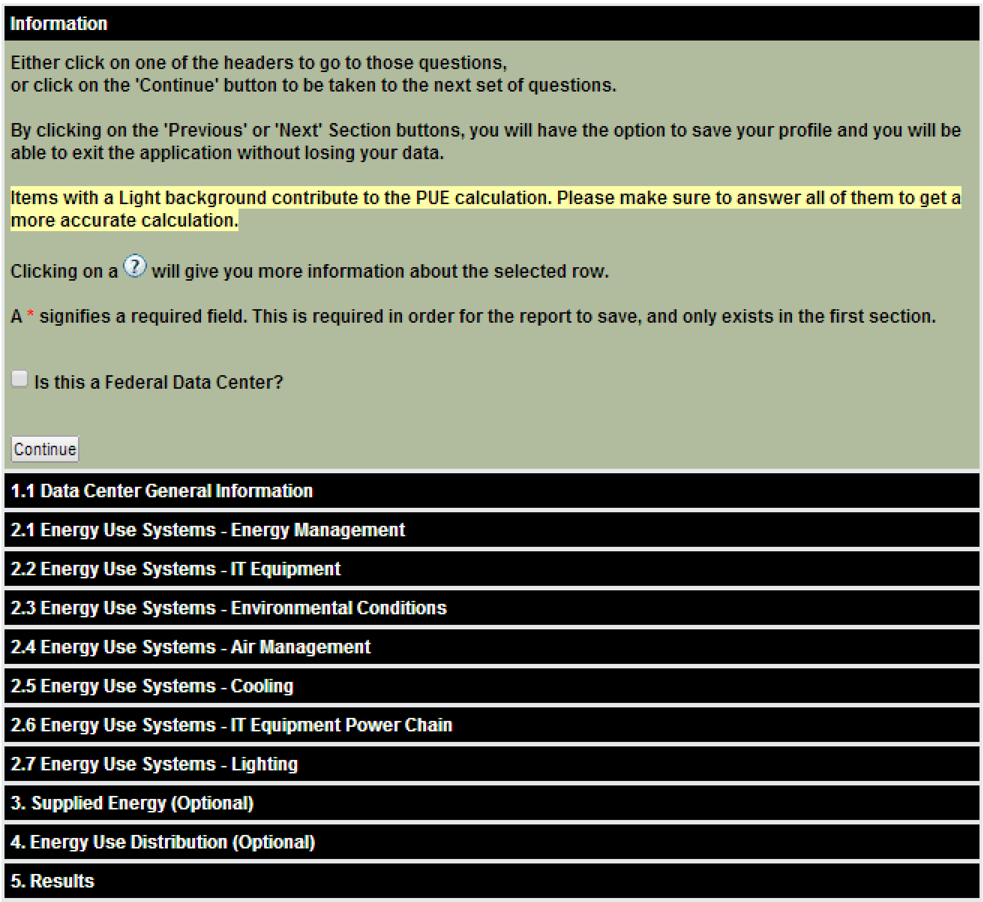
Figure 3. Main Screen



Profiler Steps

To see the detail for each step, click on the name of the step. The activity performed in each step is described in detail in the Six Steps section of this document.

Figure 4. Profiler Steps



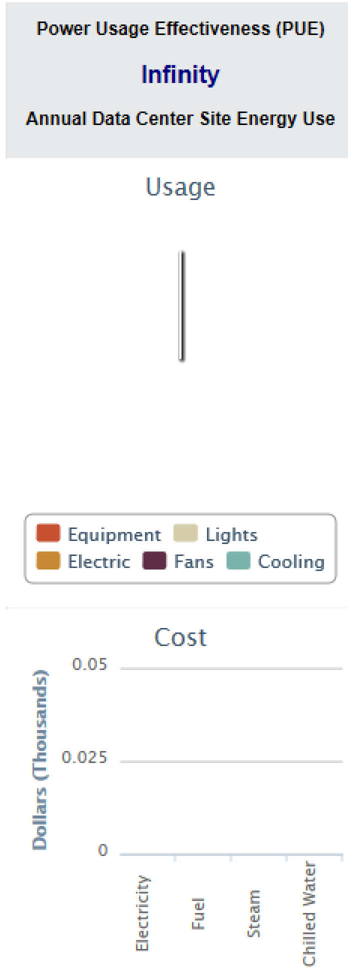
Performance Summary

The right side of the main screen has three objects that are updated automatically each time the user makes a change to specific data entry questions. The objects are:

1. Power Usage Effectiveness (PUE). This is presented as a number.
2. A pie chart called "Usage", showing relative energy use in each of five end-use categories.
3. A column chart called "Cost", showing the annual dollar cost of each of four types of energy.

When starting a new profile for a data center, the performance summary first appears as shown in Figure 5. Information needs to be entered in Steps 1 and 2 before DC Pro can present a meaningful performance summary.

Figure 5. Performance Summary: Initial



Power Usage Effectiveness (PUE)

The annual average Power Utilization Effectiveness of the data center is calculated as:

> (IT Energy Use + Lighting Energy Use + Electric Distribution Loss + Fans Energy Use + Cooling & Humidity Control Energy Use) / (IT Energy Use)

Only the data entry questions with a light background, in Steps 1 and 2, affect the PUE calculation.

The Profiler displays the PUE to nearest 0.01, but this should NOT be taken as an indication of accuracy of the tool. It is a ROUGH tool. The PUE is shown to this precision simply to provide feedback to the user when he changes the answers to questions that affect the PUE calculation.

Annual Data Center Energy Use

Usage

Only the data entry questions with a light background, in Steps 1 and 2, affect the Usage pie chart. If the user does not enter any information in Steps 3 and 4, then the pie chart reflects default, pre-calculated, estimated energy end-use breakouts. If the use enters information in Steps 3 and 4 (defining the breakouts based on meter data), then the pie chart reflects that information instead.

Pie Chart Legend	Description
Equipment	IT equipment.
Lights	Lights.
Electric	Electric distribution system loss.
Fans	Cooling system fan energy.
Cooling	All cooling and humidity control system components, other than the fans.

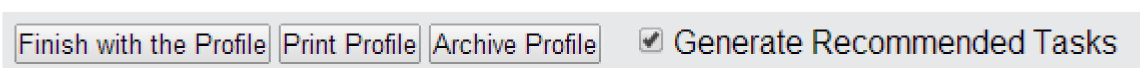
Cost

This chart is populated only if the user enters energy cost data in Step 3.

Options

The bottom of the Main Screen presents four options.

Figure 6. Profile Options



Finish with the Profile

The user can select this option at any time. The data entered in the current session will be saved, and can be recalled later for further editing.

Print Profile

This option allows the user to print the current profile, in table form.

Archive Profile

This option saves the profile, and prohibits further editing of the profile.

Generate Recommended Tasks

If box is checked when the user selects Finish with the Profile, then the Profiler will present a list of recommended actions to take, based on the user's answers to all of the data entry questions in Steps 1 and 2. See Appendix E for details on how each action is presented or not presented.

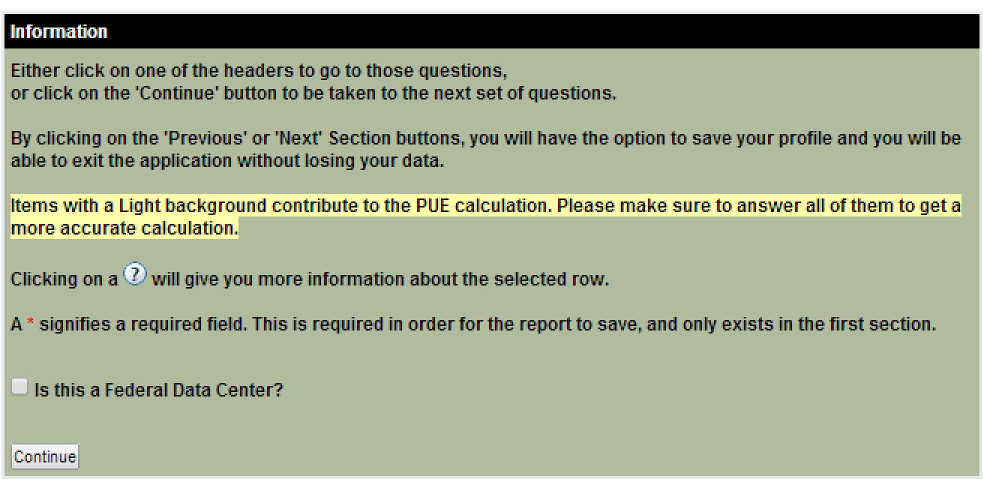
Six Steps

The Profiler has six major steps.

Step Zero – Federal Data Center	Asks the user to identify the data center as federal or not federal.
Step 1 – Data Center General Information	The user provides basic information about the data center.
Step 2 - Energy Use Systems	Questionnaire, and calculation of the Default energy end-use breakouts.
Step 3 - Supplied Energy	Optional step. Allows user to enter energy meter readings.
Step 4 - Energy Use Distribution	Optional step. Allows user to distribute the readings entered in Step 3, among the data center energy end-use categories.
Step 5 - Results	Presents the results of the Profiler's calculations.

Step Zero – Federal Data Center

Figure 7. Federal Data Center



There is one data entry field on this screen: "Is this a Federal Data Center?" (yes/no).

Step 1 – Data Center General Information

The Profiler allows users to define and edit multiple data centers. The user defines his data centers in Step 1. Basic information is asked for – data center name, location, floor area, and type.

User Inputs

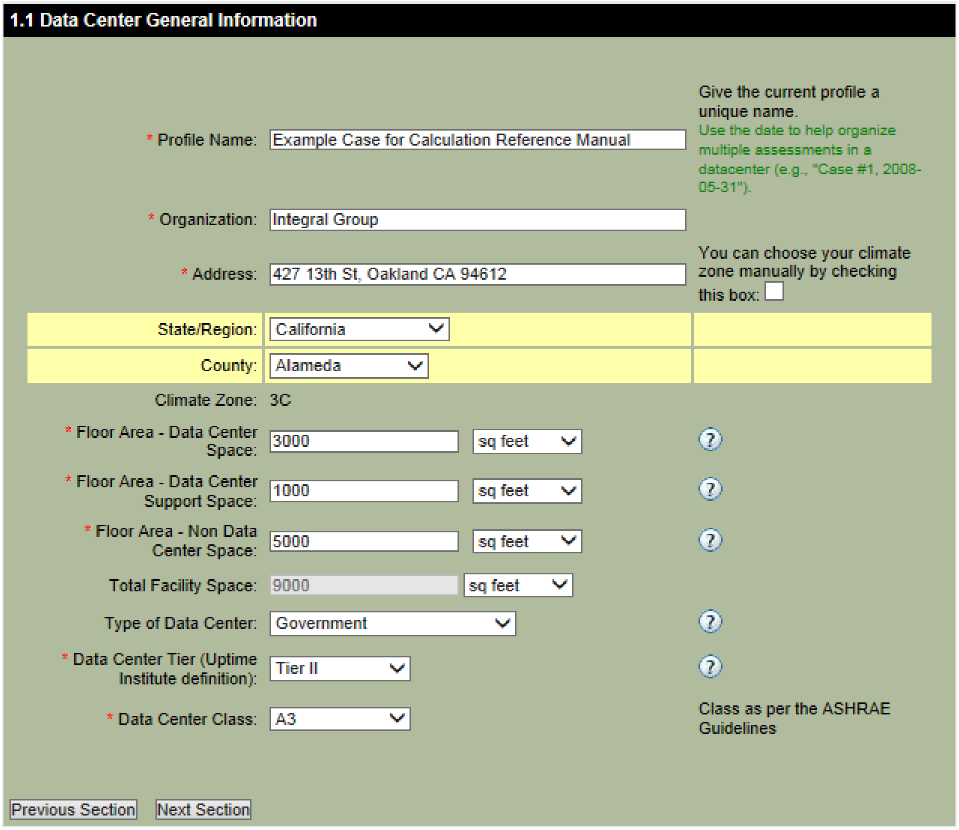
In the tables that follow, each input question is assigned a code. These codes are not visible on the screen when using the Profiling Tool. The codes are referenced in the Calculation sections of this manual, where the Profiling Tool outputs are defined.

Table 1. Data Center General Information Questions

Code	*Input Question*	*Data Type*	*Used in Calcs?*
GI.Q.01	Profile Name	Text	No
GI.Q.02	Department	Text	No
GI.Q.03	Organization	Select One	No
GI.Q.04	Address	Text	No
GI.Q.05	State/Region [all US states; District of Columbia, Puerto Rico, Pacific Islands, Virgin Islands]	Select One	**Yes**
GI.Q.06	County [choices depend on State/Region selected]	Select One	**Yes**
GI.Q.08	Floor Area – Data Center Space [value]	Integer	No
GI.Q.09	Floor Area – Data Center Space [units] square feet square meters	Select One	No
GI.Q.10	Floor Area – Data Center Support Space [value]	Integer	No
GI.Q.11	Floor Area – Data Center Support Space [units] square feet square meters	Select One	No
GI.Q.12	Floor Area – Non Data Center Space [value]	Integer	No
GI.Q.13	Floor Area – Non Data Center Space [units] square feet square meters	Select One	No

Code	*Input Question*	*Data Type*	*Used in Calcs?*
GI.Q.14	Total Facility Space [value]	Integer	No
GI.Q.15	Total Facility Space [units]	Select One	No
GI.Q.16	Type of Data Center Colocation Financial Government Other Corporate Managed Disaster Recovery Telecom Switches ISP Routers Operations/Processing Data Storage Internet Service Provider	Select One	No
GI.Q.17	Data Center Tier (Uptime Institute Definition) Tier 1 Tier 2 Tier 3 Tier 4 Mixed	Select One	No
GI.Q.18	Data Center Class (as per the ASHRAE Guidelines) A1 A2 A3 A4 B C	Select One	No

Figure 8. Data Center General Information Questions

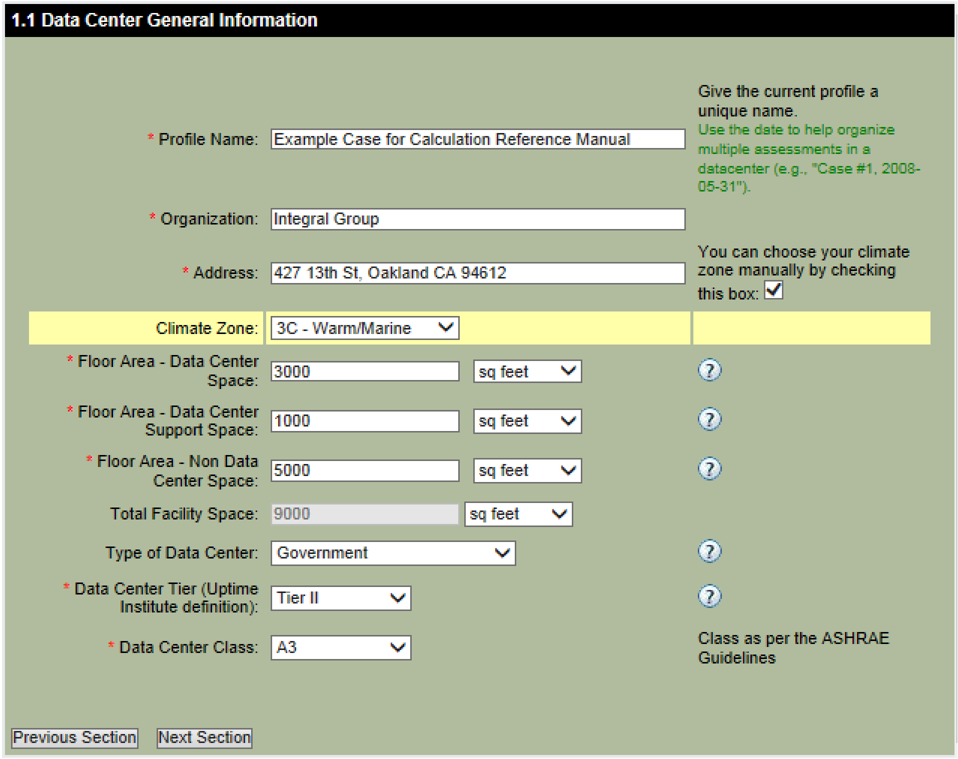


Calculations

The Profiler determines which climate zone the data center is in. See Appendix A.

Note that the user has the option of entering the climate zone directly, as shown in Figure 9.

Figure 9. Data Center General Information Questions: Climate Zone Option



There are fifteen climate zones to choose from, as shown in Table 2. See Appendix A for details.

Table 2. Data Center General Information Questions: Climate Zone Option

Code	*Input Question*	*Data Type*	*Used in Calcs?*
GI.Q.05	State/Region	Hidden	
GI.Q.06	County	Hidden	
GI.Q.07	Climate Zone 1A – Very Hot/Humid 2A – Hot/Humid 2B – Hot/Dry 3A – Warm/Humid 3B – Warm/Dry 3C – Warm/Marine 4A – Mixed/Humid 4B – Mixed/Dry 4C – Mixed Marine 5A – Cool/Humid 5B – Cool/Dry 6A – Cold/Humid 6B – Cold/Dry 7 – Very Cold 8 – Subarctic	Select One	**Yes**

Step 2 – Energy Use Systems

Steps 2.1 through 2.7 are primarily questionnaires. Answers to the questions can serve any of three purposes:

1. To determine whether an Action is recommended or not recommended, in the "Suggested Next Steps" section of Step 5. The details of the Action selections are provided in Appendix E.

2. To influence the output values that the Profiler calculates. Not every question influences the calculated values. Many of the tables in this manual have a rightmost column with the heading "Used in Calcs?" This column indicates which questions affect the calculated results.

3. To collect benchmark data that is not used immediately by the Profiler, but may be useful for future studies.

Step 2 also estimates how the data center's energy use is distributed among five end-use categories, based on the answers to the Step 2 questions. These are referred to as the Default energy end-use breakouts.

After completing Step 2, the user can go directly to Step 5 where results are presented. The results will be based on the Default energy end-use breakouts.

If the user wishes to replace the Default breakouts with actual measured energy use data, then he should complete Steps 3 and 4. The results presented in Step 5 will then reflect the measured data.

User Inputs

The questions are grouped into seven subject areas:

2.1 Energy Management
2.2 IT Equipment
2.3 Environmental Conditions
2.4 Air Management
2.5 Cooling
2.6 IT Equipment Power Chain
2.7 Lighting

Nested Questions

Some questions are shown/hidden depending on the user's answer to a previous question. For example, if the data center is cooled by air-cooled chillers, the questions about cooling towers are hidden. The arrangement of nested questions is documented in each of the following sections.

Step 2.1. Energy Management

Figure 10. Energy Management Questions

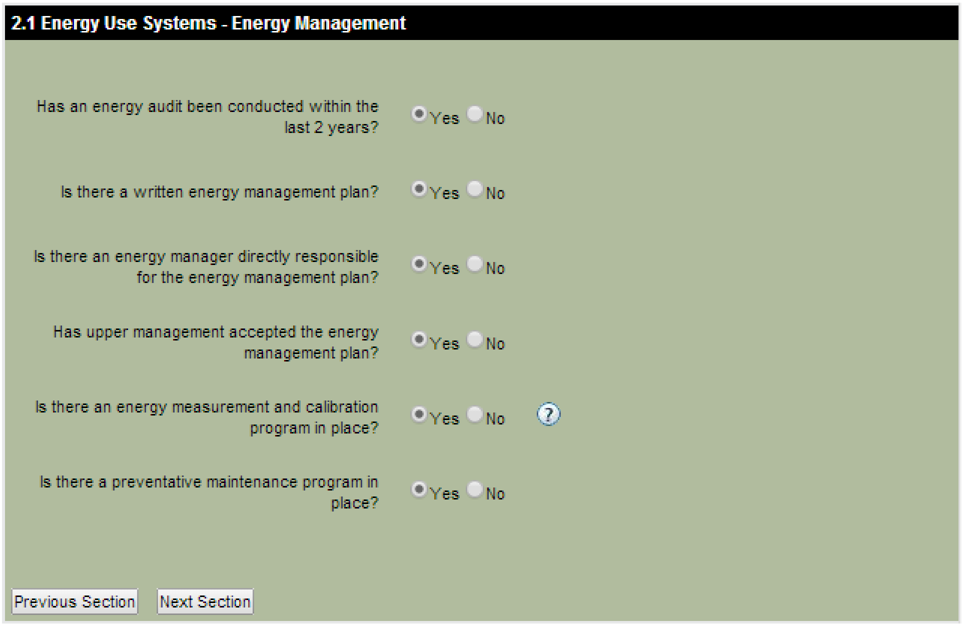


Table 3. Energy Management Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
EM.Q.01	Has an energy audit been conducted within the last 2 years?	Y/N	No
EM.Q.02	Is there a written energy management plan?	Y/N	No
EM.Q.02.1	Is there an energy manager directly responsible for the energy management plan?	Y/N	No
EM.Q.02.2	Has upper management accepted the energy management plan?	Y/N	No
EM.Q.03	Is there an energy measurement and calibration program in place?	Y/N	No
EM.Q.04	Is there a preventative maintenance program in place?	Y/N	No

Nested Questions

If the answer to EM.Q.02 is:	Show EM.Q.02.1?	Show AM.Q.02.2?
Yes	Yes	Yes
No	No	No

Step 2.2. IT Equipment

Figure 11. IT Equipment Questions

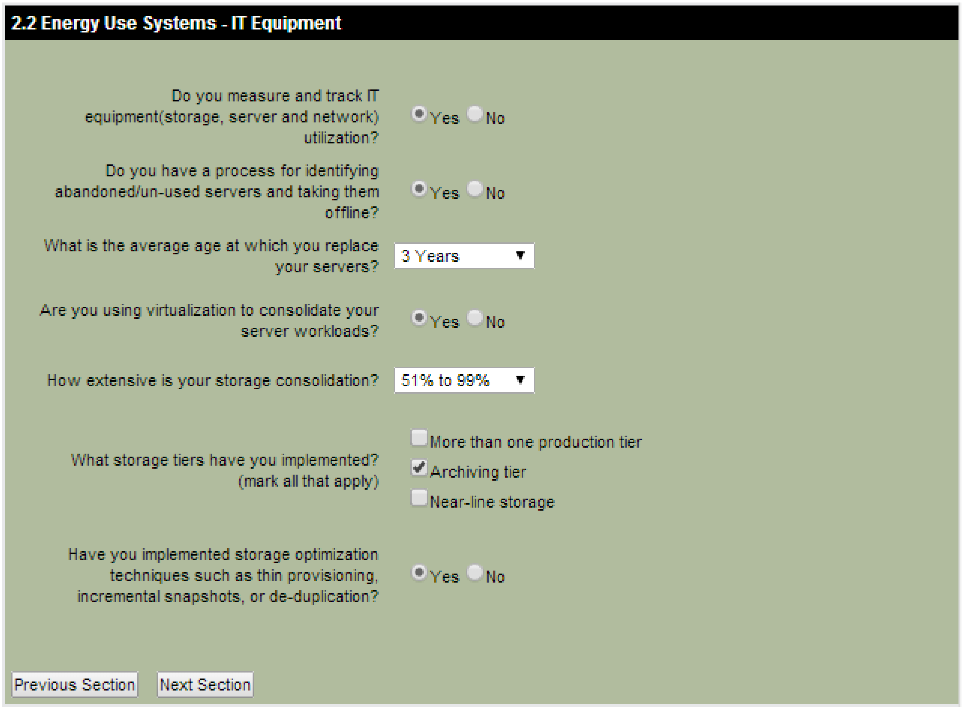


Table 4. IT Equipment Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
IT.Q.01	Do you measure and track IT equipment (storage, server & network) utilization?	Y/N	No
IT.Q.02	Do you have a process for identifying abandoned/un-used servers and taking them offline?	Y/N	No
IT.Q.03	What is the average age at which you replace your servers? 0-2 years 3 years 4 years 5+ years	Select One	No
IT.Q.04	Are you using virtualization to consolidate your server workloads?	Y/N	No

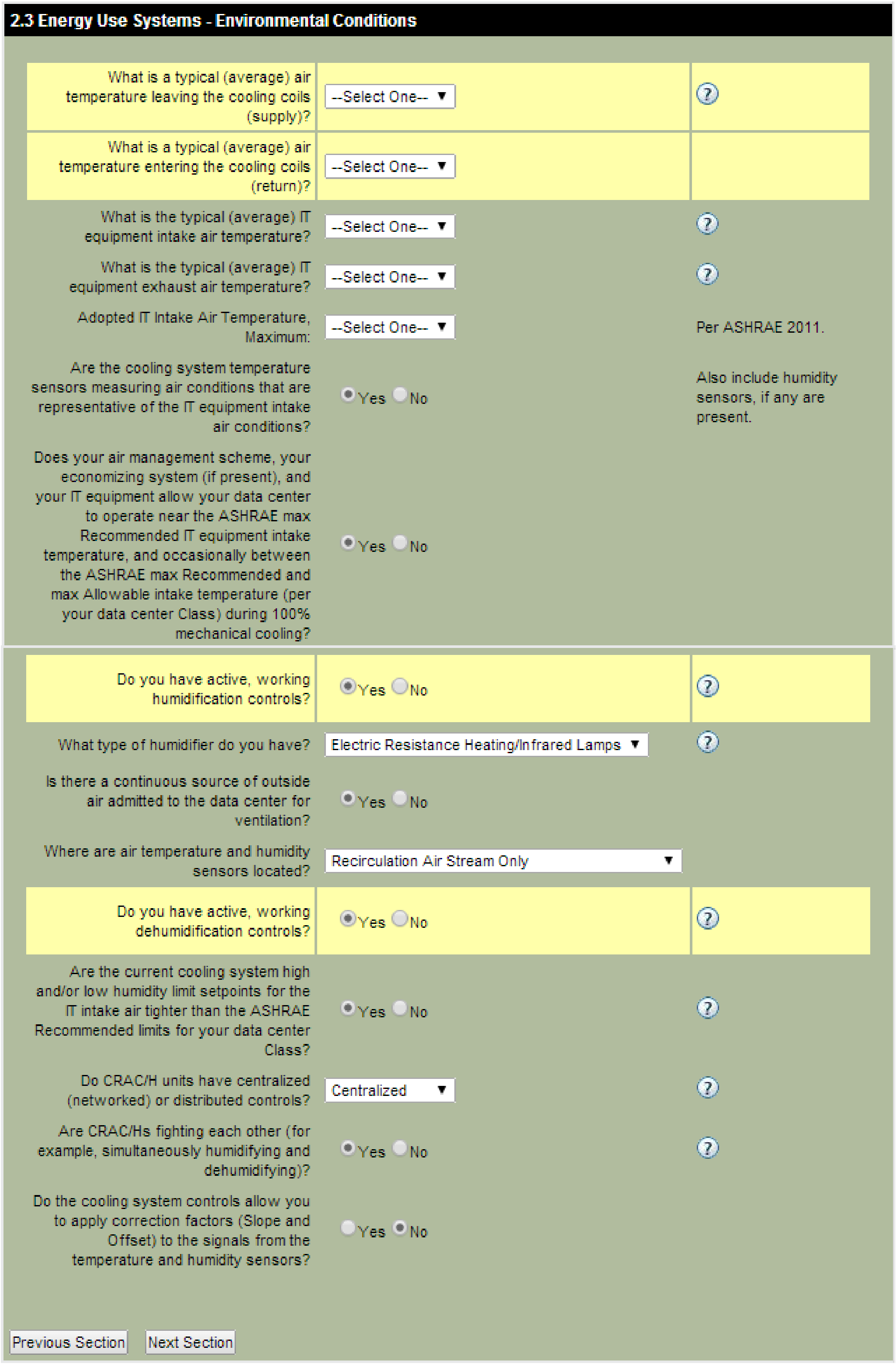
Question ID	*Question*	*Data Type*	*Used in Calcs?*
IT.Q.05	How extensive is your storage consolidation? 0% 1% to 50% 51% to 99% 100%	Select One	No
IT.Q.06	What storage tiers have you implemented? (mark all that apply) More than one production tier Archiving tier Near-line storage	Select Any	No
IT.Q.07	Have you implemented storage optimization techniques such as thin provisioning, incremental snapshots, or de-duplication?	Y/N	No

Nested Questions

None.

Step 2.3. Environmental Conditions

Figure 12. Environmental Conditions Questions



2.3 Energy Use Systems - Environmental Conditions

What is a typical (average) air temperature leaving the cooling coils (supply)?	--Select One--	?
What is a typical (average) air temperature entering the cooling coils (return)?	--Select One--	
What is the typical (average) IT equipment intake air temperature?	--Select One--	?
What is the typical (average) IT equipment exhaust air temperature?	--Select One--	?
Adopted IT Intake Air Temperature, Maximum:	--Select One--	Per ASHRAE 2011.
Are the cooling system temperature sensors measuring air conditions that are representative of the IT equipment intake air conditions?	Yes No	Also include humidity sensors, if any are present.
Does your air management scheme, your economizing system (if present), and your IT equipment allow your data center to operate near the ASHRAE max Recommended IT equipment intake temperature, and occasionally between the ASHRAE max Recommended and max Allowable intake temperature (per your data center Class) during 100% mechanical cooling?	Yes No	
Do you have active, working humidification controls?	Yes No	?
What type of humidifier do you have?	Electric Resistance Heating/Infrared Lamps	?
Is there a continuous source of outside air admitted to the data center for ventilation?	Yes No	
Where are air temperature and humidity sensors located?	Recirculation Air Stream Only	
Do you have active, working dehumidification controls?	Yes No	?
Are the current cooling system high and/or low humidity limit setpoints for the IT intake air tighter than the ASHRAE Recommended limits for your data center Class?	Yes No	?
Do CRAC/H units have centralized (networked) or distributed controls?	Centralized	?
Are CRAC/Hs fighting each other (for example, simultaneously humidifying and dehumidifying)?	Yes No	?
Do the cooling system controls allow you to apply correction factors (Slope and Offset) to the signals from the temperature and humidity sensors?	Yes No	

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Table 5. Environmental Conditions Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
EC.Q.01	What is a typical (average) air temperature leaving the cooling coils (supply)? 55 F (13 C) 60 F (16 C) 65 F (18 C) 70 F (21 C) 75 F (24 C) 80 F (27 C) 85 F (29 C) 90 F (32 C) 95 F (35 C) 100 F (38 C) 105 F (41 C) 110 F (43 C) 115 F (46 C) >115 F (>46 C)	Select One	**Yes**
EC.Q.02	What is a typical (average) air temperature entering the cooling coils (return)? 55 F (13 C) 60 F (16 C) 65 F (18 C) 70 F (21 C) 75 F (24 C) 80 F (27 C) 85 F (29 C) 90 F (32 C) 95 F (35 C) 100 F (38 C) 105 F (41 C) 110 F (43 C) 115 F (46 C) 120 F (49 C) 125 F (52 C) 130 F (54 C) 135 F (57 C) 140 F (60 C) >140 F (>60 C)	Select One	**Yes**

Question ID	*Question*	*Data Type*	*Used in Calcs?*
EC.Q.03	What is a typical (average) IT equipment intake temperature? 55 F (13 C) 60 F (16 C) 65 F (18 C) 70 F (21 C) 75 F (24 C) 80 F (27 C) 85 F (29 C) 90 F (32 C) 95 F (35 C) 100 F (38 C) 105 F (41 C) 110 F (43 C) 115 F (46 C) >115 F (>46 C)	Select One	No
EC.Q.04	What is the typical (average) IT equipment exhaust air temperature? 55 F (13 C) 60 F (16 C) 65 F (18 C) 70 F (21 C) 75 F (24 C) 80 F (27 C) 85 F (29 C) 90 F (32 C) 95 F (35 C) 100 F (38 C) 105 F (41 C) 110 F (43 C) 115 F (46 C) 120 F (49 C) 125 F (52 C) 130 F (54 C) 135 F (57 C) 140 F (60 C) 145 F (63 C) 150 F (66 C) 155 F (68 C) 160 F (71 C) 165 F (74 C) 170 F (77 C) 175 F (79 C) 180 F (82 C) >180 F (>82 C)	Select One	No

Question ID	*Question*	*Data Type*	*Used in Calcs?*
EC.Q.05	Adopted IT Intake Air Temperature, Maximum: 65 F (18 C) 70 F (21 C) 75 F (24 C) 80 F (27 C) 85 F (29 C) 90 F (32 C) 95 F (35 C) 100 F (38 C) 105 F (41 C) 110 F (43 C) 115 F (46 C) >115 F (>46 C)	Select One	No
EC.Q.06	Are the cooling system temperature sensors measuring air conditions that are representative of the IT equipment intake air conditions?	Y/N	No
EC.Q.07	Does your air management scheme, your economizing system (if present), and your IT equipment allow your data center to operate near the ASHRAE max Recommended IT equipment intake temperature, and occasionally between the ASHRAE max Recommended and max Allowable intake temperature (per your data center Class) during 100% mechanical cooling?	Y/N	No
EC.Q.08	Do you have active, working humidification controls?	Y/N	**Yes**
EC.Q.08.1	What type of humidifier do you have? Electric Resistance Heating/Infrared Lamps Steam from Boiler Direct Evaporative Ultrasonic	Select One	No
EC.Q.09	Do you have active, working dehumidification controls?	Y/N	**Yes**
EC.Q.09.1	Is there a continuous source of outside air admitted to the data center for ventilation?	Y/N	No
EC.Q.09.2	Where are air temperature and humidity sensors located? Outside Air Stream Only Recirculation Air Stream Only Outside Air Stream and recirculation Air Stream	Select One	No
EC.Q.10	Are the current cooling system high and/or low humidity limit setpoints for the IT intake air tighter than the ASHRAE Recommended limits for your data center Class?	Y/N	No
EC.Q.11	Do CRAC/H units have centralized (networked) or distributed controls? Centralized Distributed	Select One	No

Question ID	*Question*	*Data Type*	*Used in Calcs?*
EC.Q.12	Are CRAC/Hs fighting each other (for example, simultaneously humidifying and dehumidifying)?	Y/N	No
EC.Q.13	Do the cooling system controls allow you to apply correction factors (Slope and Offset) to the signals from the temperature and humidity sensors?	Y/N	No

The Profiler assumes the de/humidification system(s) are working properly, not fighting each other. For more details on how the data center is modeled, see Appendix D.

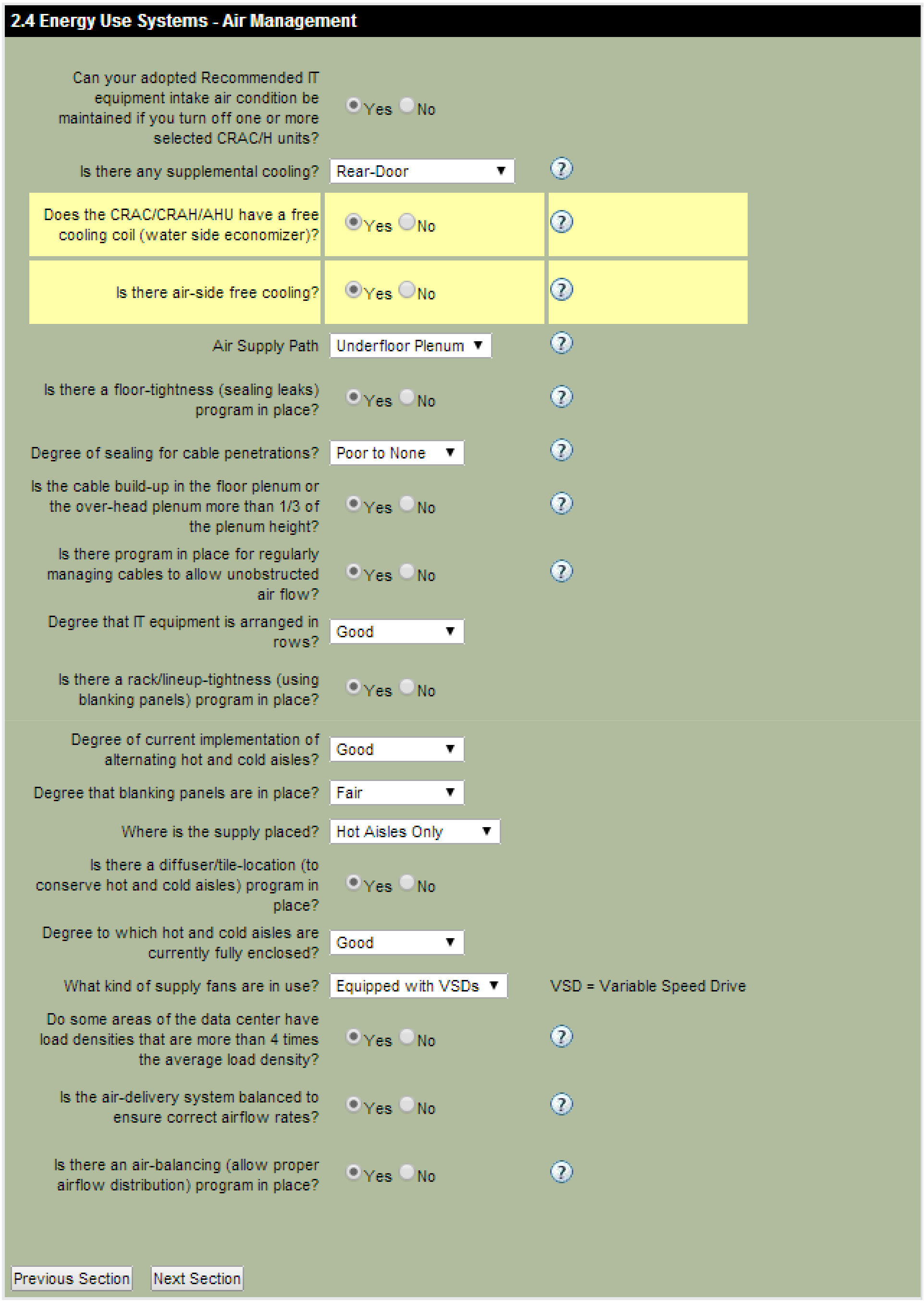
Nested Questions

If the answer to EC.Q.08 is:	Show EC.Q.08.1?	Show EC.Q.09.1?	Show EC.Q.09.2?
Yes	Yes	Yes	Yes
No	No	See next table	See next table

If the answer to EC.Q.09 is:		Show EC.Q.09.1?	Show EC.Q.09.2?
Yes		Yes	Yes
No		No	No

Step 2.4. Air Management

Figure 13. Air Management Questions



2.4 Energy Use Systems - Air Management

Can your adopted Recommended IT equipment intake air condition be maintained if you turn off one or more selected CRAC/H units?	Yes / No
Is there any supplemental cooling?	Rear-Door
Does the CRAC/CRAH/AHU have a free cooling coil (water side economizer)?	Yes / No
Is there air-side free cooling?	Yes / No
Air Supply Path	Underfloor Plenum
Is there a floor-tightness (sealing leaks) program in place?	Yes / No
Degree of sealing for cable penetrations?	Poor to None
Is the cable build-up in the floor plenum or the over-head plenum more than 1/3 of the plenum height?	Yes / No
Is there program in place for regularly managing cables to allow unobstructed air flow?	Yes / No
Degree that IT equipment is arranged in rows?	Good
Is there a rack/lineup-tightness (using blanking panels) program in place?	Yes / No
Degree of current implementation of alternating hot and cold aisles?	Good
Degree that blanking panels are in place?	Fair
Where is the supply placed?	Hot Aisles Only
Is there a diffuser/tile-location (to conserve hot and cold aisles) program in place?	Yes / No
Degree to which hot and cold aisles are currently fully enclosed?	Good
What kind of supply fans are in use?	Equipped with VSDs — VSD = Variable Speed Drive
Do some areas of the data center have load densities that are more than 4 times the average load density?	Yes / No
Is the air-delivery system balanced to ensure correct airflow rates?	Yes / No
Is there an air-balancing (allow proper airflow distribution) program in place?	Yes / No

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Table 6. Air Management Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
AM.Q.01	Can your adopted Recommended IT equipment intake air condition be maintained if you turn off one or more selected CRAC/H units?	Y/N	No
AM.Q.03	Is there any supplemental cooling? None In-Row Modular Overhead Rear-Door Liquid-Cooled Cabinet	Select One	No
AM.Q.04	Does the CRAC/CRAH/AHU have a free cooling coil (water side economizer)?	Y/N	**Yes**
AM.Q.05	Is there air-side free cooling?	Y/N	**Yes**
AM.Q.07	Air Supply Path Overhead Ducts Overhead Plenum Underfloor Plenum In-Row Free	Select One	No
AM.Q.07.4	Is there a floor-tightness (sealing leaks) program in place?	Y/N	No
AM.Q.07.5	Degree of sealing for cable penetrations? Poor to None Fair Good	Select One	No
AM.Q.07.6	Is the cable build-up in the floor plenum or the over-head plenum more than 1/3 of the plenum height?	Y/N	No
AM.Q.07.7	Is there a program in place for regularly managing cables to allow unobstructed air flow?	Y/N	No
AM.Q.13	Degree that IT equipment is arranged in rows? Poor to None Fair Good	Select One	No
AM.Q.13.1	Is there a rack/lineup-tightness (using blanking panels) program in place?	Y/N	No

Question ID	*Question*	*Data Type*	*Used in Calcs?*
AM.Q.13.2	Degree of current implementation of alternating hot and cold aisles? Poor to None Fair Good	Select One	No
AM.Q.13.2.1	Degree that blanking panels are in place? Poor to None Fair Good	Select One	No
AM.Q.13.2.3	Supply Air: Where is the supply air placed? Cold Aisles Only Hot Aisles Only Hot and Cold Aisles Not Applicable	Select One	No
AM.Q.13.2.4	Is there a diffuser/tile-location (to conserve hot and cold aisles) program in place?	Y/N	No
AM.Q.13.2.6	Degree to which hot and cold aisles are currently fully enclosed? Poor to None Fair Good	Select One	No
AM.Q.15	What kind of supply fans are in use? Constant Speed Equipped with VSDs	Select One	No
AM.Q.16	Do some areas of the data center have load densities that are more than 4 times the average load density?	Y/N	No
AM.Q.17	Is the air-delivery system balanced to ensure correct airflow rates?	Y/N	No
AM.Q.18	Is there an air-balancing (allow proper airflow distribution) program in place?	Y/N	No

Nested Questions

If the answer to AM.Q.07 is:	Show AM.Q.07.4?	Show AM.Q.07.5?	Show AM.Q.07.6?	Show AM.Q.07.7?
Overhead Ducts	No	No	No	No
Overhead Plenum	No	Yes	Yes	Yes
Underfloor Plenum	Yes	Yes	Yes	Yes
In-Row	No	Yes	No	No
Free	No	No	No	No

If the answer to AM.Q.13 is:	Show AM.Q.13.1?	Show AM.Q.13.2?
Poor to None	No	No (hide all AM.Q.13.2.n, too)
Fair	Yes	Yes
Good	Yes	Yes

If the answer to AM.Q.13.2 is:	Show AM.Q.13.2.1?	Show AM.Q.13.2.3?	Show AM.Q.13.2.4?	Show AM.Q.13.2.6?
Poor to None	No	No	No	No
Fair	Yes	Yes	Yes	Yes
Good	Yes	Yes	Yes	Yes

Step 2.5. Cooling

Figure 14. Cooling Questions

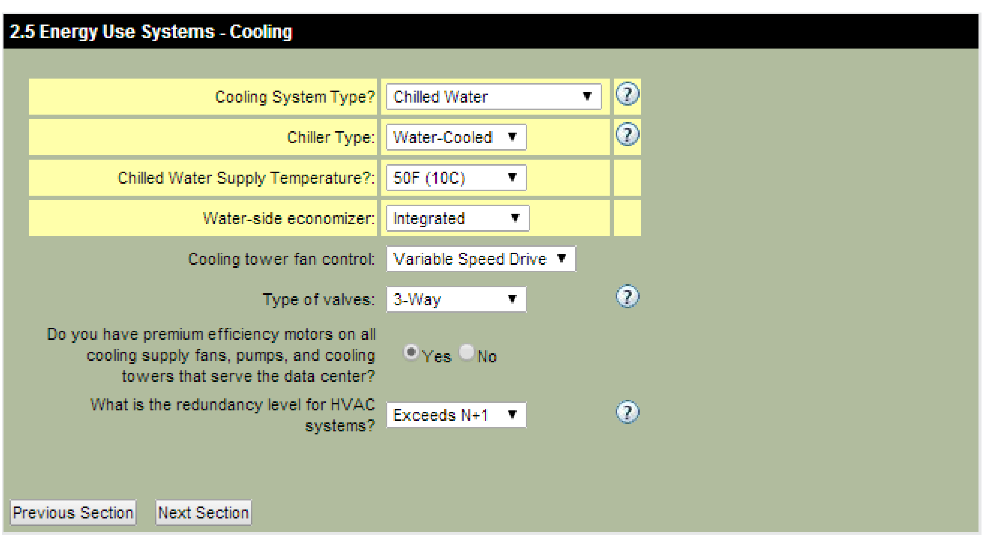


Table 7. Cooling Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
CP.Q.01	Cooling system type? Air-Cooled DX Water-Cooled DX Evaporatively-Cooled DX Chilled Water	Select One	**Yes**
CP.Q.01.1	Condenser cooling system Cooling Tower Dry Cooler	Select One	No
CP.Q.01.2	Chiller type Air-Cooled Water-Cooled	Select One	**Yes**
CP.Q.01.3	Chilled Water Supply Temperature? 45F (7C) 50F (10C) 55F (13C)	Select One	**Yes**
CP.Q.01.2.1	Water-side Economizer None Integrated Non-Integrated	Select One	**Yes**
CP.Q.01.2.2	Cooling tower fan control Fixed Speed Two-Speed Motor VSD	Select One	No
CP.Q.01.5	Type of valves 2-way 3-way	Select One	No
CP.Q.06	Do you have premium efficiency motors on all cooling supply fans, pumps, and cooling towers that serve the data center?	Y/N	No
CP.Q.07	What is the redundancy level for HVAC systems? N N+1 Exceeds N+1 2N	Select One	No

Nested Questions

If the answer to CP.Q.01 is:	Show CP.Q.01.1?	Show CP.Q.01.2?	Show CP.Q.01.3?	Show CP.Q.01.5?
Air-Cooled DX	No	No	No	No
Water-Cooled DX	Yes	No	No	No
Evaporatively-Cooled DX	No	No	No	No
Chilled Water	No	Yes	Yes	Yes

If the answer to CP.Q.01.2 is:	Show CP.Q.01.2.1?	Show CP.Q.01.2.2?
Air-Cooled	No	No
Water-Cooled	Yes	Yes

Step 2.6. IT Equipment Power Chain

Figure 15. IT Equipment Power Chain Questions

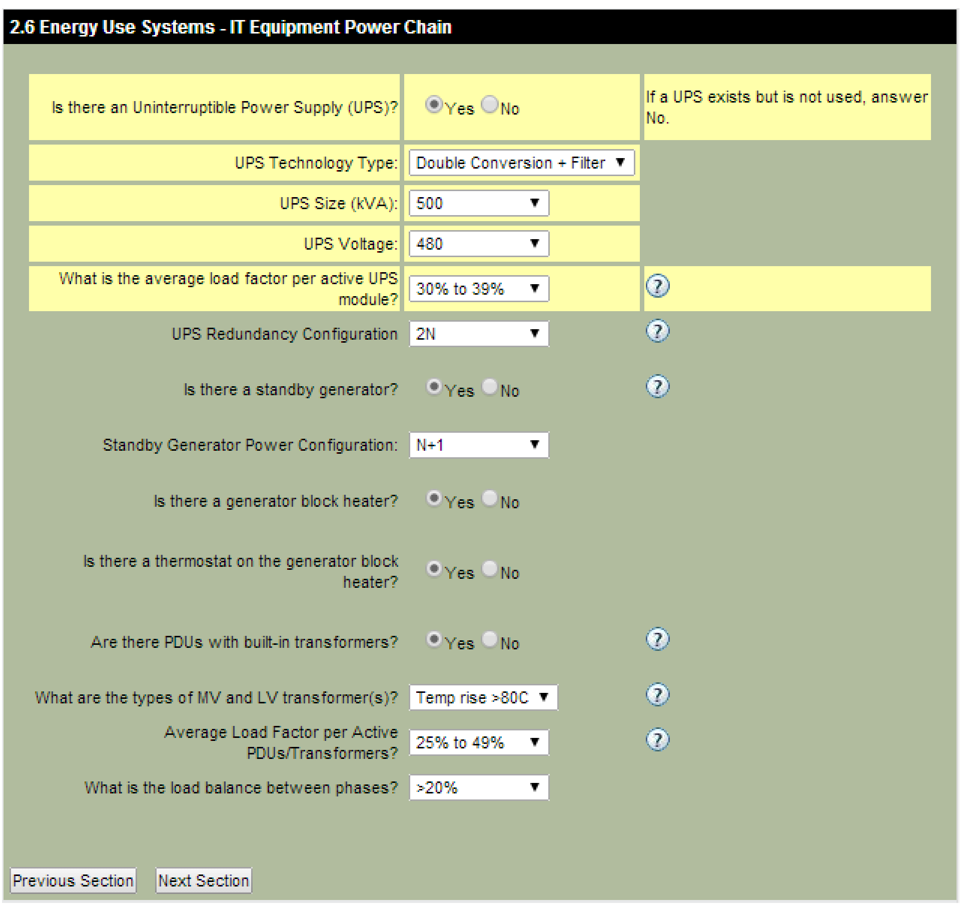


Table 8. IT Equipment Power Chain Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
ED.Q.01	Is there an Uninterruptible Power Supply (UPS)?	Y/N	**Yes**
ED.Q.01.1	UPS Technology Type Double Conversion Double Conversion + Filter Delta Conversion Rotary	Select One	**Yes**
ED.Q.01.2	UPS Size (kVA) 50 100 150 225 300 400 500 600 750 800 900 1000	Select One	**Yes**
ED.Q.01.3	UPS Voltage 480 208	Select One	**Yes**
ED.Q.01.4	What is the average load factor per active UPS module? 1% to 10% 11% to 20% 21% to 30% 31% to 40% 41% to 50% 51% to 60% 61% to 70% 71% to 80% 81% to 90% 91% to 100%	Select One	**Yes**
ED.Q.01.5	UPS Redundancy Configuration N N+1 2N	Select One	No

Question ID	*Question*	*Data Type*	*Used in Calcs?*
ED.Q.02	Is there a standby generator?	Y/N	No
ED.Q.02.1	Standby Generator Power Configuration N N+1 2N	Select One	No
ED.Q.02.2	Is there a generator block heater?	Y/N	No
ED.Q.02.2.1	Is there a thermostat on the generator block heater?	Y/N	No
ED.Q.03	Are there PDUs with built-in transformers?	Y/N	No
ED.Q.03.1	What are the types of MV and LV transformer(s)? Temp rise 80C Temp rise>80 C TP1 EPACT 2005	Select One	No
ED.Q.03.2	Average Load Factor per Active PDUs / Transformers? 0% to 24% 25% to 49% 50% to 100%	Select One	No
ED.Q.03.3	What is the load balance between the phases? <=20% >20%	Select One	No

Nested Questions

If the answer to ED.Q.01 is:	Show ED.Q.01.1?	Show ED.Q.01.2?	Show ED.Q.01.3?	Show ED.Q.01.4?	Show ED.Q.01.5?
Yes	Yes	Yes	Yes	Yes	Yes
No	No	No	No	No	No

If the answer to ED.Q.02 is:	Show ED.Q.02.1?	Show ED.Q.02.2?
Yes	Yes	Yes
No	No	No

If the answer to ED.Q.02.2 is:	Show ED.Q.02.2.1?
Yes	Yes
No	No

If the answer to ED.Q.03 is:	Show ED.Q.03.1?	Show ED.Q.03.2?	Show ED.Q.03.3?
Yes	Yes	Yes	Yes
No	No	No	No

Step 2.7. Lighting

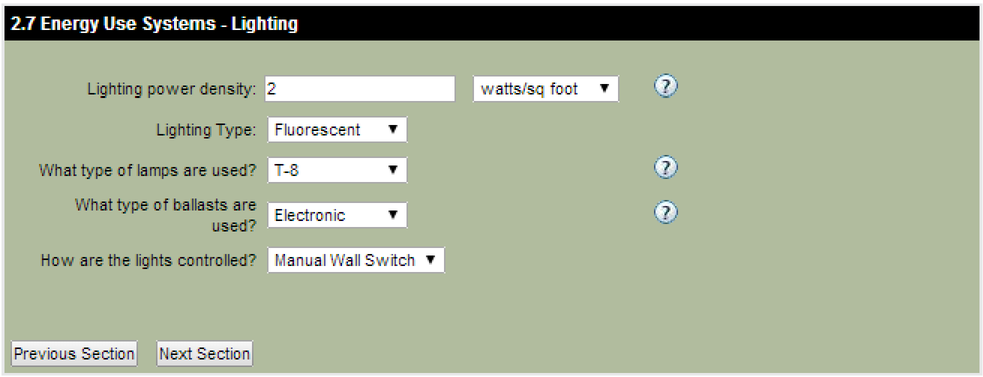


Figure 16. Lighting Questions

Table 9. Lighting Questions

Question ID	*Question*	*Data Type*	*Used in Calcs?*
LT.Q.01	Lighting power density	Real Number	No
LT.Q.02	[Lighting power density units] Watts per square foot Watts per square meter	Select One	No
LT.Q.03	Lighting Type Fluorescent LED Other	Select One	No
LT.Q.03.1	What type of lamps are used? T-12 T-8 T-5	Select One	No
LT.Q.03.2	What type of ballasts are used? Magnetic Electronic	Select One	No

Question ID	*Question*	*Data Type*	*Used in Calcs?*
LT.Q.04	How are the lights controlled? Hard-Wired Manual Wall Switch Occupancy Sensor Timer	Select One	No

Nested Questions

If the answer to LT.Q.03 is:	Show LT.Q.03.1?	Show LT.Q.03.2?
Fluorescent	Yes	Yes
LED	No	No
Other	No	No

Calculations

The Profiler takes the some of the user's inputs from Steps 1 and 2 and refers to look-up tables to determine the default, estimated data center energy end-use breakouts.

The default breakouts are defined only in terms of percentages – there is no reference to energy type (electricity, fuel, other). Energy types are addressed in Steps 3 and 4.

The lookup tables are shown in Appendices A, B, and C.

The Cooling System Energy lookup table (Appendix B) was populated by running iterations of a simple data center model in the EnergyPlus simulation software.

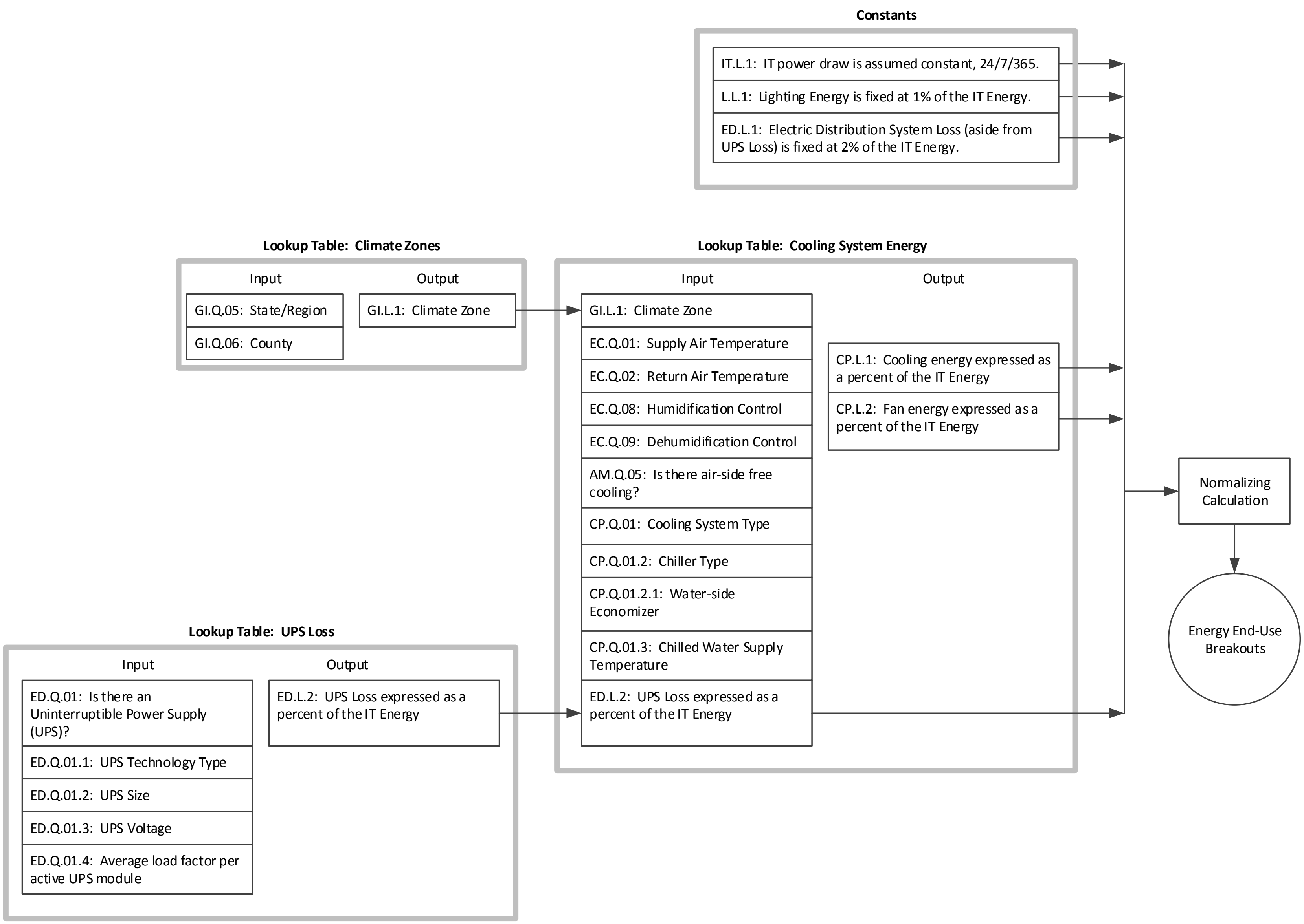
Many of the Step 2 questions address non-homogeneity in the data center, such as varying IT load densities and fighting humidity controls. In general, the answers to these questions affect only the presentation of recommended actions. They do not affect the calculation of the default energy end-use breakouts.

The EnergyPlus model assumes a completely homogenous data center. For example:

- Many real world data centers have more than one type of cooling system serving a single data center space. The model assumes there is only one type.
- Real world data centers are often a mix of row configurations, rack types, IT equipment types, air management schemes, high density areas, and low density areas. The model assumes the data center space is completely uniform in regards to these parameters.
- The model assumes that the temperature of the air leaving the cooling coils is the same at every coil, and the air temperature entering the cooling coils is the same at every coil.

When answering the Step 2 questions, the user should select the answer that best represents the majority of the data center space. Figure 17 shows all of the questions that affect the calculation of the default breakouts. It is followed by an example that walks through all the steps.

Figure 17. Default Energy End-Use Breakouts: Calculation Method



Example

Assume the user provides the answers shown in Table 10.

Table 10. Default Energy End-Use Breakouts: Example User Inputs

Data Center General Information

Question ID	*Question*	*Answer*
GI.Q.07	Climate Zone	3C – Warm/Marine

Environmental Conditions

Question ID	*Question*	*Answer*
EC.Q.01	What is a typical (average) air temperature leaving the cooling coils (supply)?	65F (18C)
EC.Q.02	What is a typical (average) air temperature entering the cooling coils (return)?	80F (27C)
EC.Q.08	Do you have active, working humidification controls?	Yes
EC.Q.09	Do you have active, working dehumidification controls?	Yes

Air Management

Question ID	*Question*	*Answer*
AM.Q.04	Does the CRAC/CRAH/AHU have a free cooling coil (water side economizer)?	No
AM.Q.05	Is there air-side free cooling?	Yes

Cooling

Question ID	*Question*	*Answer*
CP.Q.01	Cooling System Type?	Chilled Water
CP.Q.01.2	Chiller Type	Air-Cooled
CP.Q.01.2.1	Water-Side Economizer	n/a
CP.Q.01.3	Chilled Water Supply Temperature?	45F (7C)

IT Equipment Power Chain

Question ID	*Question*	*Answer*
ED.Q.01	Is there an Uninterruptible Power Supply (UPS)?	Yes
ED.Q.01.1	UPS Technology Type	Double Conversion
ED.Q.01.2	UPS Size	225
ED.Q.01.3	UPS Voltage	480
ED.Q.01.4	What is the average load factor per active UPS module?	31% to 40%

Lookups

UPS Efficiency

The Profiler uses the answers to questions…

ED.Q.01
ED.Q.01.1
ED.Q.01.2
ED.Q.01.3
ED.Q.01.4

…to look up the UPS Efficiency. See Appendix C. If there is no UPS, the UPS Efficiency is set to 100%. Figure 18 and Table 11 show the results for the current example.

Figure 18. UPS Efficiency Lookup Table Example

			Load Factor									
Nominal Capacity (kVA)	Voltage	Type	1% to 10%	11% to 20%	21% to 30%	31% to 40%	41% to 50%	51% to 60%	61% to 70%	71% to 80%	81% to 90%	91% to 100%
225	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%

Table 11. Lookup Values: UPS Efficiency

Lookup ID	*Parameter*	*Value*
ED.L.1	UPS Efficiency	92.1%

UPS Loss

The UPS Loss is 100% minus the UPS Efficiency.

Table 12. Lookup Values: UPS Loss

Lookup ID	*Parameter*	*Value*
ED.L.2	UPS Loss	100% - 92.1% = 7.9%

Electric Distribution System Loss

The electric distribution system is assumed to have a constant loss of 2% of the IT load, regardless of whether a UPS exists or not. If the user specifies that a UPS does not exist, the Electric Distribution System Loss is set to 2%. Otherwise, 2% is added to the UPS Loss.

Table 13. Lookup Values: Electric Distribution System Loss

Lookup ID	*Parameter*	*Value*
ED.L.3	Electric Distribution System Loss	7.9% + 2% = 9.9%

High and Low Electric Distribution System Loss

The Profiler uses GI.L.1, ED.L.1, and the answers to questions…

EC.Q.01
EC.Q.02
EC.Q.08
EC.Q.09
AM.Q.04
AM.Q.05
CP.Q.01
CP.Q.01.2
CP.Q.01.2.1
CP.Q.01.3

…to look up the Supply Fan energy and the Cooling System energy at two different conditions. One condition corresponds to the Electric Distribution Loss that is lower than ED.L.3 as shown in Table 13. The other condition corresponds to the Electric Distribution Loss that is higher than ED.L.3. These two conditions are shown as the first and third rows in Figure 19.

For a description of the full Cooling Energy System Lookup Table, see Appendix B.

Figure 19. Cooling Energy System Lookup Table Example

	Model Variables								Annual Energy Use (kWh/yr)											
Index Number	ASHRAE Climate Zone	Cooling System Type	Economizer	Electric Distribution System Loss (kW)	Chilled Water Supply Temp (deg F)	Supply Air Temp (deg F)	Air Side Delta-T (deg F)	Humidity Control (50=Yes 0=No)	IT Load	Lights	Electric Distribution System Loss	EDS Loss as Percent of IT Load	Supply Fans	Supply Fans as Percent of IT Load	Total Cooling Plant (Comprs + Pumps + Humidifier + Towers)	Total Cooling Plant as Percent of IT Load	Total Support Systems (Lights + EDS Loss + Fans + Comprs + Pumps + Humidifier + Towers)	Whole Data Center (IT Load + Support Systems)	PUE (Whole Data Center / IT Load)
7886	3C	CHW Air	FixedDryBulb	0	45	65	15	50	8,760,000	8,760	0	0%	1,316,497	15.03%	1,428,654	16.31%	2,753,911	11,513,911	1.31
7934	3C	CHW Air	FixedDryBulb	0	55	85	20	0	8,760,000	8,760	0	0%	941,219	10.74%	5,519	0.06%	955,498	9,715,498	1.11
7951	3C	CHW Air	FixedDryBulb	150	45	65	15	50	8,760,000	8,760	1,314,000	15%	1,513,763	17.28%	1,506,077	17.19%	4,342,600	13,102,600	1.50

Table 14. Lookup Values: High and Low Cooling and Fan Energies

Lookup ID	Parameter	Next Higher EDS Loss (15%)	Next Lower EDS Loss (0%)
CP.L.1	Total Cooling Plant as a Percent of IT Load	17.19%	16.31%
CP.L.2	Supply Fans as a Percent of IT Load	17.28%	15.03%

Potential Breakouts

The Profiler uses the answers presented in Table 10 to look up one other condition in the Cooling System Energy table. This is the condition where the Total Support System Energy Use is the lowest, in the given Climate Zone, regardless of the answers to

EC.Q.01
EC.Q.02
EC.Q.08
EC.Q.09
AM.Q.05
CP.Q.01
CP.Q.01.2
CP.Q.01.2.1
CP.Q.01.3

For the current example, this is shown as the second row in Figure 19.

Table 15. Lookup Values: Potential Best Fan and Cooling System Percentages

CP.L.3	Cooling System energy as a percent of IT Load, corresponding to the condition of minimum Total Support System Energy.	0.06%
CP.L.4	Supply Fan energy as a percent of IT Load, corresponding to the condition of minimum Total Support System Energy.	10.74%

These two values will be used in Step 5 to determine the Potential breakouts.

The Potential breakouts do not take practicality or cost into consideration. They are simply the best-case scenarios the Profiler has in its lookup tables.

Calculations

Lighting Energy

Annual lighting energy is assumed to be constant at 0.1% of the IT load, for all hours of the year.

Normalize the High and Low Cases

The Profiler takes all of the end-use category energy use percentages, for the both the High and Low Electric Distribution System Loss cases, and normalizes them so that each set adds up to 100%.

Table 16 and Table 17 each have two sections. The first section shows the energy use of each end-use category in terms of the IT Load. The second section normalizes the data to express the energy use of each end-use category in terms of the data center total energy use.

Table 16. Default Energy End-Use Breakouts: Normalizing Calculation: High EDS Loss

Total Data Center Energy Use

IT Load	Call this N.	(1.000)(N)
Lights	(0.001)(N)	(0.001)(N)
Electric Distribution System Loss	(0.150)(N)	(0.150)(N)
Fan Energy	(CP.L.2)(N)	(0.173)(N)
Cooling and Humidity Control Energy	(CP.L.1)(N)	(0.172)(N)
Total		(1.496)(N)

Breakout Percentages

IT Load	(1.000)(N) / (1.496)(N)	66.84%
Lights	(0.001)(N) / (1.496)(N)	0.07%
Electric Distribution System Loss	(0.150)(N) / (1.496)(N)	10.03%
Fan Energy	(0.173)(N) / (1.496)(N)	11.56%
Cooling and Humidity Control Energy	(0.172)(N) / (1.496)(N)	11.50%
Total		100.00%

Table 17. Default Energy End-Use Breakouts: Normalizing Calculation: Low EDS Loss

Total Data Center Energy Use

IT Load	Call this N.	(1.000)(N)
Lights	(0.001)(N)	(0.001)(N)
Electric Distribution System Loss	(0.000)(N)	(0.000)(N)
Fan Energy	(CP.L.2)(N)	(0.150)(N)
Cooling and Humidity Control Energy	(CP.L.1)(N)	(0.163)(N)
Total		(1.314)(N)

Breakout Percentages

IT Load	(1.000)(N) / (1.314)(N)	76.10%
Lights	(0.001)(N) / (1.314)(N)	0.08%
Electric Distribution System Loss	(0.000)(N) / (1.314)(N)	0.00%
Fan Energy	(0.150)(N) / (1.314)(N)	11.42%
Cooling and Humidity Control Energy	(0.163)(N) / (1.314)(N)	12.40%
Total		100.00%

Interpolation

The Profiler takes the Electric Distribution System Loss ED.L.3 in Table 13, and the breakout percentages from Table 16 and Table 17, to interpolate the final, default energy end-use breakouts, as shown in Table 18.

.

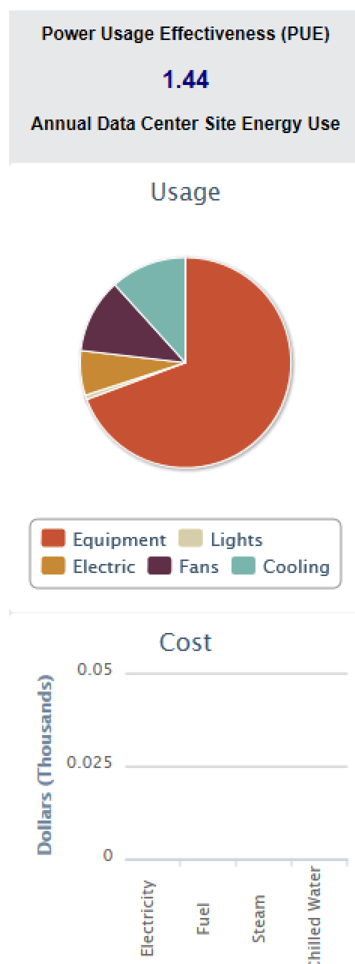
Table 18. Default Energy End-Use Breakouts: Interpolation

Breakout Percentages

End Use	Next Higher EDS Loss (15%)	Next Lower EDS Loss (0%)	Interpolated Values
IT Load	66.84%	76.10%	69.99%
Lights	0.07%	0.08%	0.07%
Electric Distribution System Loss	10.03%	0.00%	6.62%
Fan Energy	11.56%	11.42%	11.51%
Cooling and Humidity Control Energy	11.50%	12.40%	11.81%
Total	100.00%	100.00%	100.00%

PUE = 100% / 69.99% = 1.43

Figure 20. Example PUE and Energy Use Breakouts



Step 3 - Supplied Energy (optional)

Steps 3 and 4 are optional. Together, they provide the user with an opportunity to override the default breakouts, in part or in whole, with data collected from energy meters.

If the user proceeds directly to Step 5 (Results), then the Profiler will present the default energy end-use breakout percentages determined in Step 2.

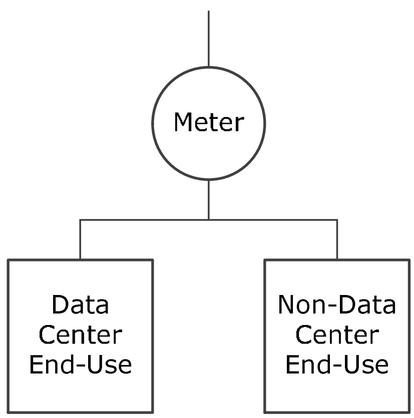
If the user skips Step 3 and goes to Step 4, there will be nothing to edit in Step 4.

If the use completes Step 3 and skips Step 4, then Step 5 will present the total measured energy use as reported by the user in Step 3, but the energy end-use breakouts will still be the defaults from Step 2.

Data Center vs Non-Data Center Energy Use

It is often the case that an existing meter records both data center and non-data center energy use. The user should enter the meter data anyway; Step 4 provides the opportunity to indicate which portion of a meter's energy use serves the data center.

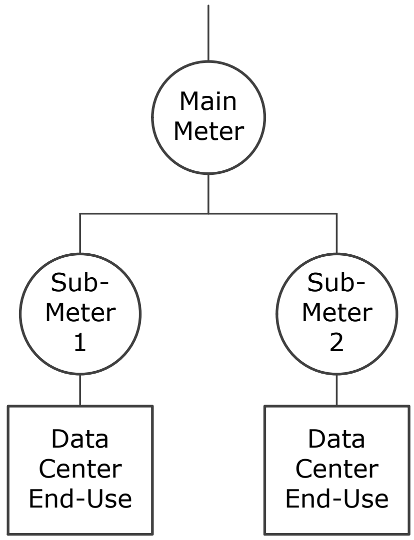
Figure 21. Capture All Data Center Energy Use



Sub-Meters

The user must take care not to double-count energy use due to submeters. Example:

Figure 22. Avoid Double-Counting Energy Use



If the user enters the reading from all three meters, the Profiler will sum all three in the calculations, giving erroneous results. In this example, the user should enter just the main meter, or just the two submeters.

Complete Meter Data

It is not necessary to enter meter readings for every end-use category. The end-use categories are:

- IT Load
- Lights
- Electric Distribution Losses
- Fans
- Cooling and Humidity Controls

For example, the user may have a meter reading for IT Load, but not the other categories. The user should enter the readings he has. The Profiler will use the meter readings that are provided, and will use the default breakout estimates from Step 2 for the remaining categories.

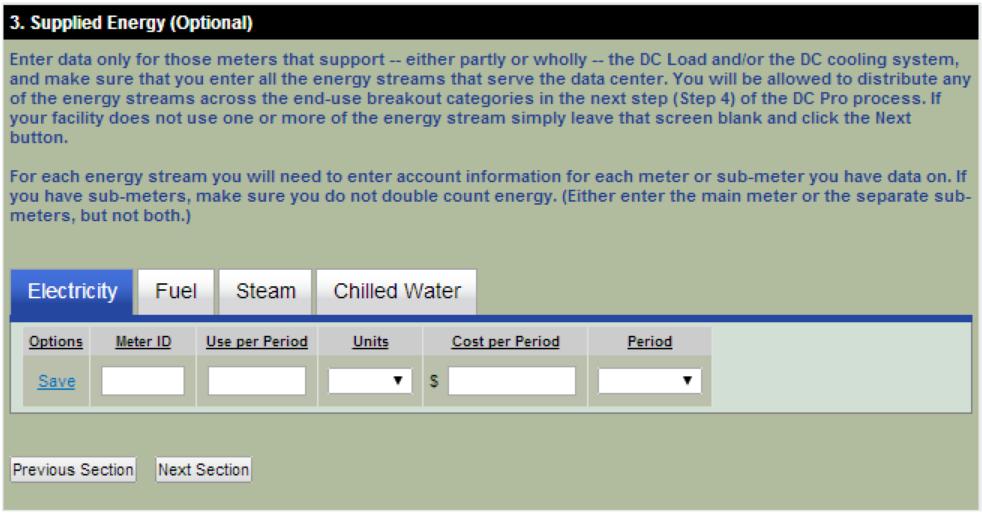
However, it is important that the meter readings for each category be complete. For example, if there is only one meter reading available, for IT Load only, and only a portion of the IT load is metered, then the user should not enter the meter reading, and instead allow the Profiler to use the default estimate.

The Step 4 section of this reference provides more instructions.

User Inputs

When starting a new data center case in the Profiler, the initial Step 3 screen will appear as shown in Figure 23; no meters are defined.

Figure 23. Supplied Energy: Meter Summary: Initial



Electric Meters

To enter electric meter data, select the Electricity tab. There are five data entry fields per electric meter. When all the fields for a given meter are filled, click on the "Save" option for that meter.

Table 19. Supplied Energy: Questions per Electric Meter

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.E.M01.01	Electric Meter 1: Meter ID	Text	No
SE.Q.E.M01.02	Electric Meter 1: Use per Period [value]	Real Number	**Yes**
SE.Q.E.M01.03	Electric Meter 1: Use per Period [units] kWh MWh GWh kJ MJ GJ TJ	Select One	**Yes**

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.E.M01.04	Electric Meter 1: Cost per Period [value] $	Real Number	**Yes**
SE.Q.E.M01.05	Electric Meter 1: Period Annual Quarterly Monthly	Select One	**Yes**

Additional electric meters are designated as…

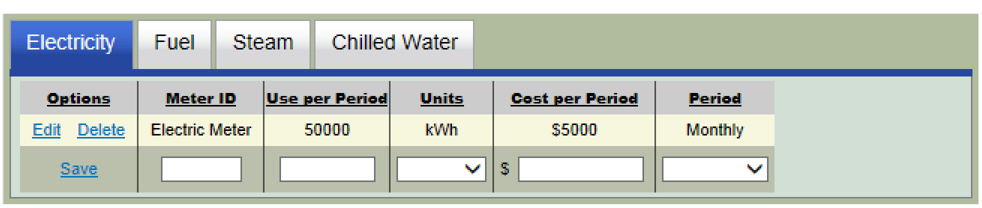
Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.E.M02.01	Electric Meter 2: Meter ID	Text	No
SE.Q.E.M02.02	Electric Meter 2: Use per Period [value]	Real Number	**Yes**
SE.Q.E.M02.03	Electric Meter 2: Use per Period [units]	Select One	**Yes**
SE.Q.E.M02.04	Electric Meter 2: Cost per Period [value]	Real Number	**Yes**
SE.Q.E.M02.05	Electric Meter 2: Period	Select One	**Yes**

Similar codes for all additional electric meters	Electric Meter 3, 4, 5, etc.	See above	See above

Example Electric Meter Input

Figure 24 shows the completed example electric meter. The values shown are for illustration only. The number of electric meters and the values for each meter will vary from one data center to another.

Figure 24. Supplied Energy: Electric Meter Example



Performance Summary Update

If an electric meter's Period is selected as Monthly, DC Pro calculates that meter's annual electricity cost as the Cost per Period multiplied by 12.

If an electric meter's Period is selected as Quarterly, DC Pro calculates that meter's annual electricity cost as the Cost per Period multiplied by 4.

Fuel Meters

If the data center is all-electric, then there will be no fuel meter data to enter. The user can leave the fields on this tab blank.

To enter fuel meter data, select the Fuel tab. There are seven data entry fields per fuel meter. (Note the horizontal scroll bar; not all seven fields are completely visible at the same time.) When all the fields for a given meter are filled, click on the "Save" option for that meter.

Figure 25. Supplied Energy: Fuel Tab

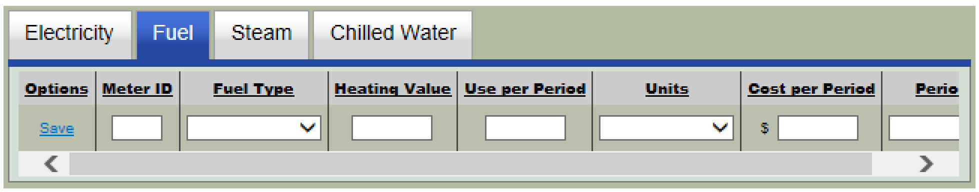


Table 20. Supplied Energy: Questions per Fuel Meter

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.F.M01.01	Fuel Meter 1: Meter ID	Text	No
SE.Q.F.M01.02	Fuel Meter 1: Fuel Type Natural gas #1 Fuel Oil #2 Fuel Oil #3 Fuel Oil #4 Fuel Oil #5 Fuel Oil #6 Fuel Oil #6 Fuel Oil (High sulfur) Diesel Kerosene Propane Other	Select One	No
SE.Q.F.M01.03	Fuel Meter 1: Heating Value [value] The Profiler assumes the value entered in this field has units of BTUs.	Real Number	**Yes**
SE.Q.F.M01.04	Fuel Meter 1: Use per Period [value]	Real Number	**Yes**

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.F.M01.05	Fuel Meter 1: Use per Period [units] MMBtu DTh KCal GCal kJ MJ GJ TJ MSCF M3 MGal (US) MGal (Imperial) MQt (US) MQt (Imperial) kiloLiters BBL MBBL Mlb MMlb Kg Short Tons (US) Long Tons (UK) Metric Tons Lb Gal SCF	Select One	**Yes**
SE.Q.F.M01.06	Fuel Meter 1: Cost per Period [value] $	Real Number	**Yes**
SE.Q.F.M01.07	Fuel Meter 1: Period Annual Quarterly Monthly	Select One	**Yes**

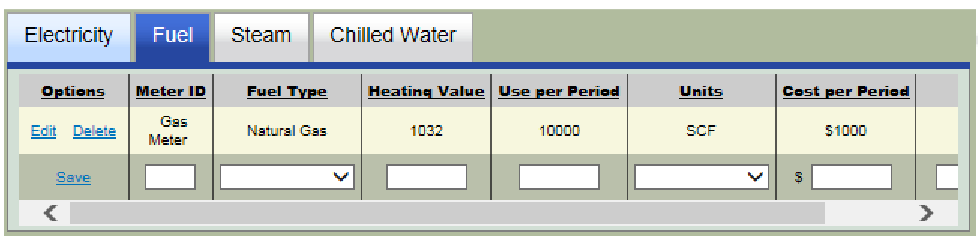
Additional fuel meters are designated as…

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.F.M02.01	Fuel Meter 2: Meter ID	Text	No
SE.Q.F.M02.02	Fuel Meter 2: Fuel Type	Select One	No
SE.Q.F.M02.03	Fuel Meter 2: Heating Value [value]	Real Number	**Yes**
SE.Q.F.M02.04	Fuel Meter 2: Use per Period [value]	Real Number	**Yes**
SE.Q.F.M02.05	Fuel Meter 2: Use per Period [units]	Select One	**Yes**
SE.Q.F.M02.06	Fuel Meter 2: Cost per Period [value]	Real Number	**Yes**
SE.Q.F.M02.07	Fuel Meter 2: Period	Select One	**Yes**
Similar codes for all additional fuel meters	Fuel Meter 3, 4, 5, etc.	See above	See above

Example Fuel Meter Input

Figure 26 shows a completed example fuel meter. The values shown are for illustration only. The number of fuel meters and the values for each meter will vary from one data center to another.

Figure 26. Supplied Energy: Fuel Meter Example



Performance Summary Update

If a fuel meter's Period is selected as Monthly, DC Pro calculates that meter's annual fuel cost as the Cost per Period multiplied by 12.

If a fuel meter's Period is selected as Quarterly, DC Pro calculates that meter's annual fuel cost as the Cost per Period multiplied by 4.

Steam Meters

Typically, the only need for steam in a data center is for humidity control; ie, humidifying air that is deemed too dry. Typically, steam is generated on-site via electric or fuel-powered humidifiers or steam boilers. In these cases, the electricity or fuel used to generate the steam should be accounted for in the Electricity or Fuel tabs, and the Steam tab left blank.

However, some data centers have access to steam that is generated off-site. If the data center in question uses steam from an off-site source, and the steam use of the site is recorded by a steam meter, then the user can enter the steam meter data here.

To enter steam meter data, select the Steam tab. There are five data entry fields per steam meter. When all the fields for a given meter are filled, click on the “Save” option for that meter.

Figure 27. Supplied Energy: Steam Meter Tab

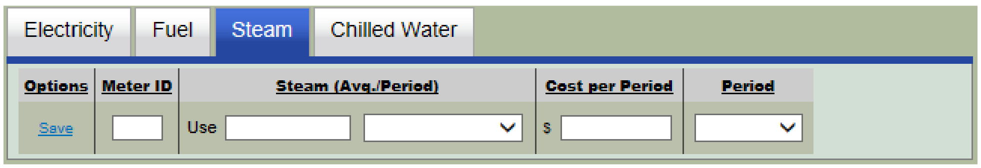


Table 21. Supplied Energy: Questions per Steam Meter

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.S.M01.01	Steam Meter 1: Meter ID	Text	No
SE.Q.S.M01.02	Steam Meter 1: Use per Period [value]	Real Number	**Yes**
SE.Q.S.M01.03	Steam Meter 1: Use per Period [units] MMBtu DTh KCal GCal kJ MJ GJ TJ klb MMlb Kg Short Tons (US) Long Tons (UK) Metric Tons Lb	Select One	**Yes**
SE.Q.S.M01.04	Steam Meter 1: Cost per Period [value] $	Real Number	**Yes**

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.S.M01.05	Steam Meter 1: Period Annual Quarterly Monthly	Select One	**Yes**

Additional steam meters are designated as…

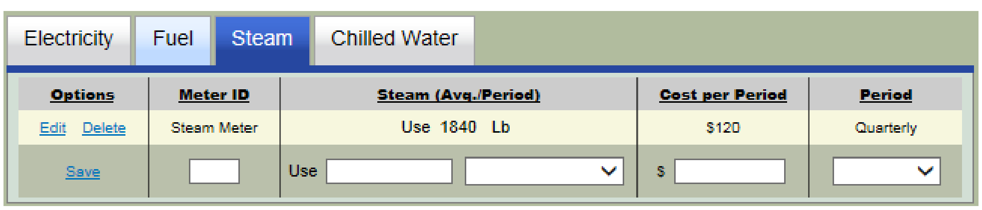
Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.S.M02.01	Steam Meter 2: Meter ID	Text	No
SE.Q.S.M02.02	Steam Meter 2: Use per Period [value]	Real Number	**Yes**
SE.Q.S.M02.03	Steam Meter 2: Use per Period [units]	Select One	**Yes**
SE.Q.S.M02.04	Steam Meter 2: Cost per Period [value]	Real Number	**Yes**
SE.Q.S.M02.05	Steam Meter 2: Period	Select One	**Yes**

Similar codes for all additional steam meters	Steam Meter 3, 4, 5, etc.	See above	See above

Example Steam Meter Input

Figure 28 shows a completed example steam meter. The values shown are for illustration only. The number of steam meters and the values for each meter will vary from one data center to another.

Figure 28. Supplied Energy: Steam Meter Example



Performance Summary Update

If a steam meter's Period is selected as Monthly, DC Pro calculates that meter's annual steam cost as the Cost per Period multiplied by 12.

If a steam meter's Period is selected as Quarterly, DC Pro calculates that meter's annual steam cost as the Cost per Period multiplied by 4.

Chilled Water Meters

Typically, for data centers that use chilled water for cooling, the chilled water is created on-site via electric or fuel-powered chillers. In these cases, the electricity or fuel used to create the chilled water should be accounted for in the Electricity or Fuel tabs, and the Chilled Water tab left blank.

However, some data centers have access to chilled water that is generated off-site. If the data center in question uses chilled water from an off-site source, and the chilled water use of the site is recorded by a chilled water meter, then the user can enter the chilled water meter data here.

To enter chilled water meter data, select the Chilled Water tab. There are five data entry fields per chilled water meter. When all the fields for a given meter are filled, click on the “Save” option for that meter.

Figure 29. Supplied Energy: Chilled Water Tab

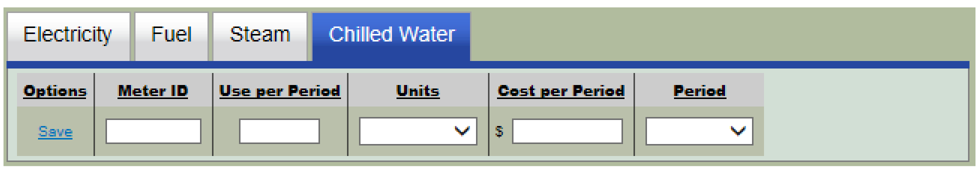


Table 22. Supplied Energy: Questions per Chilled Water Meter

Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.C.M01.01	Chilled Water Meter 1: Meter ID	Text	No
SE.Q.C.M01.02	Chilled Water Meter 1: Use per Period [value]	Real Number	**Yes**
SE.Q.C.M01.03	Chilled Water Meter 1: Use per Period [units] ton-hours MMBtu	Select One	**Yes**
SE.Q.C.M01.04	Chilled Water Meter 1: Cost per Period [value] $	Real Number	**Yes**
SE.Q.C.M01.05	Chilled Water Meter 1: Period Annual Quarterly Monthly	Select One	**Yes**

Additional chilled water meters are designated as…

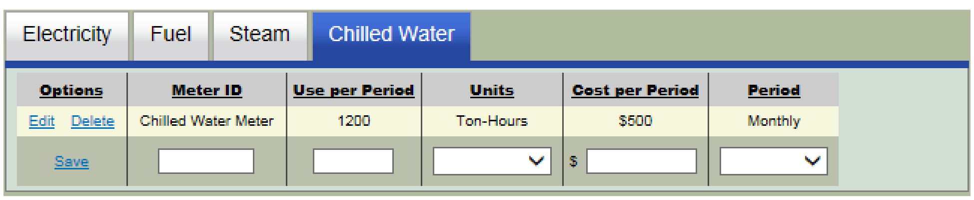
Code	*Input Question*	*Data Type*	*Used in Calcs?*
SE.Q.C.M02.01	Chilled Water Meter 2: Meter ID	Text	No
SE.Q.C.M02.02	Chilled Water Meter 2: Use per Period [value]	Real Number	**Yes**
SE.Q.C.M02.03	Chilled Water Meter 2: Use per Period [units]	Select One	**Yes**
SE.Q.C.M02.04	Chilled Water Meter 2: Cost per Period [value]	Real Number	**Yes**
SE.Q.C.M02.05	Chilled Water Meter 2: Period	Select One	**Yes**

Similar codes for all additional chilled water meters	Chilled Water Meter 3, 4, 5, etc.	See above	See above

Example Chilled Water Meter Input

Figure 30 shows a completed example chilled water meter. The values shown are for illustration only. The number of chilled water meters and the values for each meter will vary from one data center to another.

Figure 30. Supplied Energy: Chilled Water Meter Example



Performance Summary Update

If a chilled water meter's Period is selected as Monthly, DC Pro calculates that meter's annual chilled water cost as the Cost per Period multiplied by 12.

If a chilled water meter's Period is selected as Quarterly, DC Pro calculates that meter's annual chilled water cost as the Cost per Period multiplied by 4.

Calculations

Other than normalizing the energy cost of each meter to one year, there are no calculations performed in Step 3. Step 3 is mainly a data entry step.

Step 4 - Energy Use Distribution (optional)

Step 4 serves two functions. First, it determines the annual energy use for each meter entered in Step 3. Second, it provides the user with the opportunity to distribute the annual energy use for each meter across the different end-use categories.

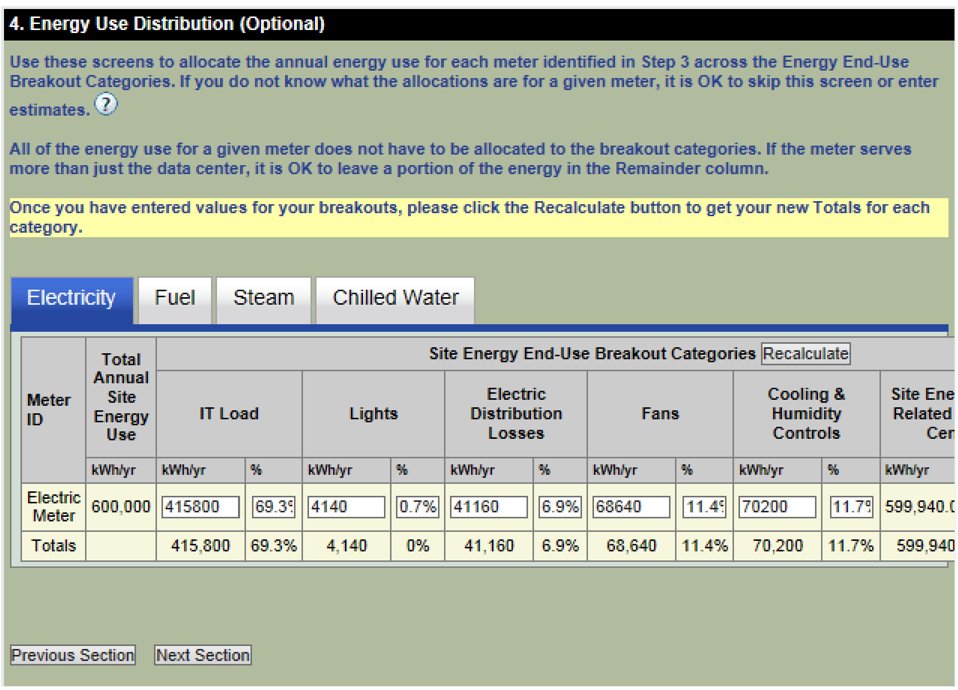
Initial Calculations

Annual Energy Use

In Step 3, the user designated the recorded energy use at each meter as monthly, quarterly, or annual. If the user selected monthly or quarterly, the Profiler extrapolates to obtain the annual energy use. There are no adjustments for weather or occupancy schedules or load variations. If one month of energy use at a given meter was entered as X, then the annual use for that meter is simply 12X.

When entering Step 4, the screen shown in Figure 31 is shown. In each tab, all the meters entered in Step 3 are shown, and the annual energy use for each meter.

Figure 31. Energy Use Distribution: Initial Display



For the calculated Total Annual Energy Use values on this screen, the Profiler first uses the corresponding per-meter Periods…

SE.Q.E.Mnn.05
SE.Q.F.Mnn.07
SE.Q.S.Mnn.05
SE.Q.C.Mnn.05

…from Step 3 to look up the number of periods per year for each meter:

Annual:	1 period per year
Quarterly:	4 periods per year
Monthly:	12 periods per year

Table 23. Energy Use Distribution: Per-Meter Total Energy Use Calculation

Electric Meters

Code	*Name*	*Calculation*
DE.C.E.M01.01	Electric Meter 1: Total Annual Energy Use	Electric Meter 1 Use per Period [SE.Q.E.M01.03], converted to kWh/yr, times the number of periods per year for Electric Meter 1.
DE.C.E.M02.01	Electric Meter 2: Total Annual Energy Use	Electric Meter 2 Use per Period [SE.Q.E.M02.03], converted to kWh/yr, times the number of periods per year for Electric Meter 2.
Similar codes for all additional electric meters	Row 3, 4, 5, etc.	See above.

Fuel Meters

Code	*Name*	*Calculation*
DE.C.F.M01.01	Fuel Meter 1: Total Annual Energy Use	Fuel Meter 1 Use per Period [SE.Q.F.M01.06], converted to kWh/yr, times the number of periods per year for Fuel Meter 1.
DE.C.F.M02.01	Fuel Meter 2: Total Annual Energy Use	Fuel Meter 2 Use per Period [SE.Q.F.M02.06], converted to kWh/yr, times the number of periods per year for Fuel Meter 2.
Similar codes for all additional fuel meters	Row 3, 4, 5, etc.	See above.

Steam Meters

Code	*Name*	*Calculation*
DE.C.S.M01.01	Steam Meter 1: Total Annual Energy Use	Steam Meter 1 Use per Period [SE.Q.S.M01.03], converted to kWh/yr, times the number of periods per year for Steam Meter 1.
DE.C.S.M02.01	Steam Meter 2: Total Annual Energy Use	Steam Meter 2 Use per Period [SE.Q.S.M02.03], converted to kWh/yr, times the number of periods per year for Steam Meter 2.
Similar codes for all additional steam meters	Row 3, 4, 5, etc.	See above.

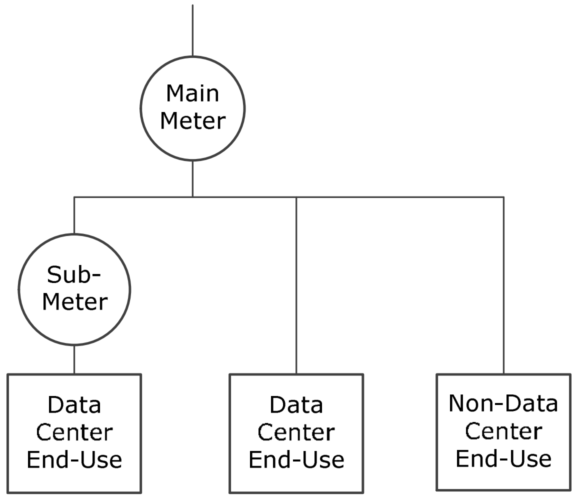
Chilled Water Meters

Code	*Name*	*Calculation*
DE.C.C.M01.01	Chilled Water Meter 1: Total Annual Energy Use	Chilled Water Meter 1 Use per Period [SE.Q.C.M01.03], converted to kWh/yr, times the number of periods per year for Chilled Water Meter 1.
DE.C.C.M02.01	Chilled Water Meter 2: Total Annual Energy Use	Chilled Water Meter 2 Use per Period [SE.Q.C.M02.03], converted to kWh/yr, times the number of periods per year for Chilled Water Meter 2.
Similar codes for all additional chilled water meters	Row 3, 4, 5, etc.	See above.

Energy End-Use Breakouts

It is up to the user to report the full energy use of every energy end-use category related to the data center. This can only be done if all of the meters serving each data center end-use category are entered in Step 3. Example:

Figure 32. Do Submeters Provide Full Coverage?

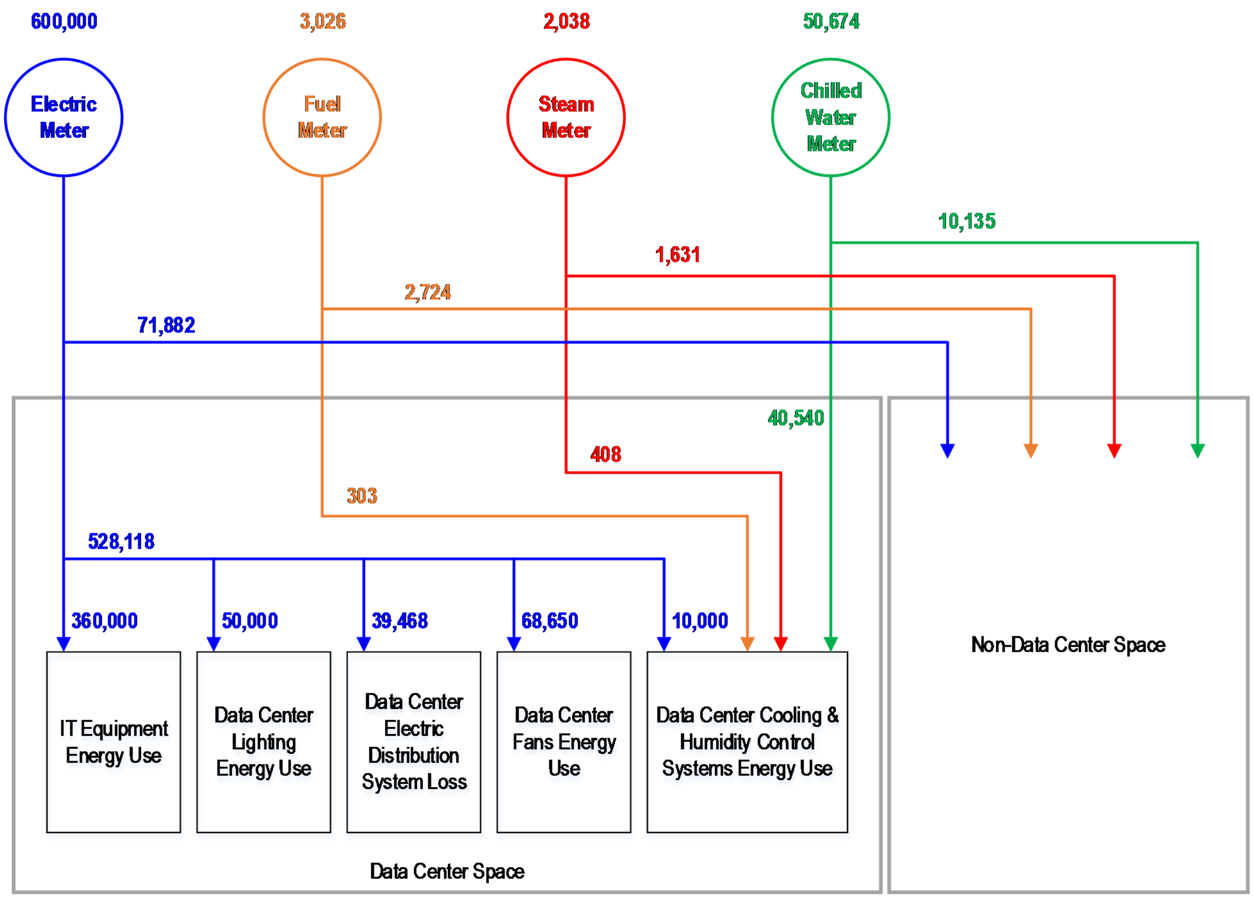


In Step 3, if the user enters the reading from the sub-meter only, and not the main meter, then the data center end-use (in this example) will be under-represented in the results. The preferred solution in this case is to enter the reading from the main meter only, and distribute the main meter use to data center and non-data center end-uses as appropriate.

User Inputs

This manual provides examples of meter data entry. Figure 33 shows a summary of the example meters. (All values shown are in units of kWh per year.) The meter totals were entered in Step 3.

Figure 33. Supplied Energy: Example



Electric Meters

There are ten input fields that can be modified, per meter. The Profiler initially assumes that all of the energy use of each electric meter reported in Step 3 is data center energy use, and it applies the default energy end use breakouts from Step 2 to each meter. The breakout categories are:

- IT Load
- Lights
- Electric Distribution Losses
- Fans
- Cooling and Humidity Controls
- Remainder (Non-Data Center Use)

There may be an initial small amount of energy showing in the Remainder category, due to round-off error.

Figure 34. Energy Use Distribution: Electric Meters: Breakout Questions

Electricity | Fuel | Steam | Chilled Water

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate: IT Load		Lights		Electric Distribution Losses		Fans		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%
Electric Meter	600,000	415800	69.3	4140	0.7%	41160	6.9%	68640	11.4	70200	11.7	599,940.00	100%	60	0%
Totals		415,800	69.3%	4,140	0%	41,160	6.9%	68,640	11.4%	70,200	11.7%	599,940	100%	60	0%

Table 24. Energy Use Distribution: Electric Meters: Breakout Questions

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.E.M01.01	Electric Meter 1: IT Load [usage]	Real Number	**Yes**
DE.Q.E.M01.02	Electric Meter 1: IT Load [%]	Percent	**Yes**
DE.Q.E.M01.03	Electric Meter 1: Lights [usage]	Real Number	**Yes**
DE.Q.E.M01.04	Electric Meter 1: Lights [%]	Percent	**Yes**
DE.Q.E.M01.05	Electric Meter 1: Electric Distribution Losses [usage]	Real Number	**Yes**
DE.Q.E.M01.06	Electric Meter 1: Electric Distribution Losses [%]	Percent	**Yes**
DE.Q.E.M01.07	Electric Meter 1: Fans [usage]	Real Number	**Yes**
DE.Q.E.M01.08	Electric Meter 1: Fans [%]	Percent	**Yes**
DE.Q.E.M01.09	Electric Meter 1: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.E.M01.10	Electric Meter 1: Cooling & Humidity Controls [%]	Percent	**Yes**

Additional electric meters are designated as…

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.E.M02.01	Electric Meter 2: IT Load [usage]	Real Number	**Yes**
DE.Q.E.M02.02	Electric Meter 2: IT Load [%]	Percent	**Yes**
DE.Q.E.M02.03	Electric Meter 2: Lights [usage]	Real Number	**Yes**
DE.Q.E.M02.04	Electric Meter 2: Lights [%]	Percent	**Yes**
DE.Q.E.M02.05	Electric Meter 2: Electric Distribution Losses [usage]	Real Number	**Yes**
DE.Q.E.M02.06	Electric Meter 2: Electric Distribution Losses [%]	Percent	**Yes**
DE.Q.E.M02.07	Electric Meter 2: Fans [usage]	Real Number	**Yes**
DE.Q.E.M02.08	Electric Meter 2: Fans [%]	Percent	**Yes**
DE.Q.E.M02.09	Electric Meter 2: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.E.M02.10	Electric Meter 2: Cooling & Humidity Controls [%]	Percent	**Yes**

Similar codes for all additional electric meters	Electric Meter 3, 4, 5, etc.	See above	See above

Distribution Calculations: Electric Meters

If an electric meter serves both data center and non-data center uses, it is up to the user to distinguish between the two.

The user is free to modify the values in any of the five active kWh/yr fields for any of the meters. If the new sum of kWh/yr for a given meter is less than the Total Annual Energy Use shown for the given meter, then the difference is assigned to Remainder (Non-Data Center Use). The Profiler calculates and shows the new values in the Percent columns.

The Profiler does not prevent the user from entering kWh/yr values that sum to more than the Total Energy Use for the given meter. However, if the user selects “Recalculate” at this point, an error message will be presented.

The user is also free to modify the values in any of the five active percentage fields for any meter. If the new sum of percentages for a given meter is less than 100%, then the difference is assigned to Remainder (Non-Data Center Use). The Profiler calculates and shows the new values in the kWh/yr columns.

The Profiler does not prevent the user from entering percentages that sum to more than 100% for a given meter. However, if the user selects “Recalculate” at this point, an error message will be presented.

If the user modifies both the kWh/yr and the percentage values, the kWh/yr values take precedence.

Example: Electric Meters

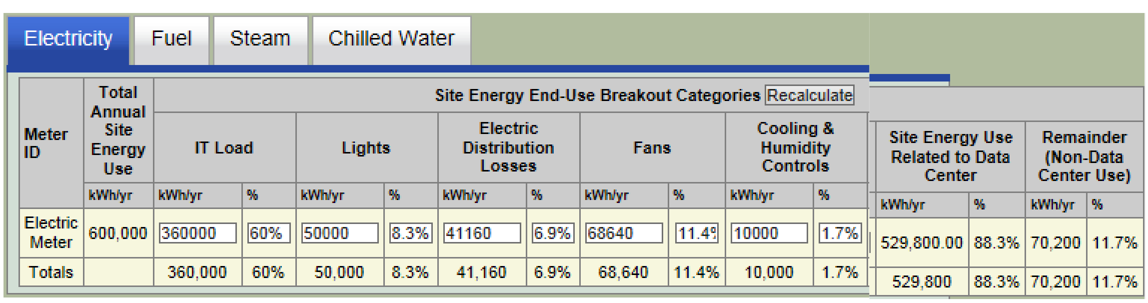
In this hypothetical example, Electric Meter 01 is the only electric meter serving the building. The building contains a data center and offices. The user entered the meter reading in Step 3.

Figure 34 shows the entire building’s annual electric use distributed to data center end uses only, with no remainder. The user estimates the actual electric use as follows:

IT	360,000 kWh/yr
Lights	50,000 kWh/yr
Electric Distribution Losses	Not sure; leaves this at the default value.
Fans	Not sure; leaves this at the default value.
Cooling & Humidity Controls	10,000 kWh/yr

When the user clicks the Recalculate button, the screen appears as shown in Figure 35. The values in the Remainder column now represent the electric energy use of all the non-data center spaces in the building.

Figure 35. Energy Use Redistribution Example: Electric Meters



Electricity | Fuel | Steam | Chilled Water

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate										Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
		IT Load		Lights		Electric Distribution Losses		Fans		Cooling & Humidity Controls					
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%	kWh/yr	%
Electric Meter	600,000	360000	60%	50000	8.3%	41160	6.9%	68640	11.4%	10000	1.7%	529,800.00	88.3%	70,200	11.7%
Totals		360,000	60%	50,000	8.3%	41,160	6.9%	68,640	11.4%	10,000	1.7%	529,800	88.3%	70,200	11.7%

The performance summary at the right side of the screen will also be refreshed, after the user clicks the Next Section button and answers Yes to the question “Would you like to save your data before you continue?” The annual data center electric cost now appears in the Cost Chart.

Figure 36. Energy Use Redistribution Example: Electric Meters: Performance Update

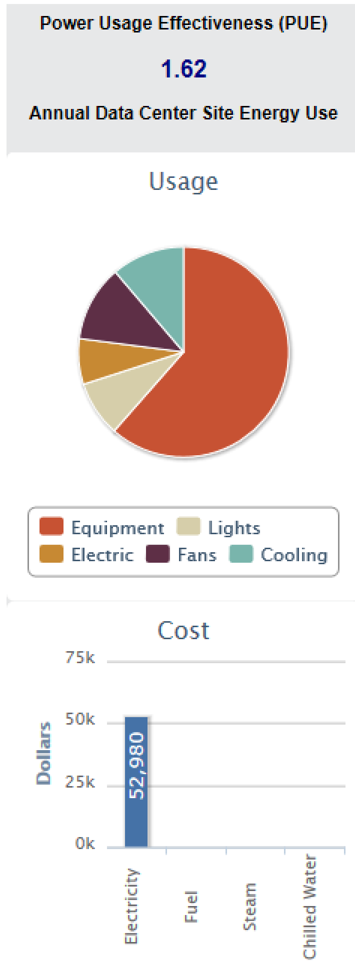


Table 25 shows how the new PUE is calculated.

Table 25. Energy Use Redistribution Example: Electric Meters: Calculations

	A	B	C	D	E	F	G	H	I	J	K
	Energy End-Use Category	Default Breakouts	Annual Energy Use From Step 4 (kWh/yr)					Data Center Breakouts			
			Electric Meters	Fuel Meters	Steam Meters	Chilled Water Meters	Total All Meter Types	For Metered Energy Reported	Defaults for End Uses Where Metered Data Not Reported	Totals	Normalized
1	IT	69.99%	360,000				360,000	68.17%		68.17%	62.02%
2	Lights	0.07%	50,000				50,000	9.47%		9.47%	8.61%
3	Electric Distribution Loss	6.62%	39,468				39,468	7.47%		7.47%	6.80%
4	Fans	11.51%	68,650				68,650	13.00%		13.00%	11.83%
5	Cooling & Humidity Control	11.81%	10,000				10,000	1.89%	9.92%	11.81%	10.74%
6	Total Data Center	100.00%	528,118				528,118	100.00%		109.92%	100.00%
7	Non-Data Center ("Remainder")		71,882								
8	Total Meter Reading		600,000								
9	PUE										1.61

Column B
These are the default energy end-use percentages from Step 2.

Columns C, D, E, F
This is the user's input data from Step 4. At this stage of our example, the user has distributed only the electric meter data.

Column G
Sums the energy use from all meters, for each end-use category.

Columns H, I, J, K
These columns adjust the breakouts based on the user's inputs in Step 4.

Column H
The meter energy from Column G is expressed as a percent of the total meter energy use reported (cell G6).

Column I
If the user reported meter data in Step 3 for fuel or steam or chilled water, but has not yet distributed the meter data in Step 4, then the value in cell I5 is the difference between the default breakout (cell B5) and the total measured breakout reported so far (cell H5). In this example, 11.81% - 1.89% = 9.92%.

Column J
Sums the values from columns H and I.

Column K
The percent values in Column K are normalized by dividing them by the value in cell J6.

PUE
The annual average Power Utilization Effectiveness of the data center is calculated as

> (IT Energy Use + Cooling & Humidity Control Energy Use + Fans Energy Use + Electric Distribution Loss + Lighting Energy Use) / (IT Energy Use)

or simply, cell K7 / cell K1.

Fuel Meters

There are two input fields that can be modified, per meter. The Profiler initially assumes that all of the fuel use reported in Step 3 is data center energy use, and that all of it occurs in the Cooling & Humidity Controls end-use category.

Figure 37. Energy Use Distribution: Fuel Meters: Breakout Questions

Electricity | **Fuel** | Steam | Chilled Water

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Gas Meter	3026.83	3026.83	100%	3026.83	100	.00	0%
Totals		3,026.83	100%	3,026.83	100%		0%

Table 26. Energy Use Distribution: Fuel Meters: Breakout Questions

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.F.M01.01	Fuel Meter 1: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.F.M01.02	Fuel Meter 1: Cooling & Humidity Controls [%]	Percent	**Yes**

Additional fuel meters are designated as…

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.F.M02.01	Fuel Meter 2: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.F.M02.02	Fuel Meter 2: Cooling & Humidity Controls [%]	Percent	**Yes**

Similar codes for all additional fuel meters	Fuel Meter 3, 4, 5, etc.	See above	See above

Distribution Calculations: Fuel Meters

If a fuel meter serves both data center and non-data center uses, it is up to the user to distinguish between the two.

The user is free to modify the value in the active kWh/yr field for each meter. If the new value of kWh/yr is less than the Total Annual Energy Use shown for the given meter, then the difference is assigned to Remainder (Non-Data Center Use). The Profiler calculates and shows the new values in the Percent columns.

The Profiler does not prevent the user from entering a kWh/yr value greater than the Total Energy Use for the given meter. However, if the user selects "Recalculate" at this point, an error message will be presented.

The user is also free to modify the value in the active percentage field. If the new percentage is less than 100%, then the difference is assigned to Remainder (Non-Data Center Use). The Profiler calculates and shows the new values in the kWh/yr columns.

The Profiler does not prevent the user from entering a value greater than 100%. However, if the user selects "Recalculate" at this point, an error message will be presented.

If the user modifies both the kWh/yr and the percentage values, the kWh/yr values take precedence.

Example: Fuel Meters

In this hypothetical example, the natural gas meter serves only a steam boiler. The boiler creates steam for data center use (humidifiers) and non-data center use (space heating). The user entered the gas meter reading in Step 3.

Figure 37 shows all of the gas going to data center end uses, with no remainder for non-data center uses. The user estimates that the data center uses 10% of the natural gas, and assigns that amount of use to the Cooling and Humidity Controls category.

When the user clicks the Recalculate button, the screen appears as shown in Figure 38. The values in the Remainder column now represent the fuel energy use of all the non-data center spaces in the building.

Figure 38. Energy Use Redistribution Example: Fuel Meters

Electricity | Fuel | Steam | Chilled Water

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Gas Meter	3026.83	302.68	10%	302.68	10	2,724.15	90%
Totals		302.68	10%	302.68	10%	2,724.15	90%

The performance summary at the right side of the screen will also be refreshed, after the user clicks the Next Section button and answers Yes to the question “Would you like to save your data before you continue?” The annual data center fuel cost now appears in the Cost Chart. If the fuel cost is very small in relation to the cost of the other types of energy, it may not be visible in the chart. Hover your pointer over the chart, and a box will appear showing the supplied energy type and its annual cost.

Figure 39. Energy Use Redistribution Example: Fuel Meters: Performance Update

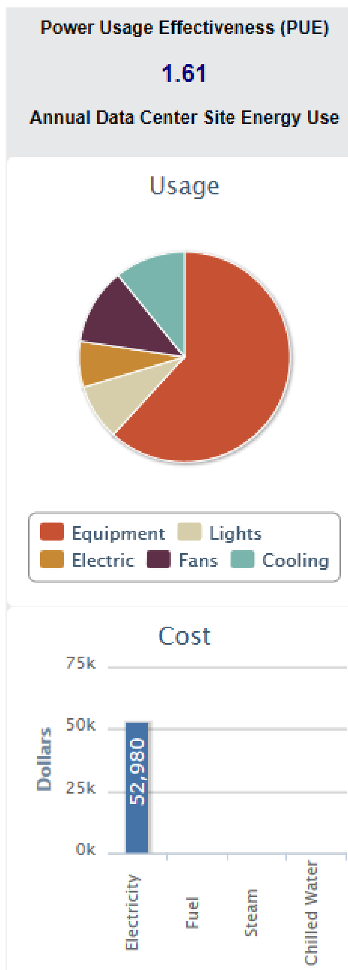


Table 27 shows how the new PUE is calculated.

Table 27. Energy Use Redistribution Example: Fuel Meters: Calculations

	A	B	C	D	E	F	G	H	I	J	K
	Energy End-Use Category	Default Breakouts	Annual Energy Use From Step 4 (kWh/yr)					Data Center Breakouts			
			Electric Meters	Fuel Meters	Steam Meters	Chilled Water Meters	Total All Meter Types	For Metered Energy Reported	Defaults for End Uses Where Metered Data Not Reported	Totals	Normalized
1	IT	69.99%	360,000				360,000	68.13%		68.13%	62.01%
2	Lights	0.07%	50,000				50,000	9.46%		9.46%	8.61%
3	Electric Distribution Loss	6.62%	39,468				39,468	7.47%		7.47%	6.80%
4	Fans	11.51%	68,650				68,650	12.99%		12.99%	11.83%
5	Cooling & Humidity Control	11.81%	10,000	303			10,303	1.95%	9.86%	11.81%	10.75%
6	Total Data Center	100.00%	528,118	303			528,421	100.00%		109.86%	100.00%
7	Non-Data Center ("Remainder")		71,882	2,724							
8	Total Meter Reading		600,000	3,027							
9	PUE										1.61

Column B
These are the default energy end-use percentages from Step 2.

Columns C, D, E, F
This is the user's input data from Step 4. At this stage of our example, the user has distributed the electric and fuel meter data.

Column G
Sums the energy use from all meters, for each end-use category.

Columns H, I, J, K
These columns adjust the breakouts based on the user's inputs in Step 4.

Column H
The meter energy from Column G is expressed as a percent of the total meter energy use reported (cell G6).

Column I
If the user reported meter data in Step 3 for steam or chilled water, but has not yet distributed the meter data in Step 4, then the value in cell I5 is the difference between the default breakout (cell B5) and the total measured breakout reported so far (cell H5). In this example, 11.81% - 1.95% = 9.86%.

Column J
Sums the values from columns H and I.

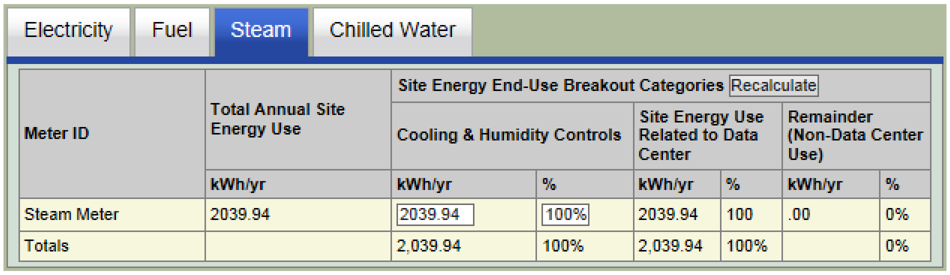
Column K
The percent values in Column K are normalized by dividing them by the value in cell J6.

PUE
The annual average Power Utilization Effectiveness of the data center is calculated as cell K7 / cell K1.

Steam Meters

There are two input fields that can be modified, per meter. The Profiler initially assumes that all of the steam use reported in Step 3 is data center energy use, and that all of it occurs in the Cooling & Humidity Controls end-use category.

Figure 40. Energy Use Distribution: Steam Meters: Breakout Questions



Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Steam Meter	2039.94	2039.94	100%	2039.94	100	.00	0%
Totals		2,039.94	100%	2,039.94	100%		0%

Table 28. Energy Use Distribution: Steam Meters: Breakout Questions

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.S.M01.01	Steam Meter 1: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.S.M01.02	Steam Meter 1: Cooling & Humidity Controls [%]	Percent	**Yes**

Additional steam meters are designated as…

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.S.M02.01	Steam Meter 2: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.S.M02.02	Steam Meter 2: Cooling & Humidity Controls [%]	Percent	**Yes**

Similar codes for all additional steam meters	Steam Meter 3, 4, 5, etc.	See above	See above

Distribution Calculations: Steam Meters

If a steam meter serves both data center and non-data center uses, it is up to the user to distinguish between the two.

The distribution calculations for the steam meters are the same as for the fuel meters.

Example: Steam Meters

In this hypothetical example, there is only one steam meter. The steam is used for data center use (humidifiers) and non-data center use (space heating). The user entered the steam meter reading in Step 3.

Figure 40 shows all of the steam going to data center end uses, with no remainder for non-data center uses. The user estimates that the data center uses 20% of the steam, and assigns that amount of use to the Cooling and Humidity Controls category.

When the user clicks the Recalculate button, the screen appears as shown in Figure 41. The values in the Remainder column now represent the steam energy use of all the non-data center spaces in the building.

Figure 41. Energy Use Redistribution Example: Steam Meters

Electricity | Fuel | Steam | Chilled Water

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Steam Meter	2039.94	407.99	20%	407.99	20	1,631.95	80%
Totals		407.99	20%	407.99	20%	1,631.95	80%

The performance summary at the right side of the screen will also be refreshed, after the user clicks the Next Section button and answers Yes to the question “Would you like to save your data before you continue?” The annual data center steam cost now appears in the Cost Chart. If the steam cost is very small in relation to the cost of the other types of energy, it may not be visible in the chart. Hover your pointer over the chart, and a box will appear showing the supplied energy type and its annual cost.

Figure 42. Energy Use Redistribution Example: Steam Meters: Performance Update

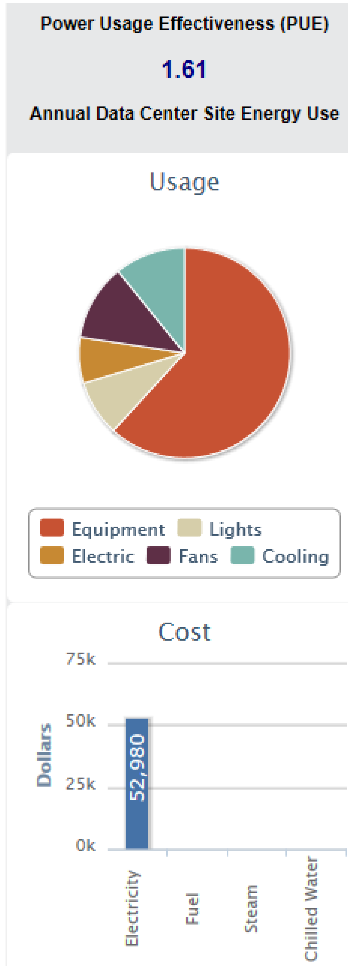


Table 29 shows how the new PUE is calculated.

Table 29. Energy Use Redistribution Example: Steam Meters: Calculations

	A	B	C	D	E	F	G	H	I	J	K
	Energy End-Use Category	Default Breakouts	Annual Energy Use From Step 4 (kWh/yr)					Data Center Breakouts			
			Electric Meters	Fuel Meters	Steam Meters	Chilled Water Meters	Total All Meter Types	For Metered Energy Reported	Defaults for End Uses Where Metered Data Not Reported	Totals	Normalized
1	IT	69.99%	360,000				360,000	68.07%		68.07%	62.01%
2	Lights	0.07%	50,000				50,000	9.45%		9.45%	8.61%
3	Electric Distribution Loss	6.62%	39,468				39,468	7.46%		7.46%	6.80%
4	Fans	11.51%	68,650				68,650	12.98%		12.98%	11.82%
5	Cooling & Humidity Control	11.81%	10,000	303	408		10,711	2.03%	9.78%	11.81%	10.76%
6	Total Data Center	100.00%	528,118	303	408		528,829	100.00%		109.78%	100.00%
7	Non-Data Center ("Remainder")		71,882	2,724	2,724						
8	Total Meter Reading		600,000	3,027	3,132						
9	PUE										1.61

Column B
These are the default energy end-use percentages from Step 2.

Columns C, D, E, F
This is the user's input data from Step 4. At this stage of our example, the user has distributed electric, fuel, and steam meter data.

Column G
Sums the energy use from all meters, for each end-use category.

Columns H, I, J, K
These columns adjust the breakouts based on the user's inputs in Step 4.

Column H
The meter energy from Column G is expressed as a percent of the total meter energy use reported (cell G6).

Column I
If the user reported meter data in Step 3 for chilled water, but has not yet distributed the meter data in Step 4, then the value in cell I5 is the difference between the default breakout (cell B5) and the total measured breakout reported so far (cell H5). In this example, 11.81% - 2.03% = 9.78%.

Column J
Sums the values from columns H and I.

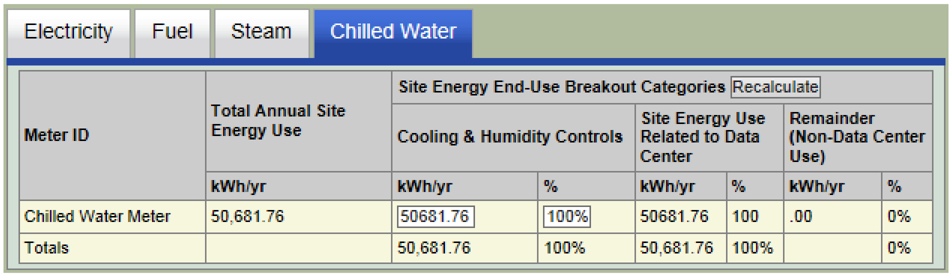
Column K
The percent values in Column K are normalized by dividing them by the value in cell J6.

PUE
The annual average Power Utilization Effectiveness of the data center is calculated as cell K7 / cell K1.

Chilled Water Meters

There are two input fields that can be modified, per meter. The Profiler initially assumes that all of the chilled water use reported in Step 3 is data center energy use, and that all of it occurs in the Cooling & Humidity Controls end-use category.

Figure 43. Energy Use Distribution: Chilled Water Meters: Breakout Questions



Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Chilled Water Meter	50,681.76	50681.76	100%	50681.76	100	.00	0%
Totals		50,681.76	100%	50,681.76	100%		0%

Table 30. Energy Use Distribution: Chilled Water Meters: Breakout Questions

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.C.M01.01	Chilled Water Meter 1: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.C.M01.02	Chilled Water Meter 1: Cooling & Humidity Controls [%]	Percent	**Yes**

Additional chilled water meters are designated as…

Code	*Input Question*	*Data Type*	*Used in Calcs?*
DE.Q.C.M02.01	Chilled Water Meter 2: Cooling & Humidity Controls [usage]	Real Number	**Yes**
DE.Q.C.M02.02	Chilled Water Meter 2: Cooling & Humidity Controls [%]	Percent	**Yes**

Similar codes for all additional chilled water meters	Chilled Water Meter 3, 4, 5, etc.	See above	See above

Distribution Calculations: Chilled Water Meters

If a chilled water meter serves both data center and non-data center uses, it is up to the user to distinguish between the two.

The distribution calculations for the chilled water meters are the same as for the fuel and steam meters.

Example: Chilled Water Meters

In this hypothetical example, there is only one chilled water meter. The user entered the chilled water meter reading in Step 3.

Figure 43 shows all of the chilled water going to data center end uses, with no remainder for non-data center uses. The user estimates that the data center uses 80% of the chilled water, and assigns that amount of use to the Cooling and Humidity Controls category.

When the user clicks the Recalculate button, the screen appears as shown in Figure 44. The values in the Remainder column now represent the chilled water energy use of all the non-data center spaces in the building.

Figure 44. Energy Use Redistribution Example: Chilled Water Meters

Electricity | Fuel | Steam | **Chilled Water**

Meter ID	Total Annual Site Energy Use	Site Energy End-Use Breakout Categories Recalculate					
		Cooling & Humidity Controls		Site Energy Use Related to Data Center		Remainder (Non-Data Center Use)	
	kWh/yr	kWh/yr	%	kWh/yr	%	kWh/yr	%
Chilled Water Meter	50,681.76	40545.41	80%	40545.41	80	10,136.35	20%
Totals		40,545.41	80%	40,545.41	80%	10,136.35	20%

The performance summary at the right side of the screen will also be refreshed, after the user clicks the Next Section button and answers Yes to the question “Would you like to save your data before you continue?” If the chilled water cost is very small in relation to the cost of the other types of energy, it may not be visible in the chart. Hover your pointer over the chart, and a box will appear showing the supplied energy type and its annual cost.

Figure 45. Energy Use Redistribution Example: Chilled Water Meters: Performance Update

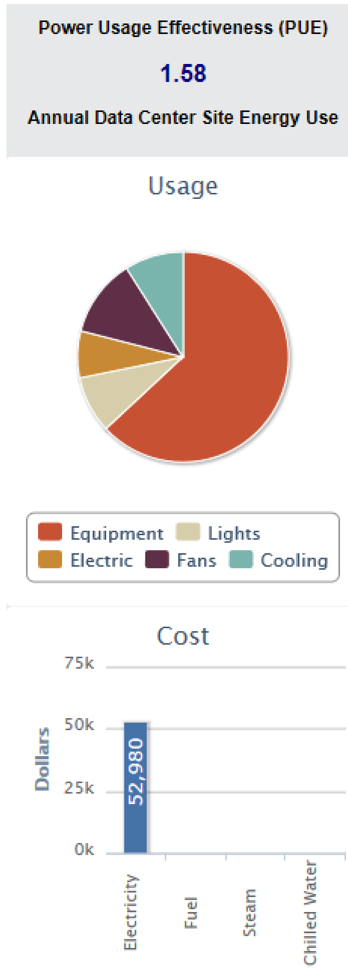


Table 31 shows how the new PUE is calculated.

Table 31. Energy Use Redistribution Example: Chilled Water Meters: Calculations

	A	B	C	D	E	F	G	H	I	J	K
			Annual Energy Use From Step 4 (kWh/yr)					Data Center Breakouts			
	Energy End-Use Category	Default Breakouts	Electric Meters	Fuel Meters	Steam Meters	Chilled Water Meters	Total All Meter Types	For Metered Energy Reported	Defaults for End Uses Where Metered Data Not Reported	Totals	Normalized
1	IT	69.99%	360,000				360,000	63.23%		63.23%	63.23%
2	Lights	0.07%	50,000				50,000	8.78%		8.78%	8.78%
3	Electric Distribution Loss	6.62%	39,468				39,468	6.93%		6.93%	6.93%
4	Fans	11.51%	68,650				68,650	12.06%		12.06%	12.06%
5	Cooling & Humidity Control	11.81%	10,000	303	408	40,540	51,251	9.00%		9.00%	9.00%
6	Total Data Center	100.00%	528,118	303	408	40,540	569,369	100.00%		100.00%	100.00%
7	Non-Data Center ("Remainder")		71,882	2,724	1,631	10,135					
8	Total Meter Reading		600,000	3,027	2,039	50,675					
9	PUE										1.58

Column B
These are the default energy end-use percentages from Step 2.

Columns C, D, E, F
This is the user's input data from Step 4. At this stage of our example, the user has distributed the energy from all four meter types.

Column G
Sums the energy use from all meters, for each end-use category.

Columns H, I, J, K
These columns adjust the breakouts based on the user's inputs in Step 4.

Column H
The meter energy from Column G is expressed as a percent of the total meter energy use reported (cell G6).

Column I
The user has distributed all of the meter data from Step 4, so Column I is now empty.

Column J
Sums the values from columns H and I.

Column K
The percent values in Column K are normalized by dividing them by the value in cell J6.

PUE
The annual average Power Utilization Effectiveness of the data center is calculated as cell K7 / cell K1.

Summary Distribution Calculations

After all the energy for all meters has been distributed as appropriate in Step 4, the result can be summarized as shown in Table 32.

Table 32. Summary Distribution Calculations

	A	B	C	D
	Energy End-Use Category	Default Breakouts	Total Annual Energy Use From Step 4 (kWh/yr)	Measured Data Center Breakouts
1	IT	69.55%	360,000	63.23%
2	Lights	0.70%	50,000	8.78%
3	Electric Distribution Loss	6.58%	39,468	6.93%
4	Fans	11.44%	68,650	12.06%
5	Cooling & Humidity Control	11.73%	51,251	9.00%
6	Total Data Center	100.00%	569,369	100.00%
7	PUE			1.58

Step 5 – Results

Step 5 presents the results of Profiler's calculations.

User Inputs

There are no input fields in Step 5.

Output

Annual Energy Use and Cost Table

The Profiler presents the data center annual energy use for each of the energy streams, and the total. If the user skips Step 3 and 4, the table in Figure 46 will contain zeroes.

Figure 46. Results: Annual Energy Use and Cost Table

5. Results

This is your customized DC Pro Summary Report.

Note: The 'Annual Energy Use' and 'Potential Annual Energy Savings' tables will only have data if you entered data into Sections 3 and 4 (Supplied Energy and Energy Use Distribution).

However you can still generate the recommended actions by clicking 'Finish with the Profile' button and making sure the checkbox is checked.

Annual Energy Use

	Total Amount (in kWh/yr)	$/yr	$/kWh
Electricity	529800	$52,980.00	$0.10
Fuel	302.68	$0.50	$0.00
Steam	407.99	$0.32	$0.00
Chilled Water	40545.41	$370.98	$0.01
Totals	**571056.08**	**$53,351.80**	**$0.09**

Calculations

Energy Use

For each energy stream type, the Profiler takes the annual energy use from each meter of that type, for all end-use categories except "Remainder", and sums to get the total annual data center energy use per energy stream type.

Energy Cost

For each energy stream type, the Profiler takes the annual energy cost from each meter of that type, for all end-use categories except "Remainder", and sums to get the total annual energy cost per energy stream type.

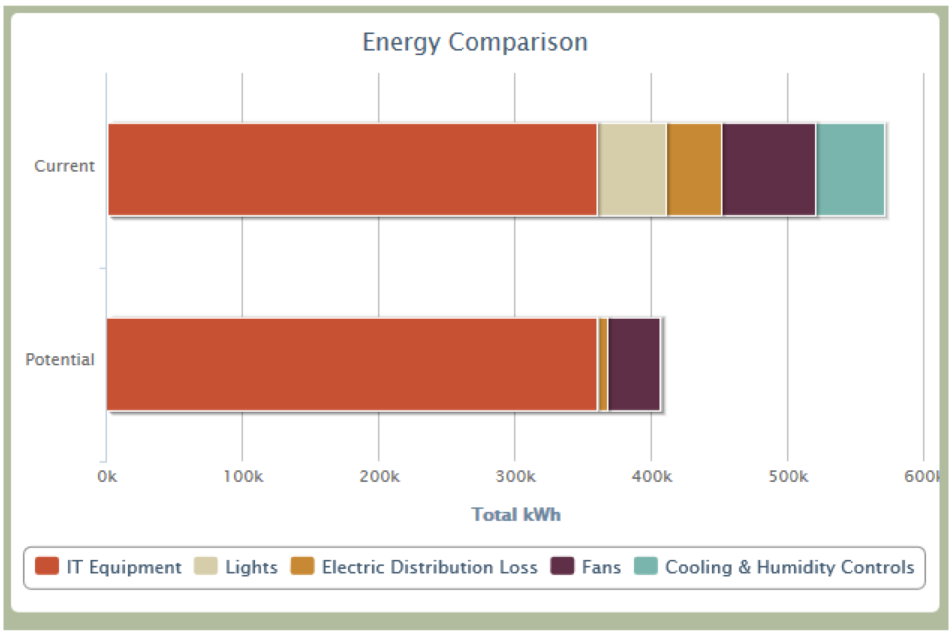
Unit Costs

The unit cost per energy stream type is the energy cost divided by the energy use.

Energy Comparison Chart

If the user skips Step 3 and 4, the chart in Figure 47 will be blank. If the chart is not blank, the user can hover their mouse pointer over the colored bars to get the numeric value of energy use for each end-use type.

Figure 47. Results: Energy Comparison Chart



Calculations

Current

The "Current" bar shows the values from Table 32.

Potential

The "Potential" bar shows the theoretical best possible performance for the given data center. The calculation is described in Table 33.

.

Table 33. Potential Energy End-Use Breakouts: Normalizing Calculation

	A	B	C	D	E
	Energy End-Use Category	Potential Breakouts as Percent of IT	Normalized	Given Energy Use (kWh/yr)	Potential Annual Energy Use (kWh/yr)
1	IT	100.00%	88.57%	360,000	360,000
2	Lights	0.10%	0.09%		360
3	Electric Distribution Loss	2.00%	1.77%		7,200
4	Fans	10.74%	9.51%		38,664
5	Cooling & Humidity Control	0.06%	0.05%		216
6	Totals	112.90%	100.00%		406,440
7	PUE				1.13

Column B
IT: IT energy use expressed as a percent of IT energy use is simply 100%.
Lights: Data center lighting energy use is considered to be 0.1% of IT energy use, throughout the Profiler. This value is not modifiable.
Electric Distribution Loss: The default minimum loss value for a data center that has no UPS, is 2% of IT energy use.
Fans: The value in cell B4 is from Table 15.
Cooling & Humidity Control: The value in cell B5 is from Table 15.

Column C
Column C normalizes the values in Column B.
Cell C1 = cell B1 / cell B6
Cell C2 = cell B2 / cell B6
Etc.

Column D
Cell D1 is the total IT energy use from the example described in the Step 4 section of this manual.

Column E
Cell E1 repeats the value from cell D1. The IT energy use in the potential best possible performing version of the given data center, is assumed to be the same as the IT energy use totaled in Step 4. In other words, no IT-side energy use reductions are taken in to consideration. The potential best possible performing data center, as defined here, depends only on the best possible performance in three end-use categories:

- Electric Distribution Loss
- Fans
- Cooling & Humidity Control

The potential best possible PUE shown in cell E7 is not presented by the Profiler, but it can easily be calculated by dividing cell E6 by cell E1. In this example, the potential PUE is 406,440 / 360,000 = 1.13.

Potential Annual Energy Savings Table

The table shown in Figure 48 presents several results. It shows the Profiler's calculation of:

- The data center's current, actual energy use.
- The Potential (best-case) energy use scenario for the data center.
- The Potential energy savings, which is simply the difference between the Current energy use and the Potential energy use.

If the user skips Step 3 and 4, the kWh/yr columns will contain zeroes, and only the % columns will be populated.

Figure 48. Results: Potential Annual Energy Savings Table

Potential Annual Energy Savings

Breakout Category	Current Energy Use		Potential Energy Use		Potential Savings		
	kWh/yr	%	kWh/yr	%	kWh/yr	%	$
IT Equipment	360000	63%	360000	88.5%	0	0%	$0.00
Data Center Lights	50000	8.8%	406.78	0.1%	49593.22	8.7%	$5,455.25
Electric Distribution Losses	41160	7.2%	7322.03	1.8%	33837.97	5.9%	$3,722.18
Fans	68640	12%	38644.07	9.5%	29995.93	5.3%	$3,299.55
Cooling	51256.08	9%	406.78	0.1%	50849.3	8.9%	$6,101.92
Totals	**571056.08**	**100%**	**406779.661**	**100%**	**164276.42**	**28.8%**	**$18,578.90**
PUE		**1.58**		**1.13**			

Calculations

Current Energy Use

The Current Energy Use columns show the results from Table 32.

Potential Energy Use

The Potential Energy Use columns show the results from Table 33.
.

Potential Savings

The Potential Savings section of the table shown in Figure 48 has three columns.

kWh/yr
The values in the kWh/yr column are the difference between the Current energy use column and the Potential energy use column.

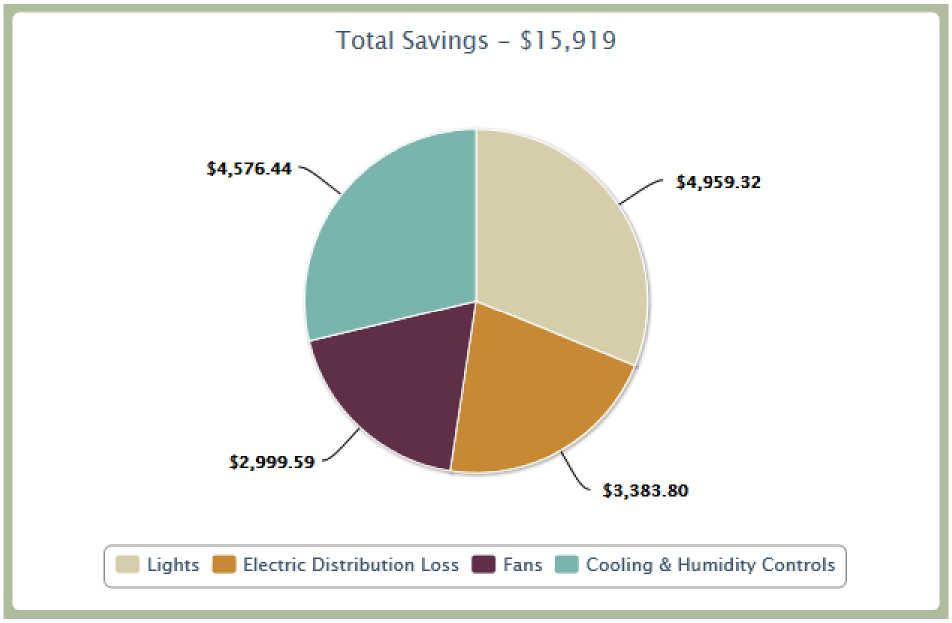
%
The values in the % column are calculated by dividing the potential kWh/yr savings by the total Current energy use.

$
The values in the $ column are obtained by multiplying the potential kWh/yr savings by the unit costs shown in Figure 46.

Total Savings Chart

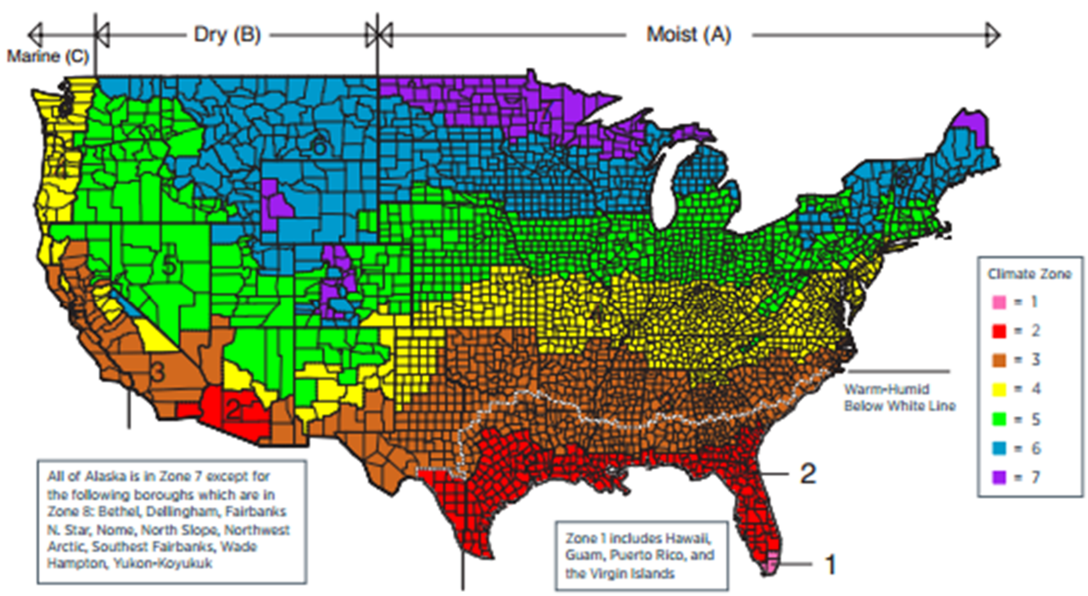
The chart shown in Figure 49 repeats the information from the table in Figure 48.

Figure 49. Results: Total Savings Chart



Appendix A. Lookup Table: Climate Zones

Temperature Climate Zone	Moisture: Moist (A) Dry (B) Marine (C)	Temperature	Moisture	Representative Location
1	A	Very Hot	Moist	FL Miami
2	A	Hot	Moist	TX Houston
2	B	Hot	Dry	AX Pheonix
3	A	Warm	Moist	GA Atlanta
3	B	Warm	Dry	CA LA
3	C	Warm	Marine	CA SF
4	A	Mixed	Moist	MD Baltimore
4	B	Mixed	Dry	NM Albuquerque
4	C	Mixed	Marine	WA Seattle
5	A	Cool	Moist	IL Chicago
5	B	Cool	Dry	CO Boulder
6	A	Cold	Moist	MN Minneapolis
6	B	Cold	Dry	MT Helena
7	_	Very Cold		MN Duluth
8	_	Subarctic		AK Fairbanks



Appendix B. Lookup Table: Cooling System Energy

A calculation model for a generic data center was created. The cooling system energy lookup table was generated by running iterations of the model. This process is described in Appendix D.

Some model parameters are held constant for all iterations.

Model Constants

Envelope	Geometry is a rectangle. No envelope loads assumed. All adiabatic surfaces.	
Building Height	10	ft
IT Load (Constant)	1,000	kW
Average Lighting Load (Constant)	1	kW
Data Center Floor Area	10,000	sf
IT Load Density	100	Watts/sf
Average Lighting Power Density	0.1	Watts/sf

Eight parameters in the model are variables.

Model Variables

Variable	Values			DX System Simulation	CHW System Simulation
Climate Zone	1A, 2A, 2B, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 6A, 6B, 7, 8			15	15
Electric Distribution System Loss as Percent of IT Load	0%, 15%, 45%			3	3
Humidity Control	None, ASHRAE Recommended			2	2
Integrated Air Side Economizer	Yes, No			2	2
Cooling System Type	CRAC	Air-Cooled DX		2	4
	CRAC	Water-Cooled DX			
	CRAH	Air-Cooled Chiller			
	CRAH	Water-Cooled Chiller	No WSE		
	CRAH	Water-Cooled Chiller	Integrated WSE		
	CRAH	Water-Cooled Chiller	Non-Integrated WSE		
Supply Air Temperature (F)	55, 65, 75, 85			4	4
Air Side Delta-T (F)	5, 10, 15, 20			4	4
Chilled Water Supply Temperature (F)	45, 55			1	2

Sub-total Iterations	5,760	23,040
Total Iterations		28,800

Iterations were performed for all meaningful combinations of the variables; this resulted in 28,800 runs.

Only a portion of the 28,800 runs are shown here, for illustration.

Cooling System Energy Lookup Table

	Model Variables								Annual Energy Use (kWh/yr)											
Index Number	ASHRAE Climate Zone	Cooling System Type	Economizer	Electric Distribution System Loss (kW)	Chilled Water Supply Temp (deg F)	Supply Air Temp (deg F)	Air Side Delta-T (deg F)	Humidity Control (50=Yes 0=No)	IT Load	Lights	Electric Distribution System Loss	EDS Loss as Percent of IT Load	Supply Fans	Supply Fans as Percent of IT Load	Total Cooling Plant (Comprs + Pumps + Humidifier + Towers)	Total Cooling Plant as Percent of IT Load	Total Support Systems (Lights + EDS Loss + Fans + Comprs + Pumps + Humidifier + Towers)	Whole Data Center (IT Load + Support Systems)	PUE (Whole Data Center / IT Load)
1	1A	DX Air	NoEconomizer	0	DX	55	15	50	8,760,000	8,760	0	0%	1,814,130	20.71%	5,649,483	64.49%	7,472,373	16,232,373	1.85
2	1A	DX Air	NoEconomizer	0	DX	55	5	0	8,760,000	8,760	0	0%	5,455,489	62.28%	6,986,771	79.76%	12,451,020	21,211,020	2.42
3	1A	DX Air	NoEconomizer	0	DX	55	10	0	8,760,000	8,760	0	0%	2,717,932	31.03%	4,920,069	56.17%	7,646,761	16,406,761	1.87
4	1A	DX Air	NoEconomizer	0	DX	55	5	50	8,760,000	8,760	0	0%	5,455,489	62.28%	7,501,664	85.64%	12,965,913	21,725,913	2.48
5	1A	DX Air	NoEconomizer	0	DX	55	10	50	8,760,000	8,760	0	0%	2,717,932	31.03%	6,161,821	70.34%	8,888,513	17,648,513	2.01
6	1A	DX Air	NoEconomizer	0	DX	55	15	0	8,760,000	8,760	0	0%	1,814,130	20.71%	4,389,198	50.11%	6,212,088	14,972,088	1.71
7	1A	DX Air	NoEconomizer	0	DX	55	20	0	8,760,000	8,760	0	0%	1,360,189	15.53%	4,100,740	46.81%	5,469,689	14,229,689	1.62
8	1A	DX Air	NoEconomizer	0	DX	55	20	50	8,760,000	8,760	0	0%	1,360,189	15.53%	5,361,697	61.21%	6,730,646	15,490,646	1.77
9	1A	DX Air	NoEconomizer	0	DX	65	5	50	8,760,000	8,760	0	0%	5,455,489	62.28%	7,501,608	85.63%	12,965,857	21,725,857	2.48
10	1A	DX Air	NoEconomizer	0	DX	65	5	0	8,760,000	8,760	0	0%	5,455,489	62.28%	6,202,433	70.80%	11,666,683	20,426,683	2.33

Rows 11 to 28,790 not shown

28791	8_	CHW Water	FixedDryBulb	450	55	75	15	50	8,760,000	8,760	3,942,000	45%	1,835,916	20.96%	1,412,614	16.13%	7,199,291	15,959,291	1.82
28792	8_	CHW Water	FixedDryBulb	450	55	75	20	50	8,760,000	8,760	3,942,000	45%	1,383,281	15.79%	1,326,017	15.14%	6,660,059	15,420,059	1.76
28793	8_	CHW Water	FixedDryBulb	450	55	85	5	0	8,760,000	8,760	3,942,000	45%	5,425,734	61.94%	1,188,249	13.56%	10,564,743	19,324,743	2.21
28794	8_	CHW Water	FixedDryBulb	450	55	85	10	0	8,760,000	8,760	3,942,000	45%	2,713,964	30.98%	869,993	9.93%	7,534,717	16,294,717	1.86
28795	8_	CHW Water	FixedDryBulb	450	55	85	15	0	8,760,000	8,760	3,942,000	45%	1,818,729	20.76%	760,546	8.68%	6,530,035	15,290,035	1.75
28796	8_	CHW Water	FixedDryBulb	450	55	85	5	50	8,760,000	8,760	3,942,000	45%	5,425,074	61.93%	2,074,343	23.68%	11,450,177	20,210,177	2.31
28797	8_	CHW Water	FixedDryBulb	450	55	85	20	0	8,760,000	8,760	3,942,000	45%	1,369,185	15.63%	702,660	8.02%	6,022,604	14,782,604	1.69
28798	8_	CHW Water	FixedDryBulb	450	55	85	10	50	8,760,000	8,760	3,942,000	45%	2,713,681	30.98%	1,568,568	17.91%	8,233,009	16,993,009	1.94
28799	8_	CHW Water	FixedDryBulb	450	55	85	15	50	8,760,000	8,760	3,942,000	45%	1,818,246	20.76%	1,401,748	16.00%	7,170,754	15,930,754	1.82
28800	8_	CHW Water	FixedDryBulb	450	55	85	20	50	8,760,000	8,760	3,942,000	45%	1,368,341	15.62%	1,318,466	15.05%	6,637,567	15,397,567	1.76

This lookup table is contained within DC Pro. As users describe their data center, DC Pro looks up the appropriate values in this table, as described in the body of the Calculation Reference Manual.

Appendix C. Lookup Table: UPS Efficiency

The UPS efficiency table is based on data provided in March 2013 by:

Munther Salim, PhD
Hewlett Packard
msalim@hp.com

The data covers 12 UPS capacities, 2 voltages, 4 technology types, and 10 load factors.

This lookup table is contained within DC Pro. As users describe their UPS, DC Pro looks up the appropriate values in this table, as described in the body of the Calculation Reference Manual.

This table is also available as an Excel file.

UPS Efficiency Lookup Table

			Load Factor									
Nominal Capacity (kVA)	Voltage	Type	1% to 10%	11% to 20%	21% to 30%	31% to 40%	41% to 50%	51% to 60%	61% to 70%	71% to 80%	81% to 90%	91% to 100%
50	480	Double Conversion	78.0%	84.9%	87.0%	89.5%	90.7%	91.7%	92.5%	92.5%	92.5%	92.0%
50	480	Double Conversion + Filter	77.7%	83.9%	87.0%	88.9%	89.7%	90.7%	92.3%	92.3%	92.0%	92.0%
50	480	Delta Conversion	80.0%	84.7%	87.4%	90.7%	91.6%	93.1%	93.8%	94.3%	94.7%	94.9%
50	480	Rotary	72.1%	83.3%	87.7%	89.9%	91.2%	92.0%	92.4%	92.7%	92.9%	93.0%
50	208	Double Conversion	79.0%	85.9%	88.0%	90.5%	91.7%	92.7%	93.5%	93.5%	93.5%	93.0%
50	208	Double Conversion + Filter	78.7%	84.9%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
50	208	Delta Conversion	79.0%	83.7%	86.2%	89.5%	90.1%	91.6%	92.1%	92.6%	92.7%	92.9%
50	208	Rotary	71.1%	82.1%	86.5%	88.4%	89.7%	90.3%	90.7%	90.7%	90.9%	91.0%
100	480	Double Conversion	80.7%	86.9%	90.2%	91.7%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
100	480	Double Conversion + Filter	79.5%	85.8%	89.2%	90.9%	92.0%	93.5%	94.5%	94.3%	94.1%	94.0%
100	480	Delta Conversion	80.0%	84.7%	87.4%	90.7%	91.6%	93.1%	93.8%	94.3%	94.7%	94.9%
100	480	Rotary	72.1%	83.3%	87.7%	89.9%	91.2%	92.0%	92.4%	92.7%	92.9%	93.0%
100	208	Double Conversion	79.7%	85.9%	89.0%	90.5%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
100	208	Double Conversion + Filter	78.7%	84.9%	88.0%	89.5%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
100	208	Delta Conversion	79.0%	83.7%	86.2%	89.5%	90.1%	91.6%	92.1%	92.6%	92.7%	92.9%
100	208	Rotary	71.1%	82.1%	86.5%	88.4%	89.7%	90.3%	90.7%	90.7%	90.9%	91.0%
150	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
150	480	Double Conversion + Filter	79.5%	85.8%	89.2%	90.9%	92.0%	93.5%	94.5%	94.3%	94.1%	94.0%
150	480	Delta Conversion	80.0%	84.7%	87.4%	90.7%	91.6%	93.1%	93.8%	94.3%	94.7%	94.9%
150	480	Rotary	76.7%	86.2%	89.7%	91.5%	92.4%	92.8%	93.0%	93.1%	93.1%	93.1%
150	208	Double Conversion	79.7%	85.9%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
150	208	Double Conversion + Filter	78.7%	84.9%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
150	208	Delta Conversion	79.0%	83.7%	86.2%	89.5%	90.1%	91.6%	92.1%	92.6%	92.7%	92.9%
150	208	Rotary	75.7%	85.2%	88.7%	90.5%	91.4%	91.8%	92.0%	92.1%	92.1%	92.1%
225	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
225	480	Double Conversion + Filter	79.5%	85.8%	89.2%	90.9%	92.0%	93.5%	94.5%	94.3%	94.1%	94.0%
225	480	Delta Conversion	80.0%	84.7%	87.4%	90.7%	91.6%	93.1%	93.8%	94.3%	94.7%	94.9%
225	480	Rotary	72.1%	83.3%	87.7%	89.9%	91.2%	92.0%	92.4%	92.7%	92.9%	93.0%
225	208	Double Conversion	79.7%	85.9%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
225	208	Double Conversion + Filter	78.7%	84.9%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
225	208	Delta Conversion	79.0%	83.7%	86.2%	89.5%	90.1%	91.6%	92.1%	92.6%	92.7%	92.9%
225	208	Rotary	71.1%	82.1%	86.5%	88.4%	89.7%	90.3%	90.7%	90.7%	90.9%	91.0%

			Load Factor									
Nominal Capacity (kVA)	Voltage	Type	1% to 10%	11% to 20%	21% to 30%	31% to 40%	41% to 50%	51% to 60%	61% to 70%	71% to 80%	81% to 90%	91% to 100%
300	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
300	480	Double Conversion + Filter	79.5%	85.8%	89.2%	90.9%	92.0%	93.5%	94.5%	94.3%	94.1%	94.0%
300	480	Delta Conversion	80.0%	84.7%	87.4%	90.7%	91.6%	93.1%	93.8%	94.3%	94.7%	94.9%
300	480	Rotary	76.1%	85.7%	89.3%	91.2%	92.3%	92.9%	93.2%	93.4%	93.6%	93.7%
300	208	Double Conversion	79.7%	85.9%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
300	208	Double Conversion + Filter	78.7%	84.9%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
300	208	Delta Conversion	79.0%	83.7%	86.2%	89.5%	90.1%	91.6%	92.1%	92.6%	92.7%	92.9%
300	208	Rotary	75.1%	84.5%	88.1%	89.7%	90.8%	91.2%	91.5%	91.4%	91.6%	91.7%
400	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
400	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
400	480	Delta Conversion	88.0%	91.5%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
400	480	Rotary	73.3%	84.1%	88.4%	90.6%	91.8%	92.6%	93.0%	93.3%	93.4%	93.6%
400	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
400	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
400	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
400	208	Rotary	72.3%	82.9%	87.2%	89.1%	90.3%	90.9%	91.3%	91.3%	91.4%	91.6%
500	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
500	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
500	480	Delta Conversion	88.0%	91.5%	95.0%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
500	480	Rotary	73.3%	84.1%	88.4%	90.6%	91.8%	92.6%	93.0%	93.3%	93.4%	93.6%
500	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
500	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
500	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
500	208	Rotary	72.3%	82.9%	87.2%	89.1%	90.3%	90.9%	91.3%	91.3%	91.4%	91.6%
600	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
600	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
600	480	Delta Conversion	88.0%	93.3%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
600	480	Rotary	72.4%	83.6%	88.0%	90.3%	91.7%	92.6%	93.1%	93.5%	93.8%	94.0%
600	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
600	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
600	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
600	208	Rotary	71.4%	82.4%	86.8%	88.8%	90.2%	90.9%	91.4%	91.5%	91.8%	92.0%
750	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
750	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
750	480	Delta Conversion	88.0%	93.3%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
750	480	Rotary	76.7%	86.4%	90.1%	91.9%	92.9%	93.5%	93.8%	94.0%	94.1%	94.1%
750	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
750	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
750	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
750	208	Rotary	75.7%	85.2%	88.9%	90.4%	91.4%	91.8%	92.1%	92.0%	92.1%	92.1%

			Load Factor									
Nominal Capacity (kVA)	Voltage	Type	1% to 10%	11% to 20%	21% to 30%	31% to 40%	41% to 50%	51% to 60%	61% to 70%	71% to 80%	81% to 90%	91% to 100%
800	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
800	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
800	480	Delta Conversion	88.0%	93.3%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
800	480	Rotary	76.7%	86.4%	90.1%	91.9%	92.9%	93.5%	93.8%	94.0%	94.1%	94.1%
800	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
800	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
800	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
800	208	Rotary	75.7%	85.2%	88.9%	90.4%	91.4%	91.8%	92.1%	92.0%	92.1%	92.1%
900	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
900	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
900	480	Delta Conversion	88.0%	93.3%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
900	480	Rotary	78.1%	87.6%	91.2%	93.0%	93.9%	94.5%	94.8%	94.9%	95.0%	95.0%
900	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
900	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
900	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
900	208	Rotary	77.1%	86.4%	90.0%	91.5%	92.4%	92.8%	93.1%	92.9%	93.0%	93.0%
1000	480	Double Conversion	80.7%	86.9%	90.2%	92.1%	93.2%	94.2%	95.8%	95.8%	95.5%	95.3%
1000	480	Double Conversion + Filter	79.5%	85.8%	89.1%	90.9%	92.0%	93.0%	94.5%	94.3%	94.1%	94.0%
1000	480	Delta Conversion	88.0%	93.3%	95.2%	96.1%	96.5%	96.8%	97.0%	97.0%	97.1%	97.1%
1000	480	Rotary	78.1%	87.6%	91.2%	93.0%	93.9%	94.5%	94.8%	94.9%	95.0%	95.0%
1000	208	Double Conversion	79.7%	85.7%	89.0%	90.9%	91.7%	92.7%	94.3%	94.3%	94.0%	93.8%
1000	208	Double Conversion + Filter	78.7%	84.7%	88.0%	89.9%	90.7%	91.7%	93.3%	93.3%	93.0%	92.8%
1000	208	Delta Conversion	68.9%	92.0%	93.9%	94.5%	93.8%	95.1%	97.0%	97.0%	95.1%	95.1%
1000	208	Rotary	77.1%	86.4%	90.0%	91.5%	92.4%	92.8%	93.1%	92.9%	93.0%	93.0%

Appendix D. EnergyPlus Models

Overview

DC Pro does not perform energy simulations of data center cooling systems. It relies on a large number of pre-calculated results, contained in a lookup table. Values are taken from the lookup table in accordance with the answers DC Pro users provide to the input questions.

This appendix describes the EnergyPlus simulations that were created to generate the values that occupy the lookup table.

For a description of the Cooling System Energy Lookup Table itself, see Appendix B.

For a description of the DC Pro input questions, and how DC Po uses the answers to the questions to select values from the lookup table, see the body of the Calculation Reference Manual.

EnergyPlus Models

Six base EnergyPlus models were created to address six primary mechanical cooling system types:

1. Air-Cooled DX
2. Water-Cooled DX
3. Air-Cooled Chiller
4. Water-Cooled Chiller
5. Water-Cooled Chiller with Integrated Waterside Economizing
6. Water-Cooled Chiller with Non-Integrated

All base models were created in DesignBuilder v3 to set up the geometry and the basic HVAC system nodes and loops. This included but was not limited to:

- Geometry and construction assemblies
- Equipment internal loads
- Airside distribution system
- Airside zone supply and return
- Chilled water and condenser water loops (as needed)

All systems are structured as built-up AirLoopHVAC types serving one thermal zone. The AHU provides all air tempering, including cooling, heating, and moisture conditioning. Each thermal zone contains a singleDuctVAVNoReheat terminal.

Climate is controlled with a DualSetpoint thermostat and a humidistat.

All equipment is set to autosize in EnergyPlus. Models are iterated over many different weather locations and setpoints, so sizing varies as needed.

Each model includes parametric definitions to allow iteration through all variable options. These parametrics include airside economizing and humidity control setpoints.

Constants and Variables

Some model parameters are held constant for all iterations, as shown in the following table.

Model Constants

Envelope	Geometry is a rectangle. No envelope loads assumed. All adiabatic surfaces.	
Building Height	10	ft
IT Load (Constant)	1,000	kW
Average Lighting Load (Constant)	1	kW
Data Center Floor Area	10,000	sf
IT Load Density	100	Watts/sf
Average Lighting Power Density	0.1	Watts/sf

The data center floor area, IT load, and lighting load are fixed. This does not hinder DC Pro's ability to address data centers of different sizes and loads, as all end-use energy breakouts presented in Step 2 of the Profiler are expressed in ***relative terms***; ie, as percent of the IT load. (Steps 3 and 4 of the Profiler allow the user to enter actual energy use and distribute it to the end uses.)

Eight parameters in the model are variables:

Model Variables

Variable	Values			DX System Simulation	CHW System Simulation
Climate Zones	1A, 2A, 2B, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 6A, 6B, 7, 8			15	15
Electric Distribution System Loss as Percent of IT Load	0%, 15%, 45%			3	3
Humidity Control	None, ASHRAE Recommended			2	2
Integrated Air Side Economizer	Yes, No			2	2
Cooling System Type	CRAC	Air-Cooled DX		2	4
	CRAC	Water-Cooled DX			
	CRAH	Air-Cooled Chiller			
	CRAH	Water-Cooled Chiller	No WSE		
	CRAH	Water-Cooled Chiller	Integrated WSE		
	CRAH	Water-Cooled Chiller	Non-Integrated WSE		
Supply Air Temperature (F)	55, 65, 75, 85			4	4
Air Side Delta-T (F)	5, 10, 15, 20			4	4
Chilled Water Supply Temperature (F)	45, 55			1	2

Sub-total Iterations	5,760	23,040
Total Iterations		28,800

Iterating through all meaningful combinations of the variables yields 28,800 separate simulations.

Parametric Iterations

Iterations were performed using JePlus. JePlus allows the user to select a building model (an IDF or a set of IMF files) and put search strings in place of chosen parameters, and to specify all alternative values for the parameters. JePlus then cycles through the parametric values, placing them in the right places in the building model, runs EnergyPlus, and collects the results.

HVAC Efficiencies and Setpoints

The following table describes the HVAC system component efficiencies and setpoints used in the models. The values are drawn primarily from these sources:

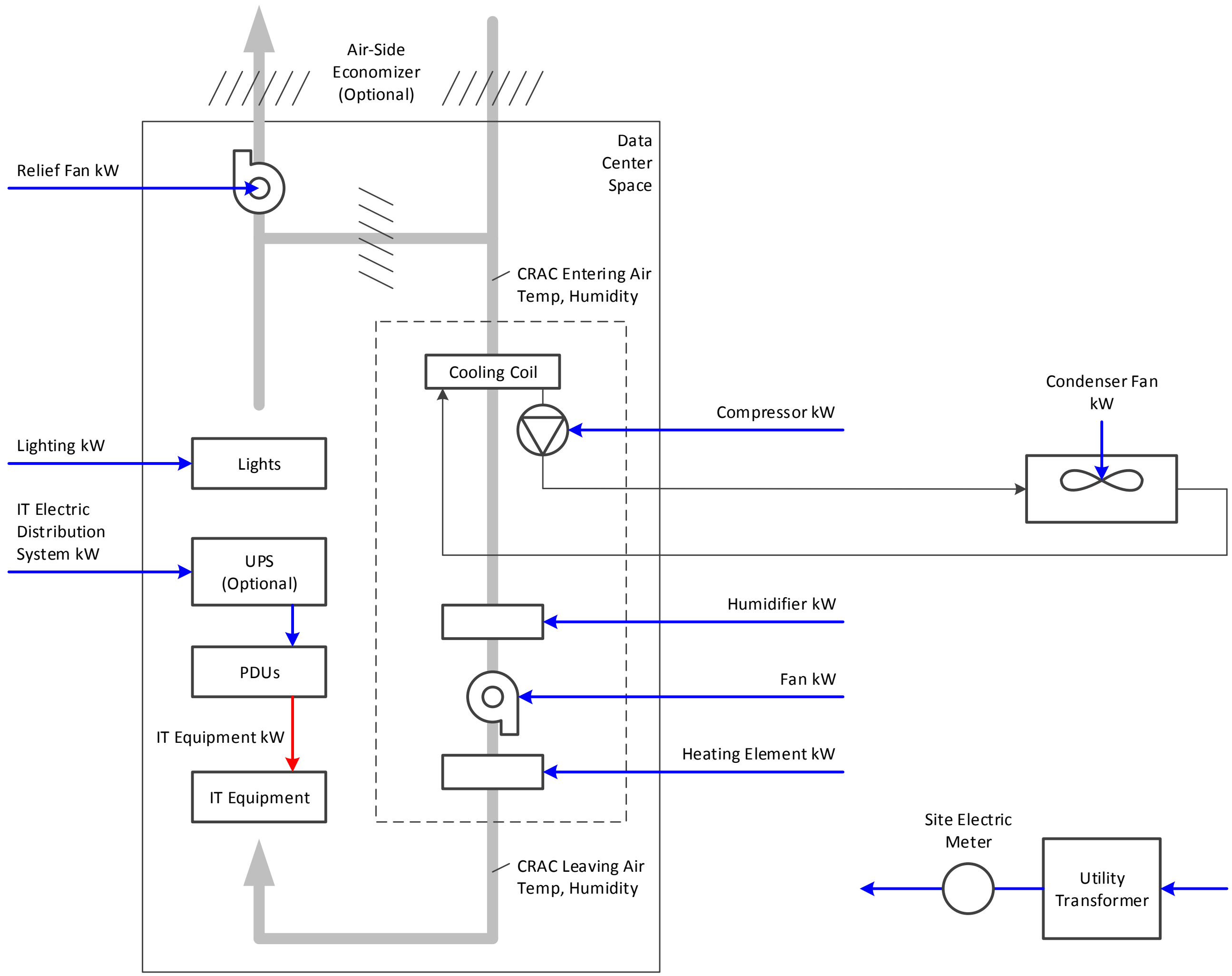
- ASHRAE Standard 90.1, 2007.
- "Thermal Guidelines for Data Processing Environments", ASHRAE TC 9.9, 2011
- "Energy Efficiency Baselines for Data Centers", Pacific Gas & Electric, Oct 1, 2010.

System Components	Parameter	Value	Units	Source
Fans	Fan System Efficiency	1,500	cfm/kW	PG&E Data Center Baseline 2010. Average of the different containment strategies, including no containment.
	Fan System Efficiency	0.67	W/cfm	Inverse of previous row.
	Nominal Motor Efficiency	90%		Assumed efficiency for typical CRAC/CRAH fan motor.
	Nominal Drive Efficiency	95%		PG&E Data Center Baseline 2010. Belt drive.
	Nominal Fan Efficiency	60%		Assumed efficiency for typical CRAC/CRAH fan.
	Total Static Pressure*	3.4	in. w.g.	Calculated from Fan System Efficiency and Nominal Fan Efficiency.
	Total Static Pressure	847	Pa	Conversion from in. w.g.
	CRAC/CRAH Fan Schedule	ON/OFF		PG&E Data Center Baseline 2010.
	Air-Side Economizer Relief Fan	Variable Speed Part-Load Curve		ASHRAE 90.1 2007.
Air-Cooled Chiller	COP	2.80		ASHRAE 90.1 2007 6.8.1c; with condenser.
	Curve Set	DOE-2 Screw		EnergyPlus.
Water-Cooled Chiller	COP	5.55		ASHRAE 90.1 2007 6.8.1c; centrifugal <300 tons.
	Curve Set	DOE-2 Centrifugal		EnergyPlus.
Air-Cooled DX Cooling	COP	2.84		ASHRAE 90.1 2007 6.8.1A; >=760 kBtu/hr Electric. EER 9.7.
	Curve Set	EnergyPlus Default DX Curve Set		EnergyPlus .
	Condenser	n/a		Included in COP value.
Water-Cooled DX Cooling	COP	3.22		ASHRAE 90.1 2007 6.8.1A. EER 11
	Curve Set	EnergyPlus Default DX Curve Set		EnergyPlus.
	Condenser	n/a		Included in COP value.

System Components	Parameter	Value	Units	Source
Chilled Water Pump	Nominal Motor Efficiency	94.1%		PG&E Data Center Baseline 2010.
	Nominal Pump Efficiency	68%		PG&E Data Center Baseline 2010.
	Static Pressure	75	ft	PG&E Data Center Baseline 2010.
Condenser Water Pump	Pump System Efficiency	19	W/gpm	ASHRAE 90.1 2007, section G3.1.3.11.
	Nominal Motor Efficiency	90%		Assumed efficiency for typical condenser water pump motor.
	Nominal Pump Efficiency	65%		Assumed efficiency for typical condenser water pump in data center application.
	Static Pressure	65	ft	Calculated from Pump System Efficiency and Nominal Pump Efficiency.
Cooling Tower	Design Wetbulb Temperature	75	deg F	PG&E Data Center Baseline 2010.
	Approach Temperature	10	deg F	PG&E Data Center Baseline 2010.
Heat Exchanger	Approach Temperature	3	deg F	Assumed.
Chilled Water Loop	CHW Supply Temperature Setpoint	45	deg F	PG&E Data Center Baseline 2010.
	CHW Delta-T	10	deg F	PG&E Data Center Baseline 2010.
Condenser Water Loop	CW Temperature Setpoint	Ambient wetbulb +5 deg F	deg F	PG&E Data Center Baseline 2010.
	CW Delta-T	10	deg F	PG&E Data Center Baseline 2010.
Humidifier	Type of Humidifier	Electric Steam Generator		PG&E Data Center Baseline 2010.
	Max Allowed Humidity	60%	RH	ASHRAE Thermal Guidelines, Recommended range
	Min Allowed Humidity	40%	RH	ASHRAE Thermal Guidelines, Recommended range

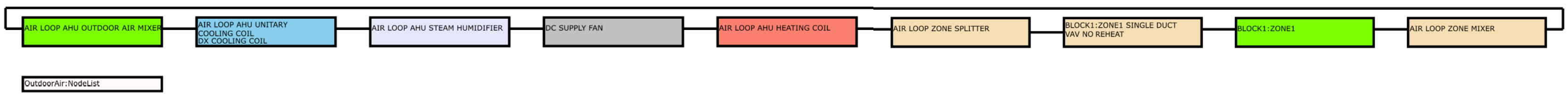
Cooling System Type 1: Air-Cooled DX

Simple System Schematic



EnergyPlus Block Diagram

Primary Cooling System: Air cooled DX using the Coil:Cooling:DX:SingleSpeed object.



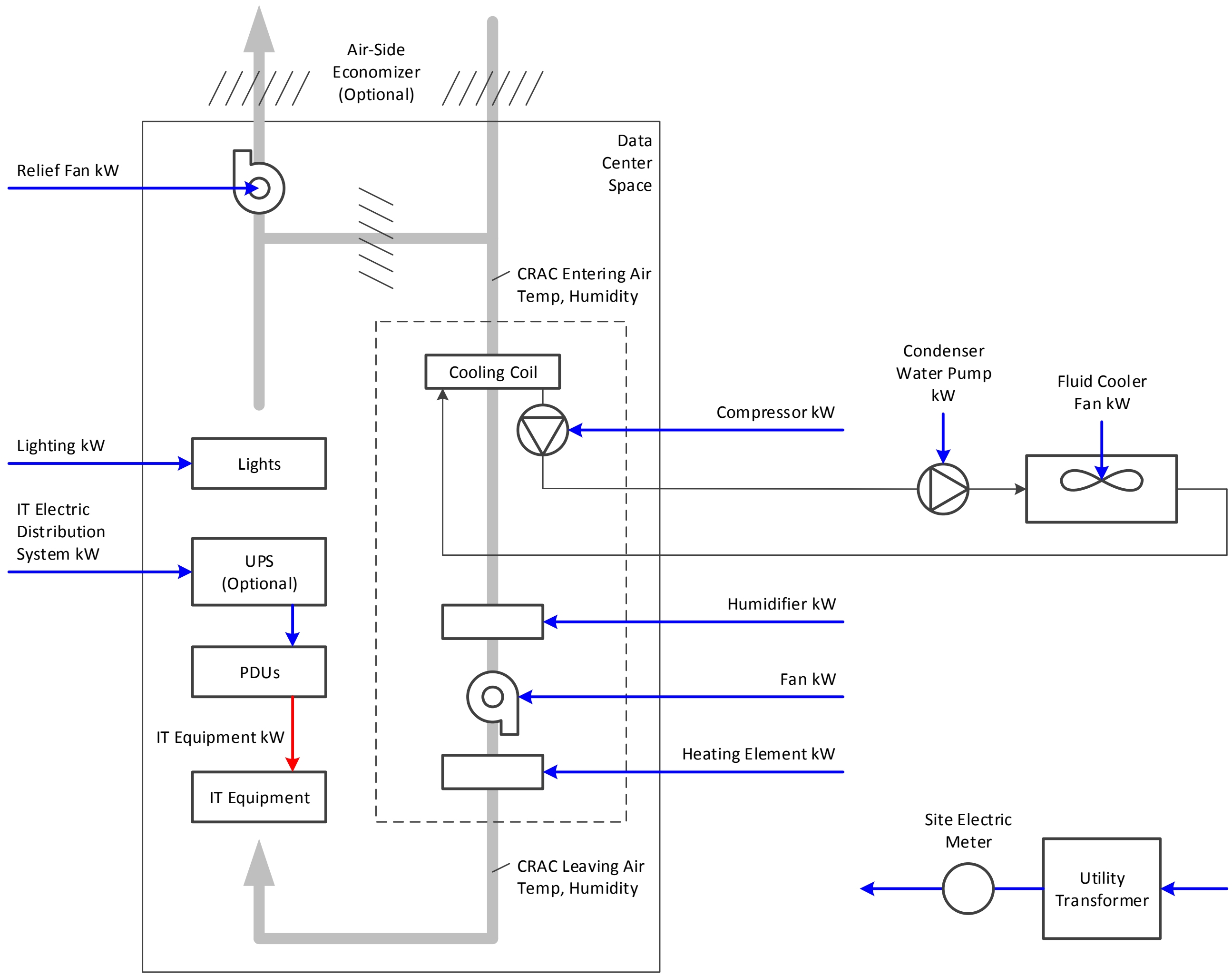
Unused Non-Parent Objects:

- AIR LOOP SETPOINT MANAGER
- HUMIDITY RATIO MIN
- HUMIDITY MAX SINGLE ZN DEHUMIDIFICATION
- AIR LOOP AHU OUTSIDE AIR SYSTEM MIXED AIR MANAGER
- AIR LOOP AHU OUTDOOR AIR CONTROLLER
- DC RELIEF FAN

The following are not supported: objects related to controls, AirTerminal:SingleDuct:Uncontrolled, or ZoneHVAC:IdealLoadsAirSystem

Cooling System Type 2: Water-Cooled DX

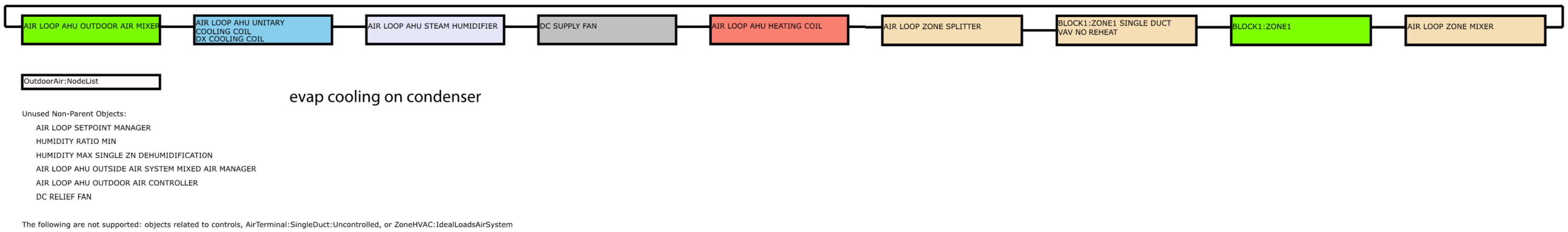
Simple System Schematic



EnergyPlus Block Diagram

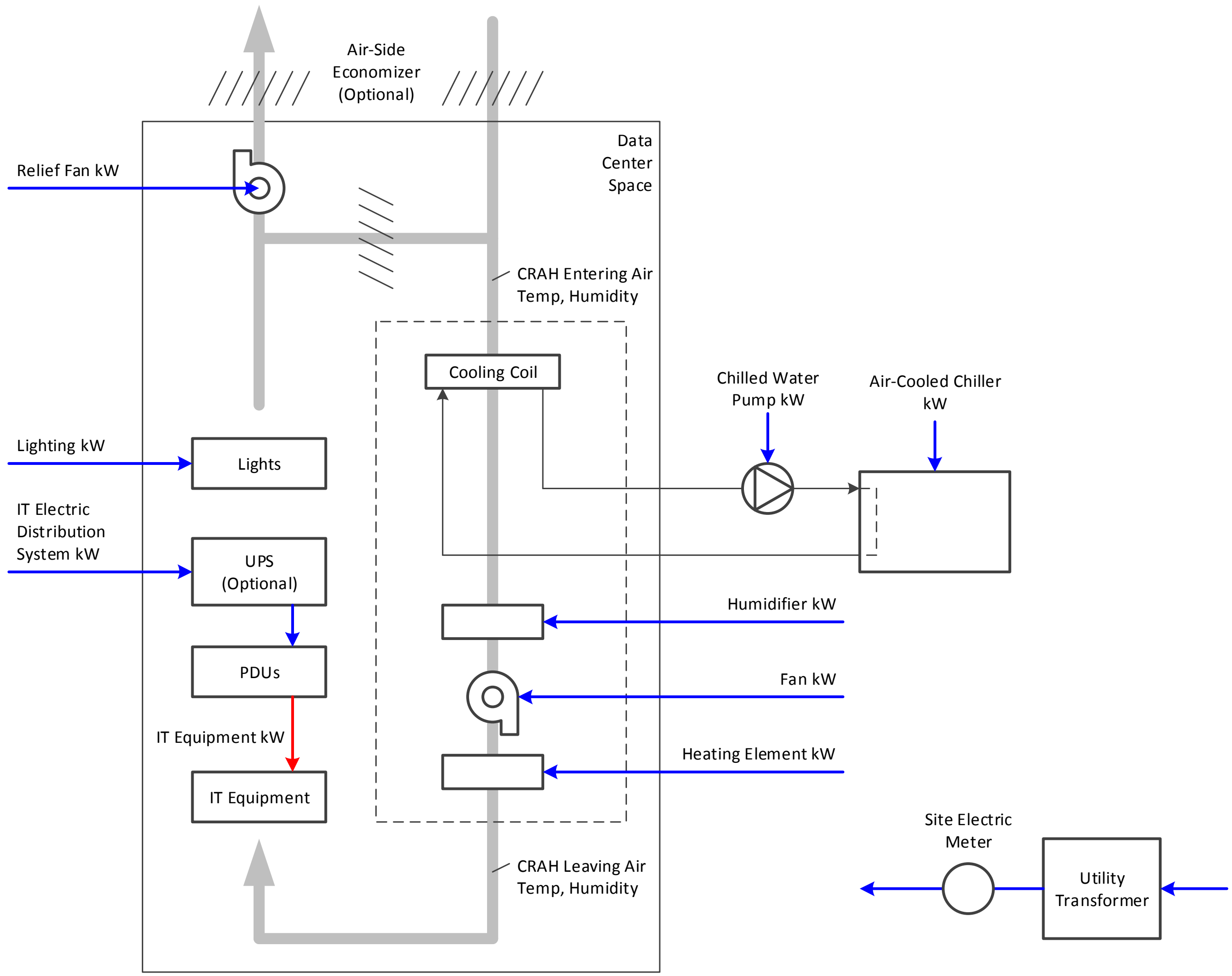
Primary Cooling System: Air-Cooled DX using the Coil:Cooling:DX:SingleSpeed object.

The cooling coil element is the same object used in Type 1, with an evaporatively cooled condenser. The EnergyPlus object for the evaporatively cooled condenser is enabled and the overall compressor efficiency (COP) is changed to match a water-cooled DX system.



Cooling System Type 3: Air-Cooled Chiller

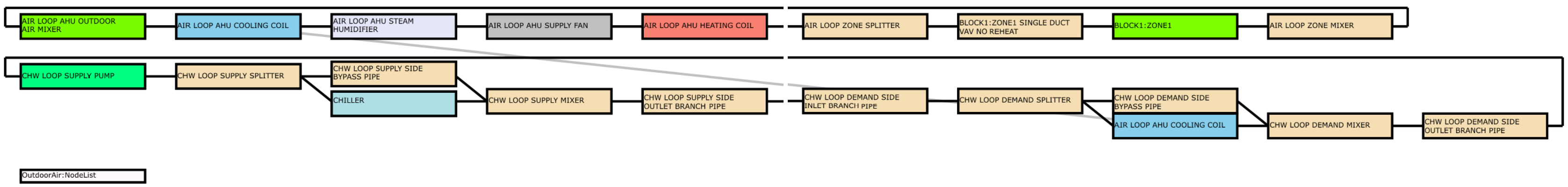
Simple System Schematic



EnergyPlus Block Diagram

Primary Cooling System: Air-Cooled DX using the Chiller:Electric:EIR object for the plant and the Coil:Cooling:WaterCoil object in the distribution system.

The condenser type is set to Air-Cooled.



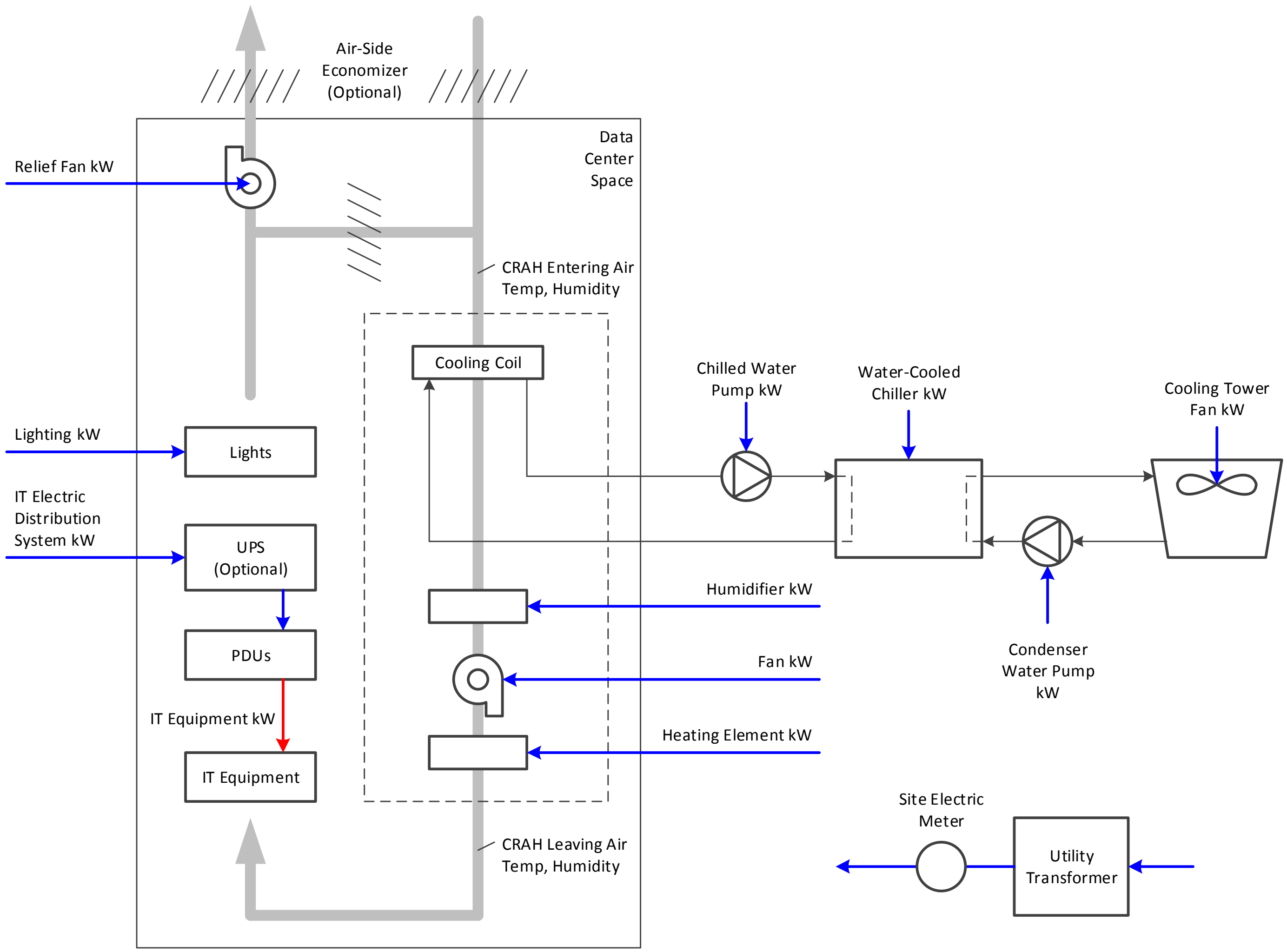
Unused Non-Parent Objects:

- CHILLER CHILLER SETPOINT MANAGER
- AIR LOOP SETPOINT MANAGER
- CHW LOOP SETPOINT MANAGER
- HUMIDITY MINIMUM SETPOINT
- HUMIDITY MAXIMUM SETPOINT
- AIR LOOP AHU OUTSIDE AIR SYSTEM MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL CONTROLLER
- AIR LOOP AHU OUTDOOR AIR CONTROLLER
- AIR LOOP AHU RELIEF FAN

The following are not supported: objects related to controls, AirTerminal:SingleDuct:Uncontrolled, or ZoneHVAC:IdealLoadsAirSystem

Cooling System Type 4: Water-Cooled Chiller

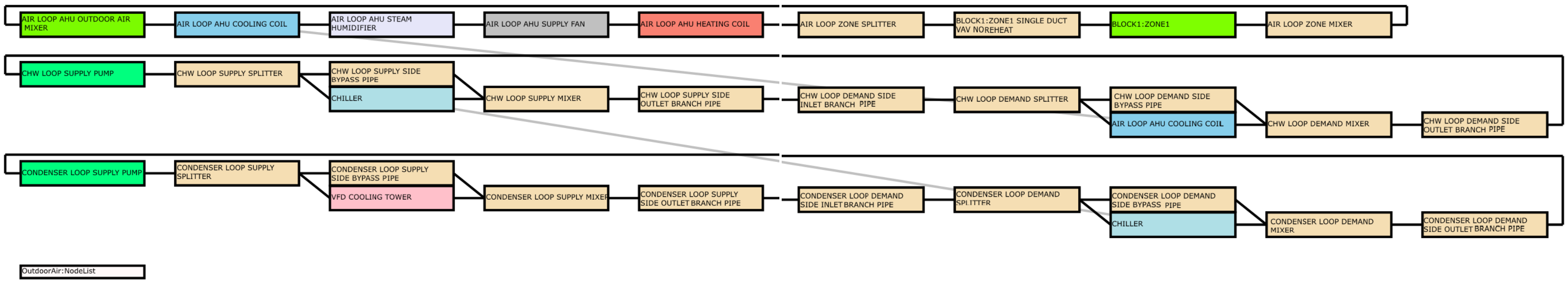
Simple System Schematic



EnergyPlus Block Diagram

Primary Cooling System: Air-Cooled DX using the Chiller:Electric:EIR object for the plant and the Coil:Cooling:WaterCoil object in the distribution system.

The cooling tower is variable speed with a constant condenser water temperature setpoint for the chiller.



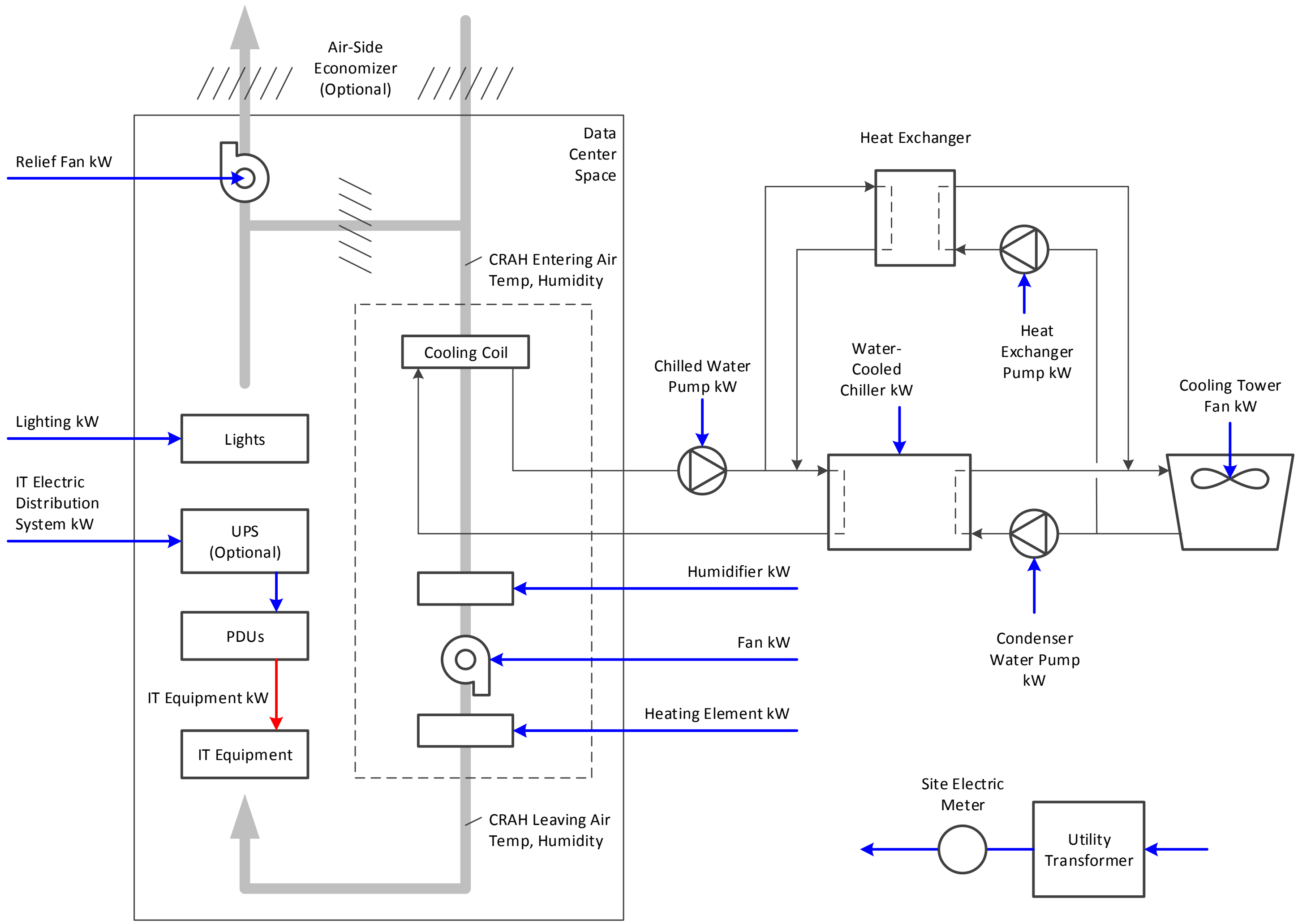
Unused Non-Parent Objects:

- CHILLER CHILLER SETPOINT MANAGER
- AIR LOOP SETPOINT MANAGER
- CHW LOOP SETPOINT MANAGER
- CONDENSER LOOP SETPOINT MANAGER
- HUMIDITY MINIMUM SETPOINT
- HUMIDITY MAXIMUM SETPOINT
- AIR LOOP AHU OUTSIDE AIR SYSTEM MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL CONTROLLER
- AIR LOOP AHU OUTDOOR AIR CONTROLLER
- AIR LOOP AHU RELIEF FAN

The following are not supported: objects related to controls, AirTerminal:SingleDuct:Uncontrolled, or ZoneHVAC:IdealLoadsAirSystem

Cooling System Type 5: Water-Cooled Chiller with Integrated Waterside Economizing

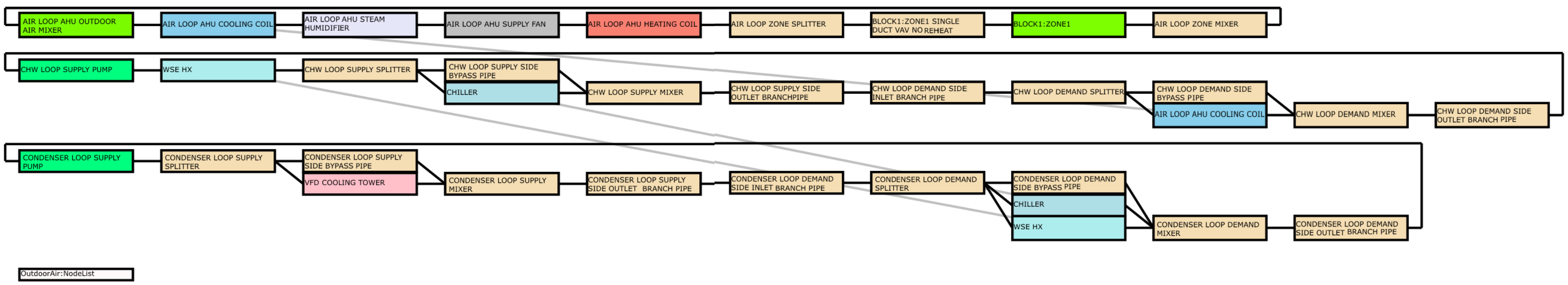
Simple System Schematic



EnergyPlus Block Diagram

Primary Cooling System: Air-Cooled DX using the Chiller:Electric:EIR object for the plant and the Coil:Cooling:WaterCoil object in the distribution system.

The cooling tower is variable speed with a condenser water temperature setpoint that follows the outside air wetbulb + an offset. The heat exchanger is assumed to have a 3.6 deg F approach between the condenser water and chilled water loops and will operate whenever the return chilled water temperature is above the condenser water temperature.



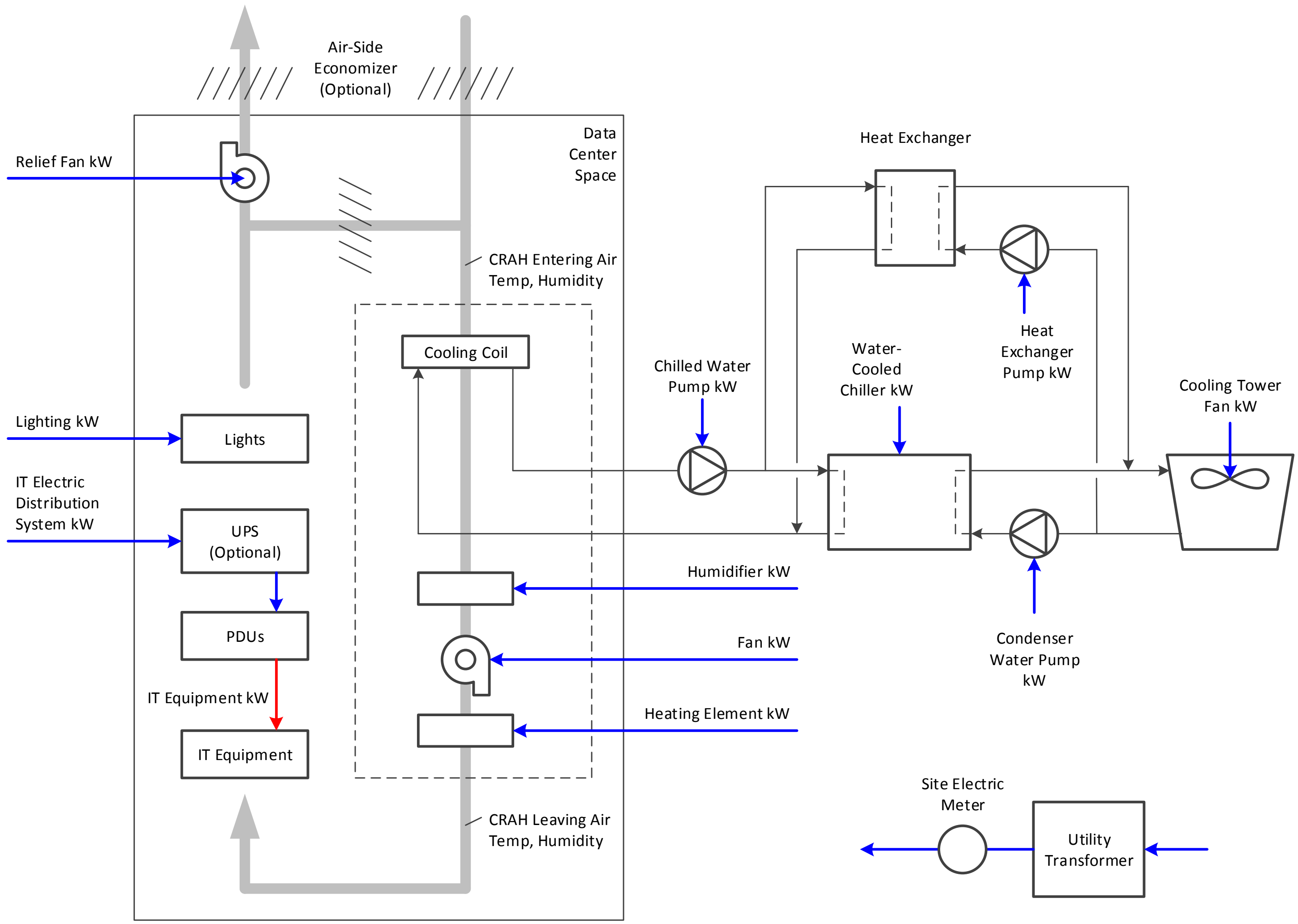
Unused Non-Parent Objects:

- CHILLER CHILLER SETPOINT MANAGER
- AIR LOOP SETPOINT MANAGER
- CHW LOOP SETPOINT MANAGER
- HUMIDITY MINIMUM SETPOINT
- HUMIDITY MAXIMUM SETPOINT
- AIR LOOP AHU OUTSIDE AIR SYSTEM MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL MIXED AIR MANAGER
- MYCONDENSERCONTROL
- AIR LOOP AHU COOLING COIL CONTROLLER
- AIR LOOP AHU OUTDOOR AIR CONTROLLER
- AIR LOOP AHU RELIEF FAN

The following are not supported: objects related to controls, AirTerminal:SingleDuct:Uncontrolled, or ZoneHVAC:IdealLoadsAirSystem

Cooling System Type 6: Water-Cooled Chiller with Non-Integrated Waterside Economizing

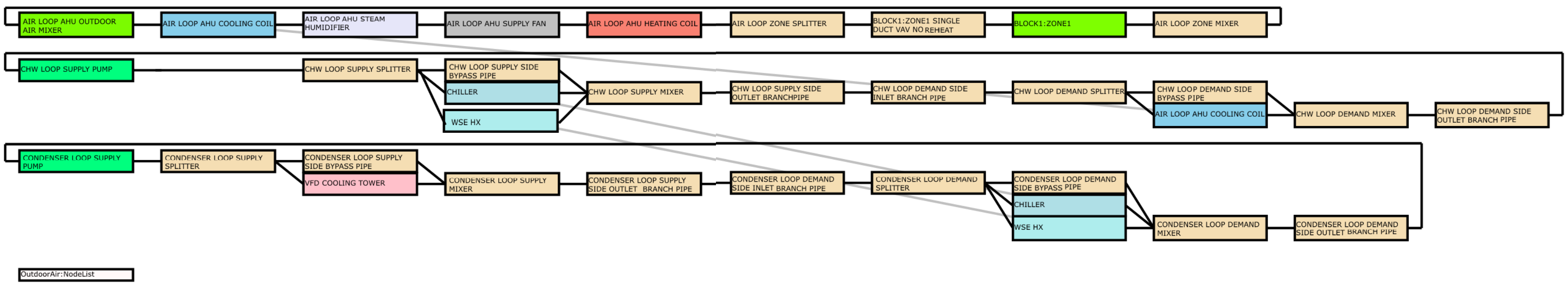
Simple System Schematic



EnergyPlus Block Diagram

Primary Cooling System: Air-Cooled DX using the Chiller:Electric:EIR object for the plant and the Coil:Cooling:WaterCoil object in the distribution system.

The cooling tower is variable speed with a condenser water temperature setpoint that follows the outside air wetbulb + an offset. The heat exchanger is assumed to have a 3.6 deg F approach between the condenser water and chilled water loops and will operate only when the full load can be conditioned by the heat exchanger.



Unused Non-Parent Objects:

- CHILLER CHILLER SETPOINT MANAGER
- AIR LOOP SETPOINT MANAGER
- CHW LOOP SETPOINT MANAGER
- HUMIDITY MINIMUM SETPOINT
- HUMIDITY MAXIMUM SETPOINT
- AIR LOOP AHU OUTSIDE AIR SYSTEM MIXED AIR MANAGER
- AIR LOOP AHU COOLING COIL MIXED AIR MANAGER
- MYCONDENSERCONTROL
- AIR LOOP AHU COOLING COIL CONTROLLER
- AIR LOOP AHU OUTDOOR AIR CONTROLLER
- AIR LOOP AHU RELIEF FAN

The following are not supported: objects related to controls, AirTerminal:SingleDuct:Uncontrolled, or ZoneHVAC:IdealLoadsAirSystem

Appendix E. Recommended Actions

DC Pro recommends a variety of energy-efficient actions that can pursued, based on the user's answers to the input questions.

The following tables describe how DC Pro selects or does not select each action before presenting them to the user. The tables correspond to the categories in Step 2 of DC Pro.

How to Read the Tables
The actions are listed at the left side of the table. There may be gaps in the numbering sequence of the Action IDs in some cases; this is due to some actions in earlier versions of DC Pro being retired. For continuity, the remaining actions were not renumbered.
The relevant input questions are listed at the top of the table.
Answers that trigger action recommendations are shown in the white cells.
For a given action, read from left to right in that row.
If more than one white cell appears in that row, then the user must input all of the answers shown in order to trigger the recommendation.
If an action has multiple rows, then the set of answers in any one of those rows is sufficient to trigger the recommendation.
An example is provided following each table.

These tables are also available as Excel files.

Energy Management (Step 2.1)

None of the questions in this table affect DC Pro's calculation of PUE.

Actions		Questions, Question IDs, and User's Answers					
		Has an energy audit been conducted within the last 2 years?	Is there a written energy management plan?	Is there an energy manager directly responsible for the energy management plan?	Has upper management accepted the energy management plan?	Is there an energy measurement and calibration program in place?	Is there a preventative maintenance program in place?
Action ID	Action Title	EM.Q.01	EM.Q.02	EM.Q.02.1	EM.Q.02.2	EM.Q.03	EM.Q.04
EM.A.01	Perform an energy audit.	No					
EM.A.02	Create an energy management plan.		No				
EM.A.03	Assign an energy manager.		Yes	No			
EM.A.04	Engage the upper management with a compelling life-cycle cost case.		Yes		No		
EM.A.05	Implement an energy measurement and calibration program.					No	
EM.A.06	Conduct regular preventative maintenance.						No
EM.A.07	Sub-meter end-use loads and track over time.						Yes
EM.A.08	Review full system operation and efficiency on a regular basis.						Yes
EM.A.09	Install monitoring equipment to measure system efficiency and performance.					No	
EM.A.10	Raise awareness and develop understanding among Data Center staff about the financial and environment impact of energy savings.	No					

<u>Example</u>
If the user answers “No” to input question EM.Q.01, then action EM.A.01 is recommended.

IT Equipment (Step 2.2)

None of the questions in this table affect DC Pro's calculation of PUE.

Actions		Questions, Question IDs, and User's Answers						
		Do you measure and track IT equipment (storage, server & network) utilization?	Do you have a process for identifying abandoned/un-used servers and taking them offline?	What is the average age at which you replace your servers?	Are you using virtualization to consolidate your server workloads?	How extensive is your storage consolidation?	What storage tiers have you implemented? (mark all that apply)	Have you implemented storage optimization techniques such as thin provisioning, incremental snapshots, or de-duplication?
Action ID	Action Title	IT.Q.01	IT.Q.02	IT.Q.03	IT.Q.04	IT.Q.05	IT.Q.06	IT.Q.07
IT.A.01	Start monitoring utilization of servers, storage, and networks to determine whether there are underutilized IT assets and understand your IT capacity growth.	No						
IT.A.02	Perform an audit to ensure all operational servers are still in active use.		No					
IT.A.03	Evaluate the potential savings from upgrading to newer equipment.			4				
				5+				
IT.A.04	Investigate using virtualization to consolidate workload and reduce the number of installed servers in your data center. Start gaining experience with new applications and replacement of end-of-life equipment.				No			
IT.A.05	Consider consolidating to network-attached (NAS or SAN) storage and using diskless servers.					0%		
						1-50%		
IT.A.06	Assess storage usage and move less performance-sensitive data to higher capacity, more efficient media.						All answers are No	
IT.A.07	Consider reducing the capacity requirements for your storage systems.							No

<u>Example</u>
If the user answers "4" or "5+" to input question IT.Q.03, then action IT.A.03 is recommended.

Environmental Conditions (Step 2.3)

The answers to questions highlighted in yellow affect DC Pro's calculation of PUE.

The entire table is too large to fit on one page; so the table is shown piecemeal below.

Actions		Questions, Question IDs, and User's Answers				
		Environmental Conditions				
		What is the typical (average) air temperature leaving the cooling coils (supply)?	What is the typical (average) air temperature entering the cooling coils (return)?	What is the typical (average) IT equipment intake air temperature?	What is the typical (average) IT equipment exhaust air temperature?	Adopted Recommended IT Intake Air Temperature, Maximum
Action ID	Action Title	EC.Q.01	EC.Q.02	EC.Q.03	EC.Q.04	EC.Q.05
EC.A.01	Consider air management measures.	(EC.Q.02 - EC.Q.01) < (EC.Q.04 - EC.Q.03)/2				
EC.A.02	Consider increasing the temperature of the air leaving the cooling coils (supply). Caveat: Above an IT air intake temperature of around 75F, the speed of the IT equipment's internal cooling fans may increase. The energy penalty for this must be weighed against the energy savings associated with a higher supply air temperature.	EC.Q.01 < (EC.Q.05 - 10F)				EC.Q.01 < (EC.Q.05 - 10F)

Actions		Questions, Question IDs, and User's Answers						
		Environmental Conditions						
		Are the cooling system temperature sensors measuring air conditions that are representative of the IT equipment intake air conditions?	Do you have active, working humidification controls?	Do you have active, working dehumidification controls?	Are the current cooling system high and/or low humidity limit setpoints for the IT intake air tighter than the ASHRAE Recommended limits for your data center Class?	Do CRAC/H units have centralized (networked) or distributed controls?	Are CRACs/CRAHs fighting each other (for example, simultaneously humidifying and dehumidifying)?	Do the cooling system controls allow you to apply correction factors to the signals from the temperature and humidity sensors?
Action ID	Action Title	EC.Q.06	EC.Q.08	EC.Q.09	EC.Q.10	EC.Q.11	EC.Q.12	EC.Q.13
EC.A.04	Place temperature/humidity sensors to get a good representation of the IT equipment intake air conditions.	No						
EC.A.05	Recalibrate temperature and humidity sensors.							Yes
EC.A.06	Network the CRAC/CRAH controls.					Distributed	Yes	
EC.A.08	Consider reducing the minimum humidity setpoint to match the ASHRAE Recommended limit for your data center Class, or disabling/eliminating humidification controls altogether.	Yes	Yes		Yes			
EC.A.09	Consider increasing the maximum humidity setpoint to match the ASHRAE Recommended limit for your data center Class, or disabling/eliminating dehumidification controls altogether.	Yes		Yes	Yes			
EC.A.10	Change the humidifiers to a more efficient type, such as direct evaporative or ultrasonic.		Yes					
			Yes					

<u>Example</u>

If the user answers "Distributed" to input question EC.Q.11 and "Yes" to input question EC.Q.12, then action EC.A.06 is recommended.

Actions		Questions, Question IDs, and User's Answers			
		Environmental Conditions			
		Do you have active, working humidification controls?	Do you have active, working dehumidification controls?	Is there a continuous source of outside air admitted to the data center for ventilation?	Humidity control sensor location?
Action ID	Action Title	EC.Q.08	EC.Q.09	EC.Q.09.1	EC.Q.09.2
EC.A.11	Consider disabling the humidity controls in the recirculation air stream, and performing all humidity control in the outside air stream only.	Yes		Yes	Recirculation Air Stream Only
			Yes	Yes	Recirculation Air Stream Only
		Yes		Yes	Outside Air Stream and Recirculation Air Stream
			Yes	Yes	Outside Air Stream and Recirculation Air Stream

Actions		Questions, Question IDs, and User's Answers	
		Case Information	Environmental Conditions
		Data Center Class as per latest ASHRAE Thermal Guidelines for Data Processing Environments?	Adopted Recommended IT Intake Air Temperature, Maximum
Action ID	Action Title	CI.Q.14	EC.Q.05
EC.A.12	Consider raising your adopted Recommended max IT equipment intake air temperature to match or exceed the ASHRAE Recommended max for your data center Class. Caveat: Above an IT air intake temperature of around 75F, the speed of the IT equipment's internal cooling fans may increase. The energy penalty for this must be weighed against the energy savings associated with a higher IT intake air temperature.	A1 A2 A3 A4 B C	< 90F (32C) < 95F (35C) < 105F (41C) < 115F (46C) < 95F (35C) < 105F (41C)
EC.A.13	Review your air management to better comply with the adopted max Recommended IT intake air temperature during 100% mechanical cooling.		EC.Q.03 < (EC.Q.05 - 5F)

Actions		Questions, Question IDs, and User's Answers	
		Environmental Conditions	
		Are the cooling system temperature sensors measuring air conditions that are representative of the IT equipment intake air conditions?	Does your air management scheme, your economizing system (if present), and your IT equipment allow your data center to operate near the ASHRAE max Recommended IT equipment intake temperature, and occasionally between the ASHRAE max Recommended and max Allowable intake temperature (per your data center Class) during 100% mechanical cooling?
Action ID	Action Title	EC.Q.06	EC.Q.07
EC.A.14	Consider changes to your air management scheme to allow your data center to operate near the ASHRAE max Recommended IT equipment intake temperature, and occasionally between the ASHRAE max Recommended and max Allowable intake temperature (per your data center Class) during 100% mechanical cooling.	Yes	No
EC.A.15	If your data center is not already operating near the ASHRAE max Recommended IT equipment intake temperature, and occasionally between the ASHRAE max Recommended and max Allowable intake temperature (per your data center Class), during 100% mechanical cooling, then adopt such operation. Data centers can often go beyond the Recommended range for additional energy savings by following the process outlined in the ASHRAE Thermal Guidelines for Data Processing Environments.	Yes	Yes

Air Management (Step 2.4)

The answers to questions highlighted in yellow affect DC Pro's calculation of PUE.

The entire table is too large to fit on one page; so the table is shown piecemeal below.

Actions		Questions, Question IDs, and User's Answers						
		Air Management						
		Air Supply Path	Is the cable build-up in the floor plenum or the over-head plenum more than 1/3 of the plenum height?	Is there program in place for regularly managing cables to allow unobstructed air flow?	Degree that IT equipment is arranged in rows?	Degree of current implementation of alternating hot and cold aisles?	Degree to which hot and cold aisles are currently fully enclosed?	What kind of supply fans are in use?
Action ID	Action Title	AM.Q.07	AM.Q.07.6	AM.Q.07.7	AM.Q.13	AM.Q.13.2	AM.Q.13.2.6	AM.Q.15
AM.A.05	Remove abandoned cable and other obstructions from underfloor and over-head.	Overhead Plenum	Yes					
		Underfloor Plenum	Yes					
AM.A.06	Implement a cable management program.	Overhead Plenum		No				
		Underfloor Plenum		No				
AM.A.07	Implement alternating hot aisle/cold aisles.				Fair	Poor to None		
					Good	Poor to None		
AM.A.08	Provide physical separation of hot and cold air:				Fair	Fair	Poor to None	
	Provide semi-enclosed aisles (e.g., aisle end doors).				Fair	Good	Poor to None	
	Provide flexible strip curtains to enclose aisles.				Good	Fair	Poor to None	
	Provide rigid enclosures to enclose aisles.				Good	Good	Poor to None	
	Use in-rack ducted exhaust.							
AM.A.09	Convert to variable speed fans that allow variation of airflow to meet cooling demand.							Constant Speed

Actions		Questions, Question IDs, and User's Answers						
		Air Management						
		Air Supply Path	Is there a floor-tightness (sealing leaks) program in place?	Degree of sealing for cable penetrations?	Degree that IT equipment is arranged in rows?	Degree of current implementation of alternating hot and cold aisles?	Supply Air: Where is the supply placed?	Is there a diffuser/tile-location (to conserve hot and cold aisles) program in place?
Action ID	Action Title	AM.Q.07	AM.Q.07.4	AM.Q.07.5	AM.Q.13	AM.Q.13.2	AM.Q.13.2.3	AM.Q.13.2.4
AM.A.10	Configure equipment in straight lineups (rows) for hot/cold aisles and cable management.				Poor to None			
AM.A.11	Place supply devices in cold aisles only.				Fair	Fair	Hot Aisles Only	
					Fair	Fair	Hot and Cold Aisles	
					Fair	Good	Hot Aisles Only	
					Fair	Good	Hot and Cold Aisles	
					Good	Fair	Hot Aisles Only	
					Good	Fair	Hot and Cold Aisles	
					Good	Good	Hot Aisles Only	
					Good	Good	Hot and Cold Aisles	
AM.A.12	Implement a tile/diffuser location program.				Fair	Fair		No
					Fair	Good		No
					Good	Fair		No
					Good	Good		No
AM.A.13	Use appropriate overhead diffusers.	Overhead Ducts						
		Overhead Plenum						
AM.A.17	Seal floor leaks (including cable cutouts).	Underfloor Plenum		Poor to None				
		Underfloor Plenum		Fair				
AM.A.18	Implement a floor-tightness program.	Underfloor Plenum	No					

Actions		Questions, Question IDs, and User's Answers							
		Air Management							
		Can your adopted Recommended IT equipment intake air condition be maintained if you turn off one or more selected CRAC/H units?	Is there any supplemental cooling?	Degree that IT equipment is arranged in rows?	Is there a rack/lineup-tightness (using blanking panels) program in place?	Degree of current implementation of alternating hot and cold aisles?	Degree that blanking panels are in place?	Do some areas of the data center have load densities that are more than 4 times the average load density?	Is the air-delivery system balanced to ensure correct airflow rates?
Action ID	Action Title	AM.Q.01	AM.Q.03	AM.Q.13	AM.Q.13.1	AM.Q.13.2	AM.Q.13.2.1	AM.Q.16	AM.Q.17
AM.A.19	Use supplemental cooling (for example, high density areas).		None					Yes	
AM.A.21	Use adequate ratio system flow to rack flow (target 1.0 or RTI=100%).								No
AM.A.22	Balance the air-distribution system (diffusers/tiles).								No
AM.A.27	Maintain tight racks to prevent bypass of air (blanking panels & sealing between racks).			Fair		Fair	Poor to None		
				Fair		Fair	Fair		
				Fair		Good	Poor to None		
				Fair		Good	Fair		
				Good		Fair	Poor to None		
				Good		Fair	Fair		
				Good		Good	Poor to None		
				Good		Good	Fair		
AM.A.28	Implement a rack and lineup tightness program.			Fair	No				
				Good	No				
AM.A.30	Shut off selected CRAC/H units, and blank the supply or return openings of the CRAC/H units to prevent backflow of air.	Yes							

Actions		Questions, Question IDs, and User's Answers						
		Air Management				Cooling		
		Does the CRAC/ CRAH/ AHU have a free cooling coil (water side economizer)?	Is there air-side free cooling?	What kind of supply fans are in use?	Is there an air-balancing (allow proper airflow distribution) program in place?	Cooling system type?	Chiller type	Water-side economizer
Action ID	Action Title	AM.Q.04	AM.Q.05	AM.Q.15	AM.Q.18	CP.Q.01	CP.Q.01.2	CP.Q.01.2.1
AM.A.31	Implement an air-balancing program.				No			
AM.A.32	Manually reduce the speed of the supply fans to supply only as much air as is needed to keep the IT equipment intake air condition within the adopted Recommended range. Alternatively, provide automatic fan speed controls to accomplish the same.			Equipped with VSD				
AM.A.38	Consider adding either an air or waterside economizer to the existing CRAC/CRAH/AHU(s).	No	No			Air-Cooled DX		
		No	No			Water-Cooled DX		
		No	No			Evaporatively-Cooled DX		
		No	No			Chilled Water	Air-Cooled	
		No	No			Chilled Water	Water-Cooled	None
AM.A.39	If the existing economizer(s) have never been commissioned or have not been retrocommissioned in the past 2 years, retrocommission them.		Yes					

<u>Example</u>

If the user answers:

“No” to input question AM.Q.04 and “No” to input question AM.Q.05 and “Air-Cooled DX” to input question CP.Q.01, or

“No” to input question AM.Q.04 and “No” to input question AM.Q.05 and “Water-Cooled DX” to input question CP.Q.01, or

“No” to input question AM.Q.04 and “No” to input question AM.Q.05 and “Evaporatively-Cooled DX” to input question CP.Q.01, or

“No” to input question AM.Q.04 and “No” to input question AM.Q.05 and “Chilled Water” to input question CP.Q.01 and “Air-Cooled” to input question CP.Q.01.2, or

“No” to input question AM.Q.04 and “No” to input question AM.Q.05 and “Chilled Water” to input question CP.Q.01 and “Water-Cooled” to input question CP.Q.01.2 and “None” to input question CP.Q.01.2.1,

then action AM.A.38 is recommended.

Cooling (Step 2.5)

The answers to questions highlighted in yellow affect DC Pro's calculation of PUE.

Actions		Questions, Question IDs, and User's Answers								
		Cooling System Type?	Condenser cooling system	Chiller Type	Chilled Water Supply Temperature?	Water-side economizer	Cooling tower fan control	Type of valves?	Do you have premium efficiency motors on all cooling supply fans, pumps and cooling towers that serve the data center?	What is the redundancy level for HVAC systems?
Action ID	Action Title	CP.Q.01	CP.Q.01.1	CP.Q.01.2	CP.Q.01.3	CP.Q.01.2.1	CP.Q.01.2.2	CP.Q.01.5	CP.Q.06	CP.Q.07
CP.A.01	Add VSDs to cooling tower fans.	Water-Cooled DX	Cooling Tower				Fixed Speed			
		Water-Cooled DX	Cooling Tower				Two-Speed Motor			
		Chilled Water		Water-Cooled			Fixed Speed			
		Chilled Water		Water-Cooled			Two-Speed Motor			
CP.A.03	If the existing chillers are in poor condition or over 5 years old, evaluate them for replacement.	Chilled Water								
CP.A.05	Convert all 3 way valves to 2 way and close off all bypasses. Add VSD to pumps. Control pump speed to pressure. Consider reset of pressure setpoint by demand.	Chilled Water						3-way		
CP.A.13	Add integrated waterside economizer to plant.	Chilled Water		Water-Cooled		None				
		Chilled Water		Water-Cooled		Non-Integrated				
CP.A.15	Recalibrate CHWS temperature sensors.	Chilled Water								
CP.A.16	Recalibrate CWS temperature sensors.	Water-Cooled DX								
		Chilled Water		Water-Cooled						
CP.A.17	Convert from air-cooled DX to water-cooled DX or evaporative precooled condensing units.	Air-Cooled DX								
CP.A.18	Consider upgrading all cooling supply fan, pump, and cooling tower fan motors to premium efficiency.								No	

<u>Example</u>
If the user answers:
"Chilled Water" to input question CP.Q.01 and "Water-Cooled" to input question CP.Q.01.2, and "None" to input question CP.Q.01.2.1, or
"Chilled Water" to input question CP.Q.01 and "Water-Cooled" to input question CP.Q.01.2, and "Non-Integrated" to input question CP.Q.01.2.1,
then action CP.A.13 is recommended.

IT Equipment Power Chain (Step 2.6)

The answers to questions highlighted in yellow affect DC Pro's calculation of PUE.

Actions		Questions, Question IDs, and User's Answers													
		Is there an Uninterruptible Power Supply (UPS)?	UPS Technology Type	UPS Size (kVA)	UPS Voltage	What is the average load factor per active UPS module?	UPS Redundancy Configuration	Is there a standby generator?	Standby generator power configuration	Is there a generator block heater?	Is there a thermostat on the generator block heater?	Are there PDUs with built-in transformers?	What are the types of MV and LV transformer(s)?	Average Load Factor per Active PDUs / Transformers	What is the load imbalance between the phases?
Action ID	Action Title	ED.Q.01	ED.Q.01.1	ED.Q.01.2	ED.Q.01.3	ED.Q.01.4	ED.Q.01.5	ED.Q.02	ED.Q.02.1	ED.Q.02.2	ED.Q.02.2.1	ED.Q.03	ED.Q.03.1	ED.Q.03.2	ED.Q.03.3
ED.A.01	If existing UPS is older than 10 years, retrofit UPS topologies for more efficient ones.	Yes													
ED.A.03	Shut Down UPS Modules, Stand-by Generators, PDUs when redundancy level is high enough.	Yes				<30%									
		Yes					2N								
								Yes	2N						
												Yes		<25%	
ED.A.06	Use High Efficiency MV and LV Transformers.											Yes	temp rise > 80C		
ED.A.15	Standby Generator block heater / heater water jacket(s) (HWJ) operate with thermostat control.							Yes		Yes	No				
ED.A.24	Improve the load balance of the UPS, PDU, and RPP between the phases.											Yes			>20%
ED.A.25	Change UPS DC capacitors if older than 5 years.	Yes													

<u>Example</u>

If the user answers "Yes" to input question ED.Q.02 and "Yes" to input question ED.Q.02.2 and "No" to input question ED.Q.02.2.1, then action ED.A.15 is recommended.

Lighting (Step 2.7)

None of the questions in this table affect DC Pro's calculation of PUE.

Actions		Questions, Question IDs, and User's Answers					
		Lighting Power Density [value]	Lighting Power Density [units]	Lighting Type	What type of lamps are used?	What type of ballasts are used?	How are the lights controlled?
Action ID	Action Title	LT.Q.01	LT.Q.02	LT.Q.03	LT.Q.03.1	LT.Q.03.2	LT.Q.04
LT.A.01	Install energy-efficient lamps and ballasts, or consider converting to LED lights.			Fluorescent	T-12		
				Fluorescent		Magnetic	
LT.A.02	Install lighting controls such a twist timer or occupancy sensors.						Hard-Wired
							Manual Wall Switch
LT.A.03	Consider converting fluorescent lights to LED.			Fluorescent	T-8		
				Fluorescent	T-12		

<u>Example</u>
If the user answers:
"Fluorescent" to input question LT.Q.03 and "T-12" to input question LT.Q.03.1, or
"Fluorescent" to input question LT.Q.03 and "Magnetic" to input question LT.Q.03.2,
then action LT.A.01 is recommended.