# PUE Estimator Tool for Data Centers:

# User's Manual

**PUE Estimator Version 1**

**Manual Updated June 02, 2016**

The User's Manual and the PUE Estimator tool were developed by Lawrence Berkeley National Laboratory (LBNL) for the U.S. Department of Energy (DOE)

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# Overview

This manual is a step-by-step guide to the PUE Estimator Version 1 (PUE Estimator) including how to access the tool, provide the required inputs, and view results. The PUE Estimator is an "early stage" assessment tool designed for data center owners and operators to diagnose how energy use is distributed in their data center and determine ways to save energy and money. The tool quickly provides an estimate of a data center's current Power Usage Effectiveness (PUE)[1] and energy use distribution. Results can be exported as stand-alone reports or for inclusion in other reporting material.

The PUE Estimator is a simplified version of the Data Center Profiler Tool (DC Pro). These tools are known collectively as the DC Pro Tools. Both tools are sponsored by the U.S. Department of Energy and hosted by the Lawrence Berkeley National Laboratory (LBNL, Berkeley Lab) on the Center of Expertise for Energy Efficiency in Data Centers website (CoE): [datacenters.lbl.gov](datacenters.lbl.gov)

*Key Features*:

- Registration is not required and the tool is free to use;
- Web-based and confidential;
- Data are not available to other users;
- Designed for use at the beginning of an energy management plan to baseline energy use;
- Accuracy of the results depends on accuracy of the information entered;


**Figure 1: Center of Expertise Homepage**

- Basic guidance for entering the data correctly is built into the tool.

[1] PUE is the ratio of Total Facility Energy to IT Equipment Energy. It is the commonly used metric to describe data center infrastructure efficiency. More specifically, PUE = (IT Energy Use + Lighting Energy Use + Electric Distribution Loss + Fans Energy Use + Cooling & Humidity Control Energy Use + Standby Generation Loss + Misc. Losses) / (IT Energy Use).

The PUE estimation is based on a look-up table of data center energy use simulation. It assumes the data center operates per design intent and does not account for operational problems that cause high-energy use (e.g., CRAC units simultaneously humidifying and dehumidifying).

For a more detailed air management assessment, please see the Data Center Air Management Tool: https://datacenters.lbl.gov/tools/5-data-center-air-management-tool-featured

For guidance on calculating PUE with sub-metering, please see the Data Center Metering and Resource Guide: https://datacenters.lbl.gov/resources/data-center-metering-and-resource-guide

# Accessing the tool

The DC Pro Tools page can be accessed from the Center of Expertise (CoE) homepage by clicking the “DC Pro Tools” listing as a Featured Resource or by clicking the Tools tab. It can be accessed directly by entering this address: https://datacenters.lbl.gov/dcpro

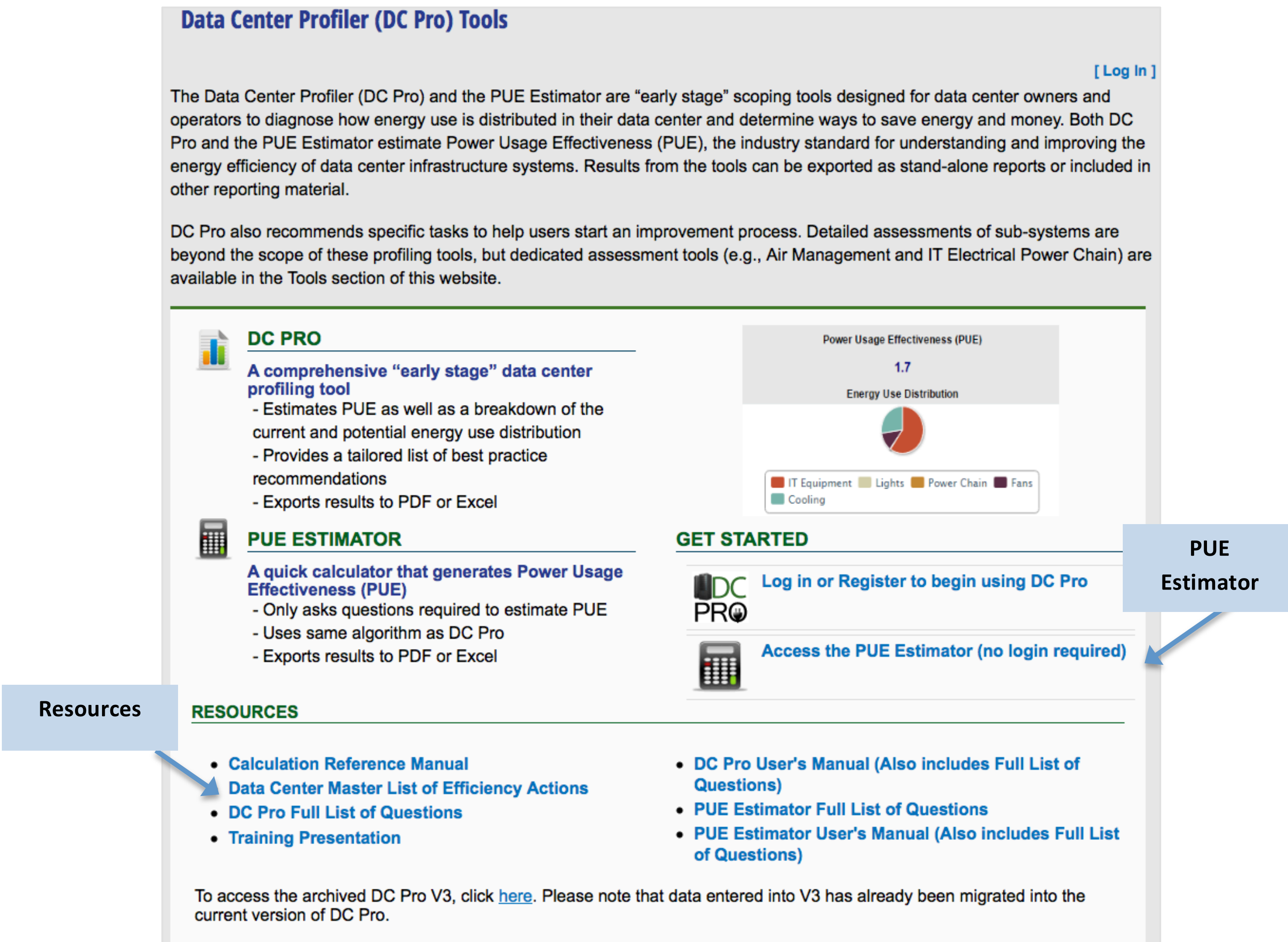


**Figure 2: DC Pro Tools Page**

The DC Pro Tools page hosts DC Pro (a robust profiling tool that provides recommendations for improvement), the PUE Estimator, and other resources that may be of interest, including:

- *Calculation Reference Manual*: In-depth look at the calculations taking place behind the PUE Estimator;
- *Data Center Master List of Energy Efficiency Actions*: Complete list of best practices that are drawn upon for the tailored list of recommended tasks provided in DC Pro; and
- *PUE Estimator Full List of Questions*: Microsoft Word document to collect data offline.

From the DC Pro Tools page click "Access the PUE Estimator." No login is required. You will be taken straight to the PUE Estimator's single input screen, Figure 3.

## Answering Questions

After all questions have been answered you will be able to view and export an estimate of the data center's current PUE and energy use distribution across five standard end-use categories. Here are a few things to remember while you are answering questions to help the tool accurately profile your data center:

- When clicked, the question icons (?) display a popup that explains the question further.
- Selecting some answers may open up additional questions.
- Data cannot be saved in the PUE Estimator.
- All questions are required because each one is used in the algorithm to estimate PUE.
- If located outside of the United States, use the Climate Zone Lookup Table, Figure 4.

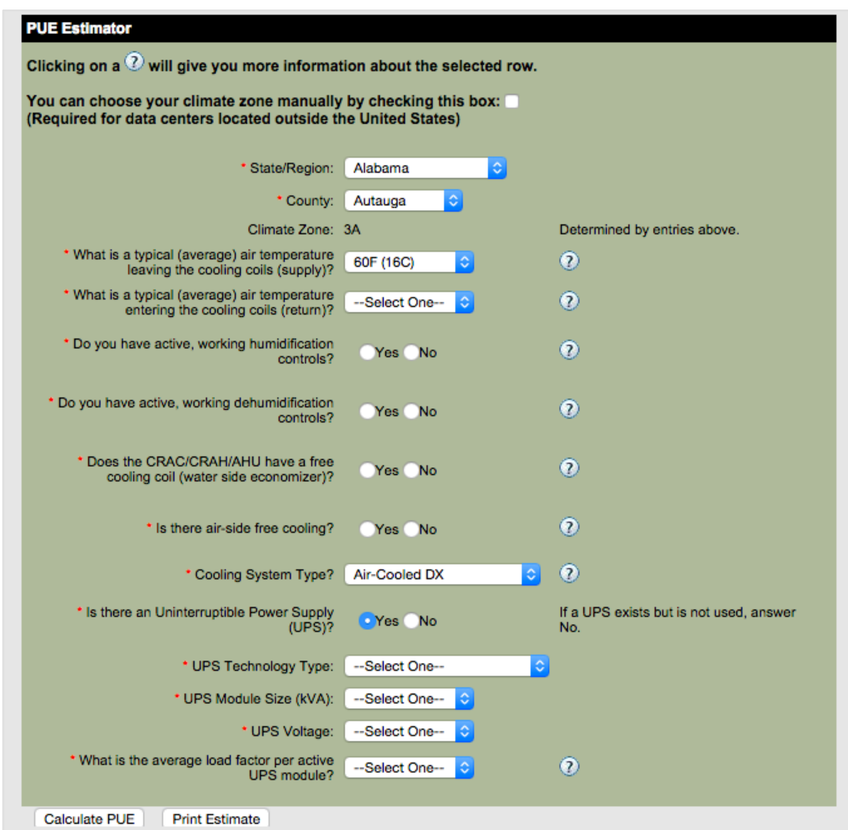


**Figure 3: PUE Estimator**

## Climate Zone

The data center's climate zone will be calculated based on the State/Region and County inputs. The PUE Estimator does not consider heating or cooling loads related to the building envelope or outside air since these loads are small compared to IT-related cooling load. The zone is considered for outside air treatment and the heat rejection side of cooling systems including economizer operation.

| 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 |

## Air Temperature Leaving the Cooling Coils

Air temperature leaving the cooling coils (supply air temperature - SAT) can be read from CRAC/CRAH/AHU display (if applicable). The next level of accuracy can be obtained by using a thermometer at the discharge of the fan (in raised floor if that is the case). For better accuracy beyond snapshot measurements, a temporary or permanent continuous measurement is recommended to collect data over a long period. This can be done using wired or wireless temperature sensors, local or central data collection and manipulation, and a dedicated or central dashboard. An average number should be used if multiple CRACs are operating. Make sure that the data from CRACs that are off are not included in the average.

## Air Temperature Entering the Cooling Coils

Air temperature entering the cooling coils (return air temperature - RAT) can be read from CRAC/CRAH/AHU display (if applicable). The next level of accuracy can be obtained by using a thermometer at the unit air intake. For better accuracy beyond snapshot measurements, a temporary or permanent continuous measurement is recommended. This can be using wired or wireless sensors, local or central data collection and manipulation, and dedicated or central dashboard. An average number should be used if multiple CRACs are operating. Make sure that the data from CRACs that are off are not included in the average.

## Active, Working Humidification

The PUE Estimator requires a "yes" or "no" answer and will assign efficiency for cooling based upon the input. Check the unit to determine if the humidification system is enabled. A water or steam connection is a sign that the unit may be equipped with an enabled humidification system; check to see if the water or steam supply valve is open and the unit display to see if humidification is enabled. The PUE Estimator does not consider the potential for simultaneous humidification and dehumidification by the different CRAC/CRAH units.

## Active, Working De-humidification

The PUE Estimator requires a "yes" or "no" answer and will assign efficiency for cooling based upon the input. This function depends on set points for the temperature of the cooling medium, along with data center ambient temperature and relative humidity. For example, if 42°F chilled water is used, de-humidification naturally happens as long as data center relative humidity is above 30%. Checking the dew point temperature at the return and the supply a few times an hour will also help to detect if de-humidification is active, as well as checking the control panel for settings and status. Cooling units with full de-humidification capability will also be equipped with re-heat coils using refrigerant (hot gas), steam, hot water, or electricity, located downstream of the cooling coil. The PUE Estimator does not consider the potential for simultaneous humidification and dehumidification by the different CRAC/CRAH units.

## CRAC/CRAH/AHU Free Cooling Coil (Water-Side Economizer)

The PUE Estimator requires a "yes" or "no" answer and will assign efficiency for cooling based on the input. If you are not sure, you may check with the source of the chilled water. Typically, if the answer is yes, you may have a heat exchanger that provides cooling to the chilled water return using condenser (cooling tower) water. For CRAC units, the "free cooling" coil is the second coil in the unit which is located upstream of the DX coil. Another scenario is where an additional cooling coil, served by condenser water, is located in the unit.

## Air-Side Free Cooling  (Air-Side Economizer)

The PUE Estimator requires a "yes" or "no" answer and will assign efficiency for cooling based on the input. Typically, if the answer is yes, the CRAC/CRAH/AHU units should have the means of getting the air directly from outside and the data center should be able to exhaust air directly to the outside. Ductwork or wall/raised floor, or ceiling plenums might facilitate the airflow.

## Cooling System Type

Options are air-cooled DX, water-cooled DX, evaporative-cooled DX, and chilled water. If there is more than one type of cooling system serving the data center, select the dominant one (the one currently carrying the highest load). Based on input, additional questions appear. Except for "Chilled water", the answer to the secondary questions related to the cooling system types does not affect the calculations. Check the site and drawings to understand what type of cooling exists.

## Chiller type

If chilled water is selected as the cooling system type, then two more questions appear. The first is chiller type. If air-cooled is selected, no more questions appear. Check the site and drawings to understand what type of chiller exists. If water-cooled chiller is selected then one additional question, water-side economizer, appears.

## Chilled Water Supply Temperature

As was mentioned, when chilled water is selected for cooling system type, two more questions appear. The first is chiller type (discussed above). The second question addresses the chilled water supply temperature (CHWST). The display on the chiller is a source for the CHWST data. Another option is installing temperature sensors anywhere in the CHWS pipe. Again, an average taken over a period of time is strongly recommended in the absence of continuous monitoring. The higher the CHWST, the better the chiller efficiency.

## Water-side Economizer

If water-cooled chiller is selected for chiller type, then another waterside economizer question appears. The options for answering this question are: none, integrated, or non-integrated. The PUE Estimator will assign different efficiency for cooling based on this input. If unsure of this answer, examine the chilled water system. Generally, the system will have a heat exchanger that cools the chilled water return using condenser water. An integrated economizer is when the heat exchanger is installed in series with the chiller (on the chilled water side). It is always on line so it can operate to lower the compressor load as long as the condenser water is cooler than CHWR. A non-integrated system has the heat exchanger installed parallel to the chiller so there are only two states of operation (on or off). That means either the chiller(s) is providing cooling or the heat exchanger but not both concurrently. Check the site and/or drawings to understand what type of economizer exists.

## Uninterruptible Power Supply (UPS)

Check the unit on site or review the drawings. A "yes" answer will cause four more questions to appear (listed below).

- *UPS Type:* Observe on site or/and review equipment data sheets. There is little impact on PUE since efficiencies of these four types of UPS are considered close. The efficiency of a rotary UPS is considered a little higher.

- *UPS Module Size (kVA):* Read the size from the unit data sheet or the unit template. Different sizes of UPS generally exhibit different efficiencies.

- *UPS Voltage*: Read the voltage from the unit data sheet or the unit template. The efficiency of 480-volt systems is considered to be about 1% higher than 208-volt units.

- *Average load factor per active UPS module:* Load factor is the power output of the UPS divided by the capacity of the UPS. It has the most impact on the PUE within the electrical distribution parameter since efficiencies typically are lower at lower load factors. The actual output can often be read from the unit display and the load factor can be calculated once the unit's capacity is known. The other option is to install power meter(s) and obtain continuous measurement. In calculating the load factor, when there are UPSs with different capacity, a weighting factor should be considered. For example if, in the same data center, a

300KVA UPS is loaded at 40% and a 600KVA UPS is loaded at 20%, the average load factor is 26% and not 30%.

## Viewing Results

By clicking Calculate PUE at the bottom of the input screen you can see the estimated PUE (value) and energy use distribution (pie chart) on the right side bar, Figure 5. Energy use distribution is also shown as a percentage if you hover the mouse over the pie chart. After you calculate PUE once, changes made to answers will automatically be reflected in the estimates.

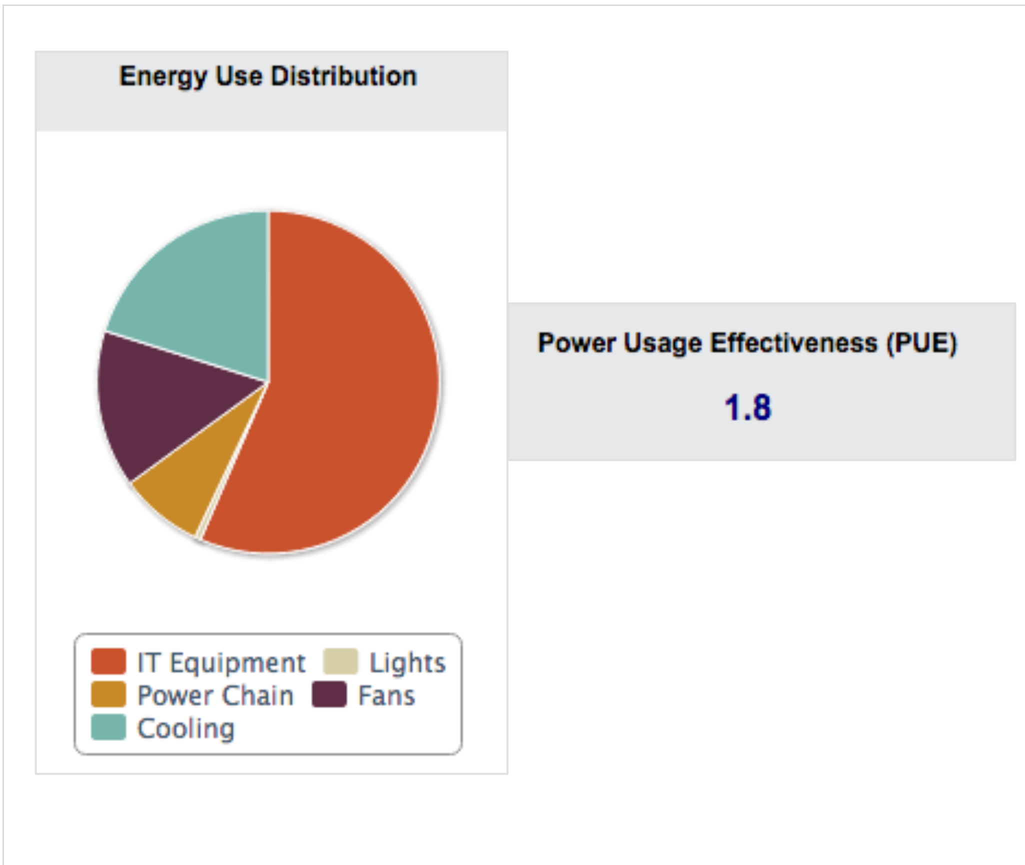


**Figure 5: Energy Use Distribution and PUE**

## Exporting Results

By clicking Print Estimate at the bottom of the input screen you are taken to a summary page to either export the entire profile to PDF or export the energy use distribution table to Excel. Click Save to PDF for PDF or Export Breakout Excel for Excel. Examples of the outputs are provided on the next page, Figure 6 and Figure 7.

Report generated through the PUE Estimator (datacenters.lbl.gov/dcpro): 1/26/2016

# PUE: 1.6

| Energy Use Distribution | % |
|---|---|
| IT Equipment | 64.4 |
| Lights | 0.6 |
| Power Chain | 1.3 |
| Fans | 27.3 |
| Cooling | 6.4 |

## PUE Estimator Inputs

| | |
|---|---|
| State/Region: | Arkansas |
| County: | Baxter |
| Climate Zone: | 4A |
| What is a typical (average) air temperature leaving the cooling coils (supply)? | 65F (18C) |
| What is a typical (average) air temperature entering the cooling coils (return)? | 70F (21C) |

**Figure 6: PDF**

| | A | B |
|---|---|---|
| 1 | **PUE: 1.8** | |
| 2 | | |
| 3–4 | **Energy Use Distribution** | **%** |
| 5 | **IT Equipment** | **56.5** |
| 6 | **Lights** | **0.6** |
| 7 | **Power Chain** | **7.9** |
| 8 | **Fans** | **14.9** |
| 9 | **Cooling** | **20.2** |
| 10 | | |

**Figure 7: Excel**

## Full List of Questions

Below is a checklist of all questions and allowed answers for the PUE Estimator. Questions that require certain answers from a previous question are noted by blue highlights.

| **Questions** | | **Inline Guidance** |
|---|---|---|
| Climate Zone (Asked only if you check the toggle switch at the top) | Select from the List | Determined by State/Region and County. |
| State/Region | Select from the list of States | |
| County | Select from the list of Counties for each State | |
| What is the typical (average) air temperature leaving the cooling coils (supply)? | Select from the list: 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 (48 C), or >115 F (>48 C) | • Select the AVERAGE supply air temperature of your cooling units.<br>• Choose units from different locations in the data center space.<br>• The supply temperature fluctuates over time for some cooling units, so obtain a time-average reading that accounts for these temporal fluctuations. |
| What is the typical (average) air temperature entering the cooling coils (return)? | Select from the list: 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 (48 C), 120 F (49 C), 125 F (52 C), 130 F (54 C), 135 F (57 C), 140 F (60 C), or >140 F (>60 C) | • Select the AVERAGE return air temperature of your cooling units.<br>• Choose units from different locations in the data center space.<br>• The return temperature varies across the intake opening for some cooling units, so obtain an average reading that accounts for these spatial variations. |
| Do you have active, working humidification controls? | Yes or No | Do you have one or more active, working, automatically-controlled humidifiers that serve the data center space? |
| Do you have active, working dehumidification controls? | Yes or No | Does the air-conditioning system that serves the data center allow you to specify an upper humidity limit (RH or dewpoint), and is the system designed to automatically control to this setpoint? |

| | | |
|---|---|---|
| Does the CRAC/CRAH/AHU have a free cooling coil (water side economizer)? | Yes or No | Is there an extra cooling coil in the CRACs/CRAHs/AHUs that is served directly with water from a cooling tower? |
| Is there air-side free cooling? | Yes or No | Are the cooling units equipped with automatically controlled louvers that bring outside air in to the data center for cooling purposes when weather conditions are favorable? |
| Cooling System Type? | Select from the list: Air-Cooled DX, Water-Cooled DX, Evaporatively-Cooled DX, or Chilled Water | DX = Direct Expansion. If you have more than one type of cooling system serving the data center, select the dominant one (the one currently carrying the highest load). |
| Chiller Type (Only asked if your Cooling System is Chilled Water) | Select from the list: Air-Cooled, Water-Cooled | • Water-cooled chillers water-cooled condensers and cooling towers.<br>• Air-cooled chillers have an air-cooled condenser. |
| Chilled Water Supply Temperature (Only asked your Cooling System is Chilled Water) | Select from the list: 45F (7C), 50F (10C), 55F (13C) | |
| Water-side Economizer (Only asked if Water-Cooled is your Chiller Type) | Select from the list: None, Integrated, or Non-Integrated | |
| Is there an Uninterruptible Power Supply (UPS)? | Yes or No | If a UPS exists but is not used, answer No. |
| UPS Technology Type (Only asked if you have a UPS) | Select from the list: Double Conversion, Double Conversion + Filter, Delta Conversion, Rotary | |
| UPS Size (kVA) (Only asked if you have a UPS) | Select from the list: 50, 100, 150, 225, 300, 400, 500, 600, 750, 800, 900, 100 | |
| UPS Voltage (Only asked if you have a UPS) | Select from the list: 480, 208 | |
| What is the average load factor per active UPS module? (Only asked if you have a UPS) | Select from the list: 1% to 10%, 11% to 20%, 21% to 30%, 31% to 40%, 41% to | Load factor = the currently active load divided by the module's maximum load capacity. |

| | | |
|---|---|---|
| | 50%, 51% to 60%, 61% to 70%, 71% to 80%, 81% to 90%, 91% to 100% | |

## PUE Calculation Method

The PUE Estimator takes user's inputs and refers to look-up tables to estimate data center energy distribution and PUE. The energy use breakouts are defined only in terms of percentages - there is no reference to energy type (electricity, fuel, other). The 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 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.

The calculation method contains four lookup tables, described below and illustrated in Figure 8.

*Constants:* Electrical distribution loss (excluding UPS) is assumed to be 2% of total IT load. Lighting is assumed to be 1% of total IT load. It also assumes that IT load is the same 24/7. If your data center information is different, then corrections should be made to the results from the PUE Estimator.

*Climate zone:* Climate Zone can be entered directly or the PUE Estimator can choose based on location of the site. This is an input to the cooling system look-up table.

*UPS loss*: UPS loss has its own look-up table and the result is an input to the cooling system look-up table and normalizing calculation.

*Cooling system energy:* Based on cooling inputs, the table produces two inputs to the normalizing calculation: one is cooling energy and the other is fan energy, both expressed as a percentage of IT load. Energy use distribution is then calculated, and these are used in the PUE calculation.

For more information on how PUE is estimated, please see the Calculation Reference Manual: [datacenters.lbl.gov/resources/dc-pro-tools-calculation-reference](datacenters.lbl.gov/resources/dc-pro-tools-calculation-reference)

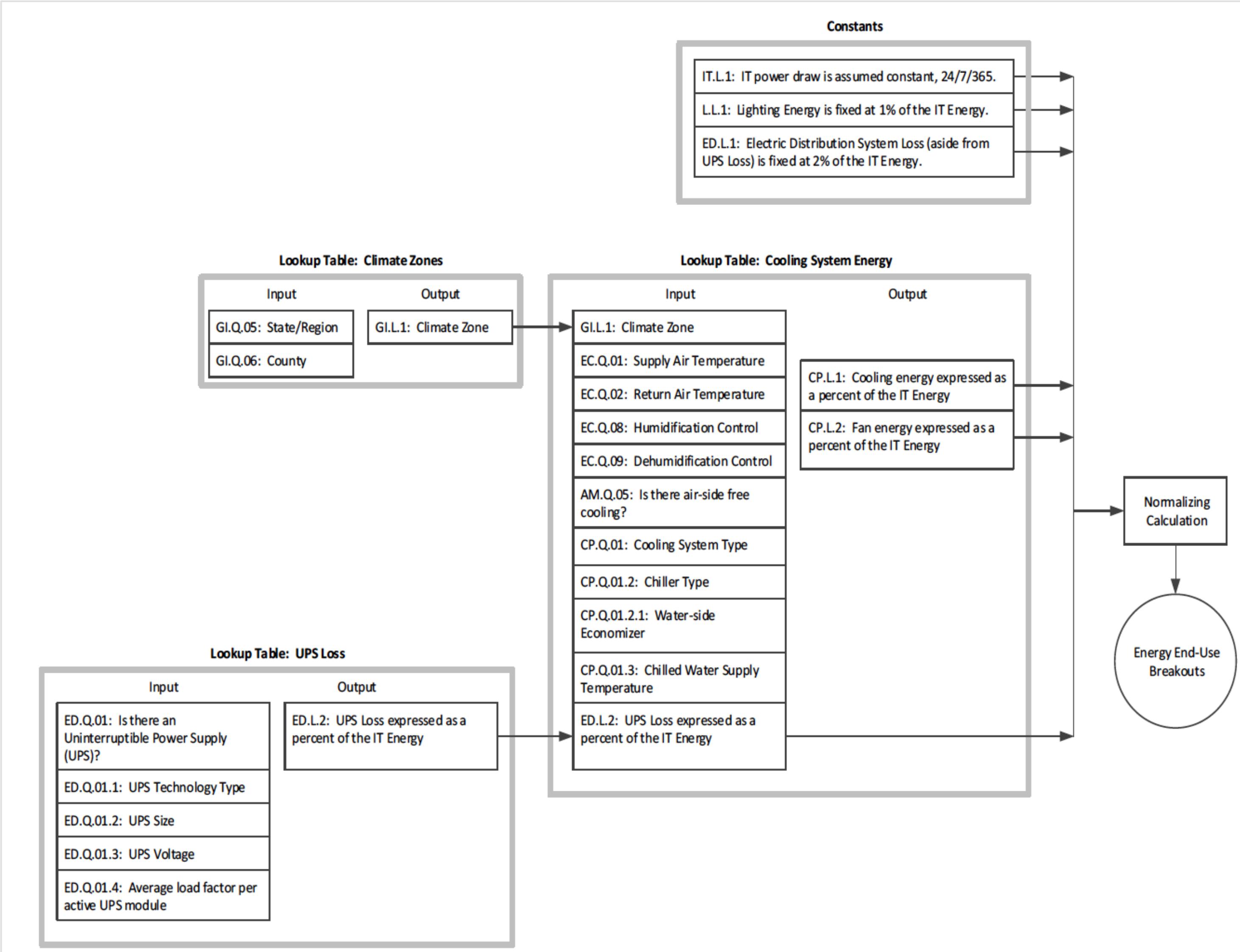


**Figure 8: PUE Calculation Method Flow Chart**