

“DC Pro” Data Center Baseline Guide

Using DCPro to establish PUE baseline

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Purpose of This Guide

The intent of this manual is to give data center operators guidance on the use of the 'DC Pro' Profiling Tool to estimate Power Usage Effectiveness (PUE) where there is inadequate metering in place.

Definitions

Power Usage Effectiveness (PUE)

PUE, as defined by the Green Grid, is an energy metric that provides an indication of the efficiency of data center infrastructure systems. The annual average PUE of the data center is the most globally recognized performance metric for the energy efficiency of data centers infrastructure support systems. It is calculated as:

$$\frac{(\text{IT Energy Use} + \text{Lighting Energy Use} + \text{Electric Distribution Loss} + \text{Fans Energy Use} + \text{Cooling \& Humidity Control Energy Use} + \text{Standby Generation Loss} + \text{Misc. Losses})}{(\text{IT Energy Use})}$$

Note: The Profiler tool 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 estimating tool. The PUE is shown to this precision simply to provide feedback to the user when the answers are changed to questions that affect the PUE calculation.

User Inputs impacting PUE calculation

The profiling tool has many inputs but only a handful affect its estimate of PUE. In this guide, the focus will be on those DCPro user inputs that affect the PUE calculations. They are listed below.

- Parameter 1-Climate Zone (direct input or as the result of State/Region and County input)
- Parameter 2- Air Management
 - Air temperature leaving the cooling coils (supply air temperature - SAT)
 - Air temperature entering the cooling coils (return air temperature - RAT)
 - Active, working humidification
 - Active, working de-humidification
 - CRAC/CRAH/AHU, free cooling coil (water side economizer)
 - CRAC/CRAH/AHU, air side economizer
- Parameter 3- Cooling
 - Chiller type
 - Chilled water supply temperature (CHWST)
 - Waterside economizer type
- Parameter 4- Uninterruptible Power Supply (UPS)
 - UPS Technology Type
 - UPS Size (kVA)
 - UPS Voltage

- Average load factor

Note: DC Pro's PUE estimation is based on a look-up table of data center energy use simulation (see calculation manual).

http://datacenters.lbl.gov/sites/all/files/DC%20Pro%20v3.0%20Calculation%20Reference%20Manual_2014-07-28.pdf. 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 de-humidifying.).

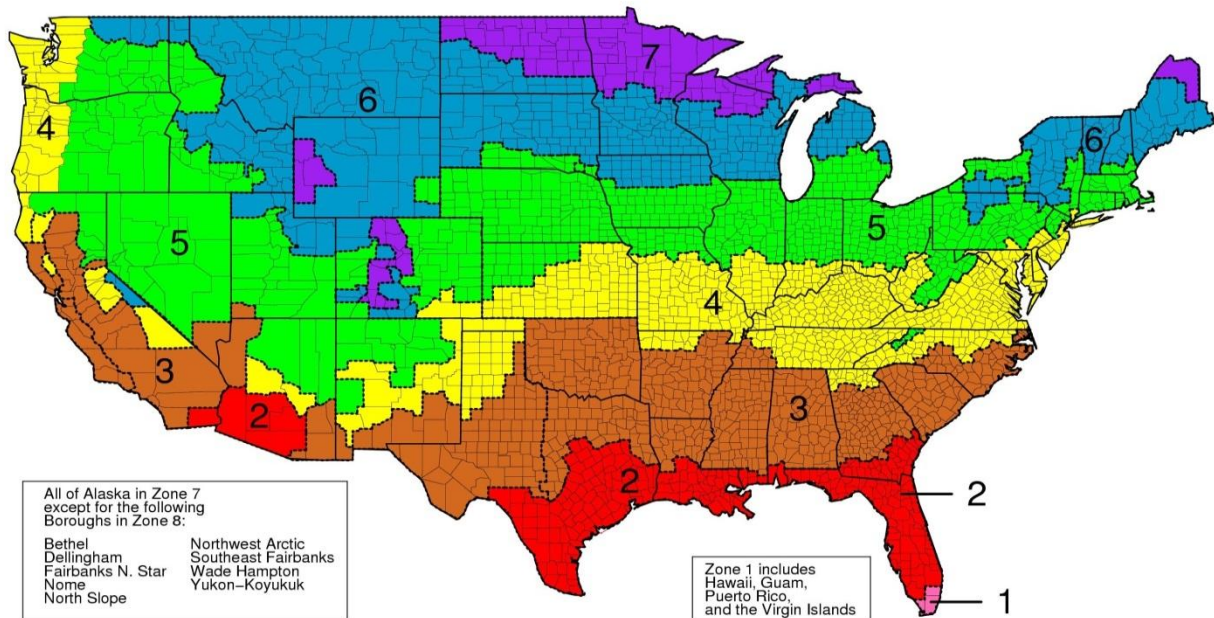
Parameter 1- Climate Zone

The data center's climate zone can be input directly or the tool will calculate it based on the State/Region and County input. Table 1 illustrates a summary of climate zone questions. If the operator decides to enter the climate zone directly, then the map in Figure 1 will provide the information. DCPro 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.

Table 1. Data Center General Information Questions Summary

<i>Input Question</i>	<i>Data Type</i>	<i>Source</i>
State/Region	Hidden	General site information
County	Hidden	General site information
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	Refer to ASHRAE zone map in Figure 1 for identifying the zone where your data center is located

Figure 1. ASHRAE Zone Map



Parameter 2- Air Management

The second parameter is air management. There are 8 elements in this category as listed below:

Air temperature leaving the cooling coils (supply air temperature - SAT)

This factor 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). Obviously, these are snap-shot measurements. For better accuracy, 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 is not included in the average.

Air temperature entering the cooling coils (return air temperature - RAT)

This factor 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. Obviously, these are snap-shot measurements. For better accuracy, 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 is not included in the average.

Active, working humidification

The input to DC Pro requires a 'yes' or 'no' answer. DC Pro 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. Note that DC Pro does not consider the potential for simultaneous humidification and dehumidification by the different CRAC/CRAH units.

Active, working de-humidification

The input to DC Pro requires a 'yes' or 'no' answer. DC Pro 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 deg 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. Note that DCPro does not consider the potential for simultaneous humidification and dehumidification by the different CRAC/CRAH units.

Table 2. Cooling Questions Summary

<i>Question</i>	<i>Data Type</i>	<i>Source</i>
What is a typical (average) air temperature leaving the cooling coils (supply)?	Select One	Unit display or wired or wireless sensors. Note that an average of data collected over a certain period is more valuable than snap shots.
What is a typical (average) air temperature entering the cooling coils (return)?	Select One	Unit display or wired or wireless sensors. Note that an average of data collected over a certain period is more valuable than snap shots.
Do you have active, working humidification controls?	Y/N	A water or steam connection is a sign that unit is equipped with a humidification system; check valve status and control panel for whether enabled.
Do you have active, working dehumidification controls?	Y/N	CHWST set point and data center ambient temperature and relative humidity impact this factor. Check control panel for settings and status.

CRAC/CRAH/AHU, free cooling coil (water side economizer)

The input for DC Pro requires a 'yes' or 'no' answer. DC Pro 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.

CRAC/CRAH/AHU, air side economizer

The DC Pro input requires a 'yes' or 'no' answer. DC Pro will assign efficiency for cooling based upon 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.

Table 3. Air Management Questions Summary

<i>Question</i>	<i>Data Type</i>	<i>Source</i>
Does the CRAC/CRAH/AHU have a free cooling coil (waterside economizer)?	Y/N	Check the chilled water system. Having heat exchanger and cooling without chillers being active are signs of having waterside economizer. Two active cooling coils in the same unit is another sign.
Is there airside free cooling?	Y/N	Having outside air connected to the CRAC/CRAH/AHU

		and outside connection to the hot aisles are signs of having an airside economizer.
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Parameter 3- Cooling Systems

Cooling system type

Options are air-cooled DX, water-cooled DX, evaporative-cooled DX, and chilled water. 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). Based on input, additional questions will 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 will appear. The first is chiller type. If air-cooled is selected, no more questions will 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, will appear. More information on chilled water supply temperature and water-side economizers is provided below.

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 will appear. The options for answering this question are none, integrated, or non- integrated. DC Pro 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.

Table 4. Cooling Systems Questions Summary

<i>Question</i>	<i>Data Type</i>	<i>Source</i>
Cooling system type? Air-Cooled DX Water-Cooled DX Evaporative-Cooled DX Chilled Water	Select One	Select the proper system by walking the site or review of the drawings. Generally, chilled water provides better efficiency than DX systems.
Chiller type Air-Cooled Water-Cooled	Select One	Select the proper system by walking the site or review of the drawings. Generally, water cooled chiller provides better efficiency than air-cooled chiller.

Chilled Water Supply Temperature?	Select One	Chiller or temperature sensors anywhere in CHWS pipe
Water-side Economizer None Integrated Non-Integrated	Select One	Select the proper system by walking the site or review of the drawings. Check to see if heat exchanger and chiller are piped in series or parallel.

Parameter 4- Electrical Distribution

Is there an Uninterruptible Power Supply (UPS)?

Check the unit on site or review the drawings. DC Pro tool assigns no additional electrical recommendations based on “no” as answer to the UPS question. A ‘yes’ answer on the other hand will cause four more questions to appear. They are as follows:

UPS Technology Type

Under type, four options are available. 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 Size (kVA)

Read the size from the unit data sheet or the unit template. Different sizes of UPS generally exhibit different efficiencies.

UPS Voltage (output)

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.

What is the 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 parameter 4 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%.

Table 5. IT Equipment Power Chain Questions Summary

<i>Question</i>	<i>Data Type</i>	<i>Source</i>
Is there an Uninterruptible Power Supply (UPS)?	Y/N	Explore
UPS Technology Type Double Conversion Double Conversion + Filter Delta Conversion Rotary	Select One	Check the unit on site or review the drawings
UPS Size (kVA) Different options from 50 to 1000	Select One	Check the unit on site or review the drawings
UPS Voltage	Select One	Read the voltage from the unit data sheet or the unit

408 208		template
What is the average load factor per active UPS module? Between 1% to 100%	Select One	Unit display of actual load or install power meter for continuous measurement

Conclusion

DC Pro can provide data center operators with an estimate of their PUE. The DCPro report identifies current PUE and a potential PUE that can be theoretically achieved by implementation of DCPro recommended energy efficiency measures. In the example illustrated in Table 5, the current PUE is 2.09. In this table energy use by different use points are identified. These include IT equipment, lighting, electrical distribution losses, fans, and cooling.

Table 5. Current and potential

Potential Annual Energy Savings							
Breakout Category	Current Energy Use		Potential Energy Use ?		Potential Savings		
	kWh/yr	%	kWh/yr	%	kWh/yr	%	\$
IT Equipment	920000	47.8%	920000	90.0%	0	0%	\$0.00
Data Center Lights	40000	2.1%	20444.44	2.0%	19555.56	1%	\$1,368.89
Electric Distribution Losses	180000	9.4%	0	0.0%	180000	9.4%	\$12,600.00
Fans	363800	18.9%	30666.67	3.0%	333133.33	17.3%	\$23,319.33
Cooling	420000	21.8%	51111.11	5.0%	368888.89	19.2%	\$25,822.22
Totals	1923800	100%	1022222.22	100%	901577.78	46.9%	\$63,110.44
PUE		2.09		1.11			

It must be noted that the profiling tool has many inputs but only a handful affect the estimate of PUE. Other inputs are used to generate recommendations on saving energy.

No DC Pro default values should be used relative to those questions affecting PUE when using DC Pro to baseline the PUE.

Measurement is desirable especially when close to boundaries of bins meaning that the uncertainty exists as which option should be selected. Example is CRAC SAT.

Calculations

Figure 2 illustrates the DC Pro PUE calculation method.

The Profiler takes the user's inputs from parameters 1 through 4 and refers to look-up tables to determine the default, estimated data center energy end-use breakouts and calculate PUE. The default 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.

There are four sections in the process chart in Figure 2.

First is clarification of 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 DCPro tool. Climate Zone can be entered directly or let DCPro indicate it based on location of the site. This is an input to the cooling system look-up table. UPS loss has its own look-up table and the result is an input to the cooling system look-up table and normalizing calculation. Finally, the cooling system look-up table, based on cooling inputs, 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 break-outs are then calculated, and these are used in the PUE calculation.

Figure 2. DCPro PUE Calculation Method Flow Chart

