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General Recommendations for a Federal Data Center Energy Management Dashboard Display

Prepared for the U.S. Department of Energy's Federal Energy Management Program

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Abbreviations and Acronyms

AHU	Air Handler Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	British Thermal unit
CRAC	Computer Room Air Conditioner
EIS	Energy Information System
EPA	Environmental Protection Agency
EPT	Energy Performance Tracking
FEMP	Federal Energy Management Program
IP	Internet Protocol
IT	Information Technology
kW	Kilowatt (1,000 Watts)
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Lab
MWh	Megawatt-hour (1,000,000 Watt-hours)
PDU	Power Distribution Units
PUE	Power Usage Effectiveness
SAT	Supply Air Temperature
UPS	Uninterruptible Power Supply
V	Volt
W	Watt

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Executive Summary

Within the past decade, the focus has increased on improving data center energy efficiency. Today, the cost of the electricity needed to run the IT equipment and its supporting infrastructure is surpassing the capital cost of the IT equipment itself over its lifetime. Data center operators are interested in reducing energy use while maintaining or increasing computational workloads. To achieve this, first, energy use needs to be measured and benchmarked. Next, energy data needs to be collected and transformed into actionable information. Throughout this process, energy use data can be presented to facilitate analysis through visual displays. Dashboards help to track energy use, inform decisions for taking corrective action and can be used to track the performance of energy-efficiency improvements once they have been implemented. This guide discusses some typical dashboard content that is useful for energy management.

Introduction

Historically, energy use by data centers has doubled every 5 to 7 years. As Figure 1 illustrates, the estimated energy use by data centers was between 65 to 85 billion (10^9) kilowatt-hours (BkWh) in 2010. From 2000–2006, computing performance increased approximately twenty-five times, but energy efficiency increased only eight times (EPA Report to Congress 2007). The average amount of power consumed per server increased by approximately four times. The 2010 estimated energy use is reported by Koomey (2011) and is not part of EPA 2007 report. Note that no actual data is available for those years beyond 2006 so numbers are just stimates.

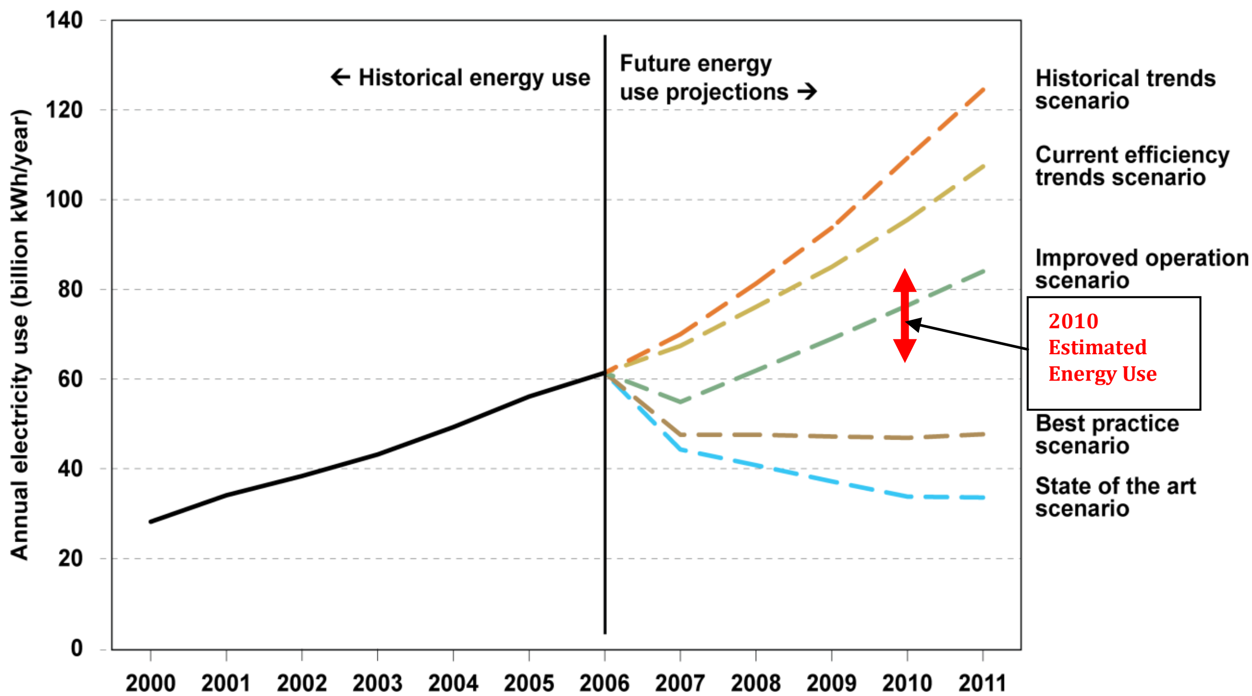

Figure 1. Energy Use by Data Centers in the United States (Modified from the EPA Report to Congress 2007)

The objective of this guide is to provide general recommendations to help select or tailor the energy elements or parameters of a data center infrastructure dashboard. Data center operators are constantly looking for strategies to reduce the power needs of their data centers, but they can't manage what they don't measure. Hence, monitoring and continuous fine-tuning of energy-intensive systems is a necessity, and a dashboard energy information system (EIS) can play a key role in helping operators manage (e.g., reduce, optimize) data center energy use. Based on dashboard readings or trends, an operator can investigate further for more detailed data and then initiate energy-efficiency actions. Most data centers are just starting to install and use dashboards for energy management.

Energy use of various physical data center components can be measured in, or near, real time, and these data can be trended and then visualized in a dashboard. A dashboard is defined as a visual display of the most important information needed to achieve one or more objectives, consolidated and arranged on a screen so that the information can be monitored at a glance. It can display monitored, measured, and calculated parameters. The fundamental philosophy behind a dashboard information system is that it provides quick access to actionable visual data.

Key Characteristics of a Dashboard

Some of the key characteristics of a dashboard are that it:

- Displays the most important performance indicators and performance measures being monitored; these are usually user-defined, user-friendly, and easy to understand.
- Displays content in various charts or graphs; measured or calculated numbers are presented graphically.
- Displays information for various stakeholders (workforce, middle management, and executives).
- Displays data on a computer screen. Different screens can display different energy parameters.
- Automatically updates displays of data without any assistance from the user.
- Supports interactivity—filtering, drilling down, or customizing screens to meet various stakeholder needs.
- Has the ability to store and generate reports on various aspects of energy, as needed or defined by the stakeholders.

Objectives and Stakeholders

The objectives of these activities are to:

- Identify and prioritize a set of data center energy parameters to be monitored/measured using a system that displays them in a dashboard format.
- Identify potential stakeholder(s) for each energy parameter. The stakeholders will be interested in tracking both the real-time and trend values of the different energy parameters, with the goal of reducing energy usage and costs.
- Document recommendations to help the data center community choose which parameters they want to monitor and manage.

The following individuals were identified as a typical set of key stakeholders interested in various energy dashboard displays and reports:

1. Director: Responsible for the overall center's activity
2. Facility Manager: Primarily responsible for the data center's physical infrastructure
3. Information Technology (IT) Manager: Primarily responsible for the information technologies (both hardware and software) in the data center

Each target stakeholder has different information display needs. Additional stakeholders could have been identified, but these stakeholders were chosen to illustrate several major user groups interested in the actionable display of energy information.

Stakeholders' List of Preferred Dashboard Displays

For an actual survey effort, a set of energy parameters for data centers was developed for each target stakeholder. The stakeholders were given the list of dashboard display elements and instructed to assign each an interest level (or priority) as it applied to them. The choices were: *1* for high priority, 2 for medium priority, *3* for low priority, and *N* to represent "no interest." Of course, not all items are applicable to every site (for example, *Reuse energy factor (REF)* would only apply to a site with the proper energy recovery system). Although this list offers initial candidates for dashboard displays, stakeholders should revise it to meet their specific needs. Table 1 shows the level of interest of different stakeholders to energy parameters.

#	Primary Information	Director	IT Manager	Facility Manager
1	Power Usage Effectiveness	1	1	1
2	Total power	1	1	1
3	Power cost	1	2	2
4	Carbon emission	2	3	3
5	IT power	2	1	2
6	Average IT utilization	2	1	N
7	IT efficiency	2	1	2
8	Power factor	N	N	2
9	UPS output power	N	2	2
10	UPS input power	N	2	2
11	PDU input power	N	2	2
12	PDU output power	N	N	2
13	Electrical chain efficiency	3	2	1
14	IT fan power	N	3	3
15	Data center temperature (map)	N	2	1
16	Subfloor, duct pressure map	N	N	2
17	Outdoor dry-bulb and wet-bulb temperatures	N	N	2
18	Total CRAC power, except fan	N	N	2
19	Chilled water plant load	N	N	2
20	Chilled water plant power	N	N	2
21	District cooling power use	N	N	2
22	Cooling efficiency	N	3	1
23	Standby generator, block heater power /energy	N	N	3
24	Standby generator, fuel equivalent	N	N	3
25	Green energy consumed (GEC)	3	N	2
26	Reuse energy factor (REF)	3	N	2

Table 1. Primary Monitoring Points and Metrics

Monitoring Points and Dashboards

Users can select from three levels of energy performance tracking (EPT) approaches. Each level of metering hardware, software, and data acquisition should be prioritized according to business drivers, and will be influenced by the available budget. These three levels correspond to the ASHRAE guidelines' (ASHRAE 2010) three defined measurement levels: minimum practical (Level 1), best practical (Level 2), and state-of-the art (Level 3).

Measurement Level	Level 1	Level 2	Level 3
Human Activity	Periodic manual measurement and recording	Some manual recording and some automated	Automated recording
Measurement Equipment	Manual	Hybrid	Automated
Measurement Frequency	Once a month, a week, a day	Some manual frequency, some continuous	Continuous
PUE Estimate Accuracy	±30%	±15%	Less than ±5%
Reliance on Manufacturer Data	High	Less	None
Infrastructure Upgrade	Very low	Limited, less expensive upgrades	High
Reports	Manual, no trending, no training	Limited trending, no vendor assistance	All types of reports, vendor-assisted implementation
Dashboards	None	Limited	Highly beneficial

Table 2. Comparison of Three Measurement Levels

The ideal option is Level 3, but the available budget plays a key role in which level is selected. Figure 2 below shows the benefits and costs of the three measurement levels, using a sliding scale. The author recommends that a Level 3 measurement package is best to enable a datadriven approach to data center energy management. The figure suggests that going from Level 1 to Level 3 will:

- Increase both cost and accuracy.
- Facilitate decision making based on better data.
- Increase automatic data collection.
- Provide continuous communication.

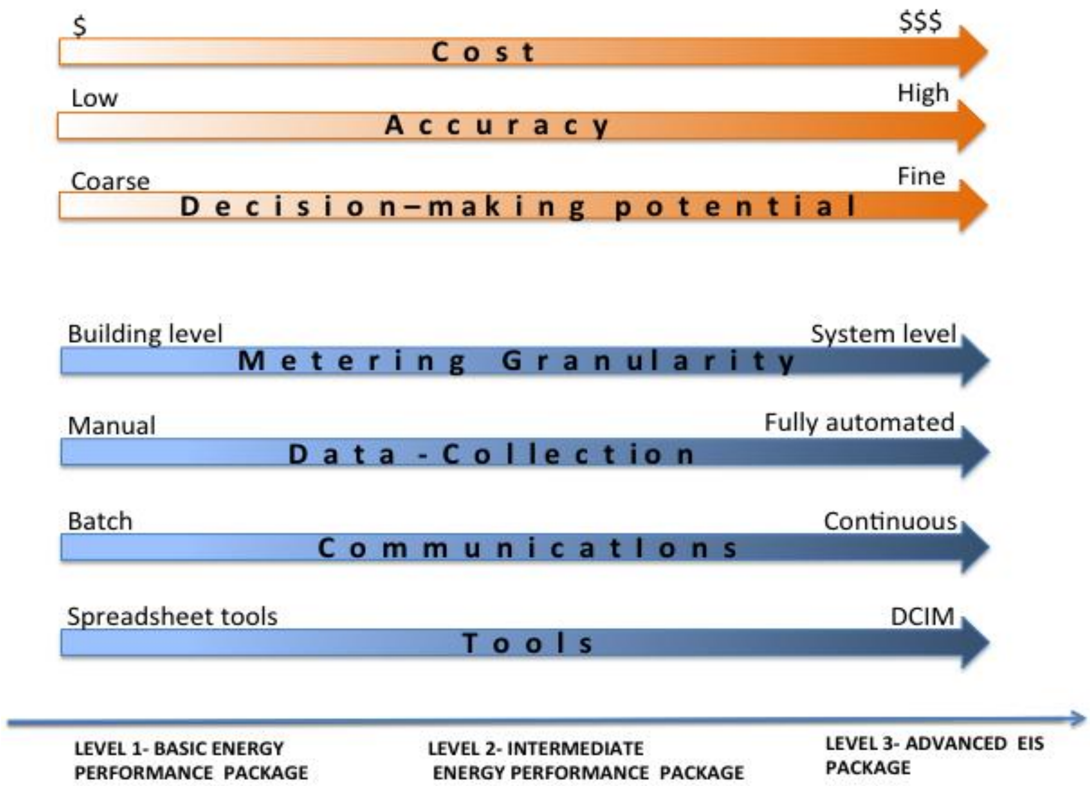

Figure 2. Monitoring-Level Sliding Scale

Recommended Information for Dashboard Displays

Standardization of dashboards and reports is important to make them more useful. Development of the energy dashboard is a team effort. Figure 3 shows a sample dashboard from ASHRAE's guide, Real-Time Energy Consumption Measurements in Data Centers (ASHRAE 2010). This level of displayed data can be only possible if an extensive (and expensive) measurement system is installed.

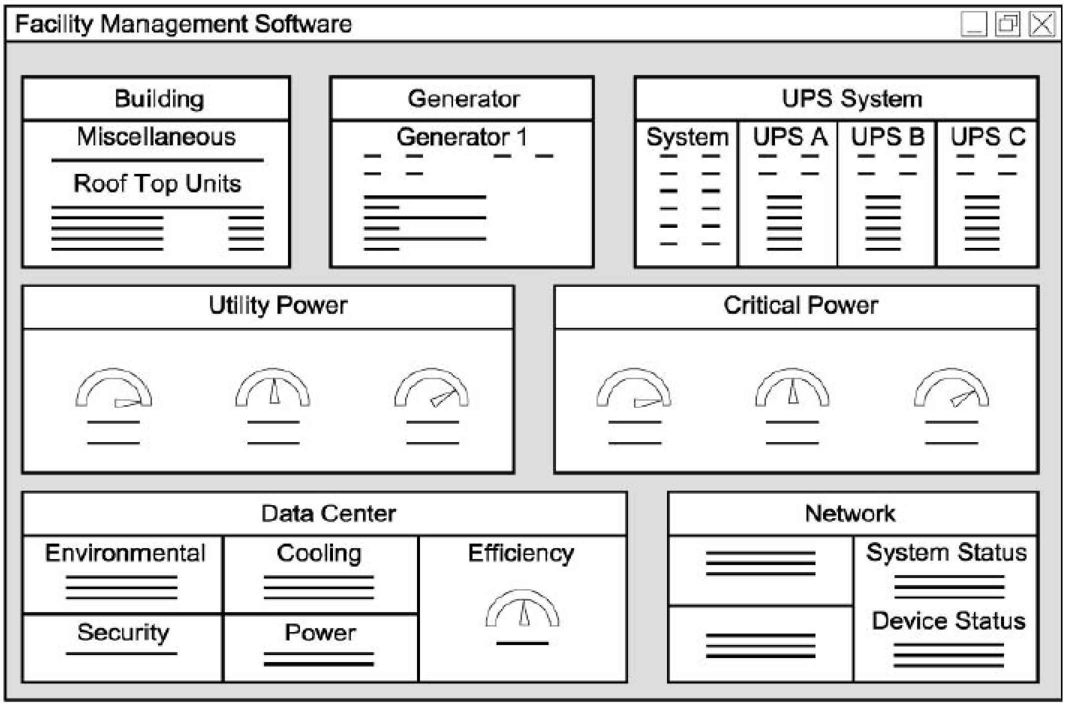

Figure 3. ASHRAE Sample Dashboard (Courtesy of ASHRAE)

Figure 4 illustrates a dashboard that is built around the key metrics and can be used by different levels of stakeholders, including senior management. The dashboard is arranged in three columns. The first column illustrates the real-time figures for energy cost, power usage by function (kWh/hour) and power usage effectiveness (PUE). The second column illustrates average figures during the last 7 days, last 30 days, and last 12 months for the same performance metrics. The third column illustrates the trending capabilities of the dashboard for the same metrics. The examples shown are for trends from the beginning of the year. By moving the cursor on the graph, a user can define trending by any start/finish (date/hour) with whatever granularity he or she desires.

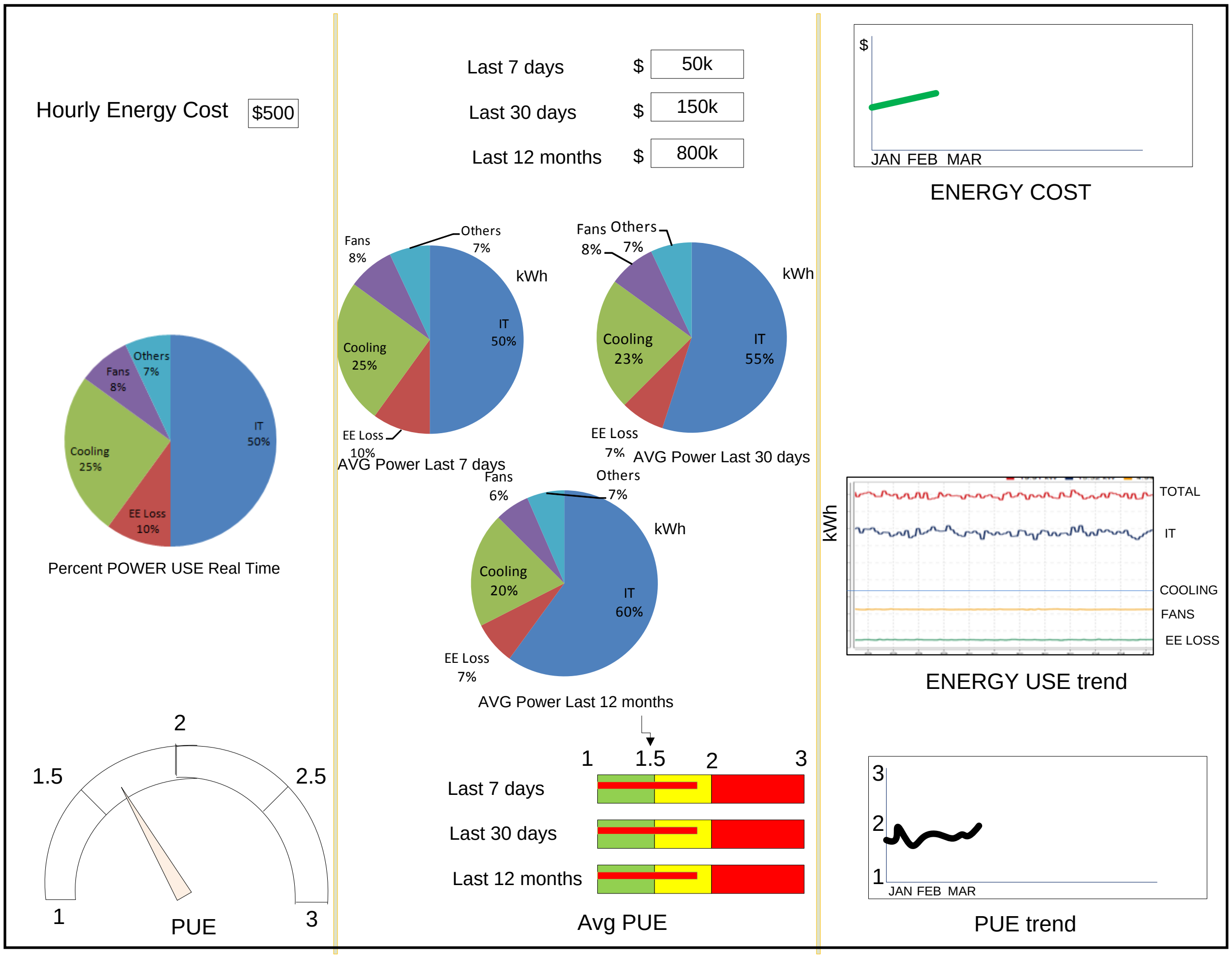

Figure 4. Suggested Dashboard for All Users Using Level 3 Tools

Figure 5 illustrates a dashboard that can best serve the IT manager, in addition to the dashboard in figure 4. The IT manager will see the same dashboard as the director but also see a second window that shows IT utilization. The first column illustrates real-time IT utilization. The second column illustrates IT utilization averages during the last 7 days, last 30 days, and last 12 months, and the third column graph is used for trending. By moving the cursor on the graph, a user can define trending by any start/finish (date/hour) with whatever granularity he or she desires. All other stakeholders can observe this dashboard if they like.

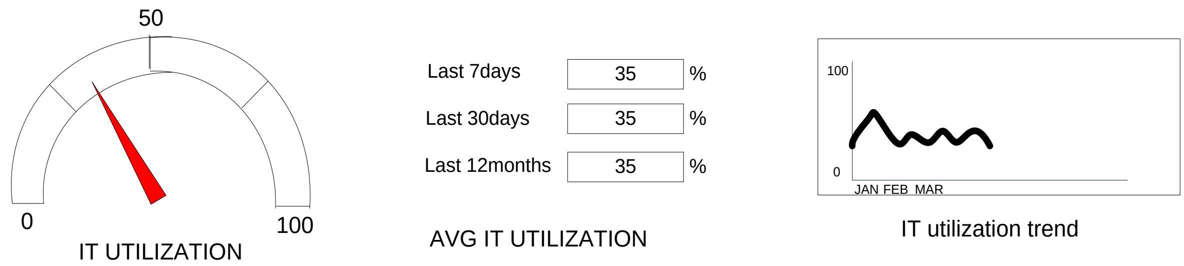

Figure 5. IT Manager's Specific Dashboard Using Level 3 Tools

Figure 6 illustrates a dashboard that can best serve a facility manager, in addition to the previous dashboards. The facility manager will see the same dashboard as the director but also see a second window will allow observation of the electrical distribution efficiency, the cooling efficiency, and a thermal map of the data center. Representative examples are shown for trending from the beginning of the year. In the actual case, by moving the cursor on the graph, a user can define trending based on any start/finish (date/hour) and with any granularity he or she desires (a few hours, few days, weeks, or more). A thermal map also can be defined for any time/date. In addition, a movie can be set up by defining the start and end point, so that changes can be observed over any period of time in the past. All other stakeholders can observe this dashboard if they like.

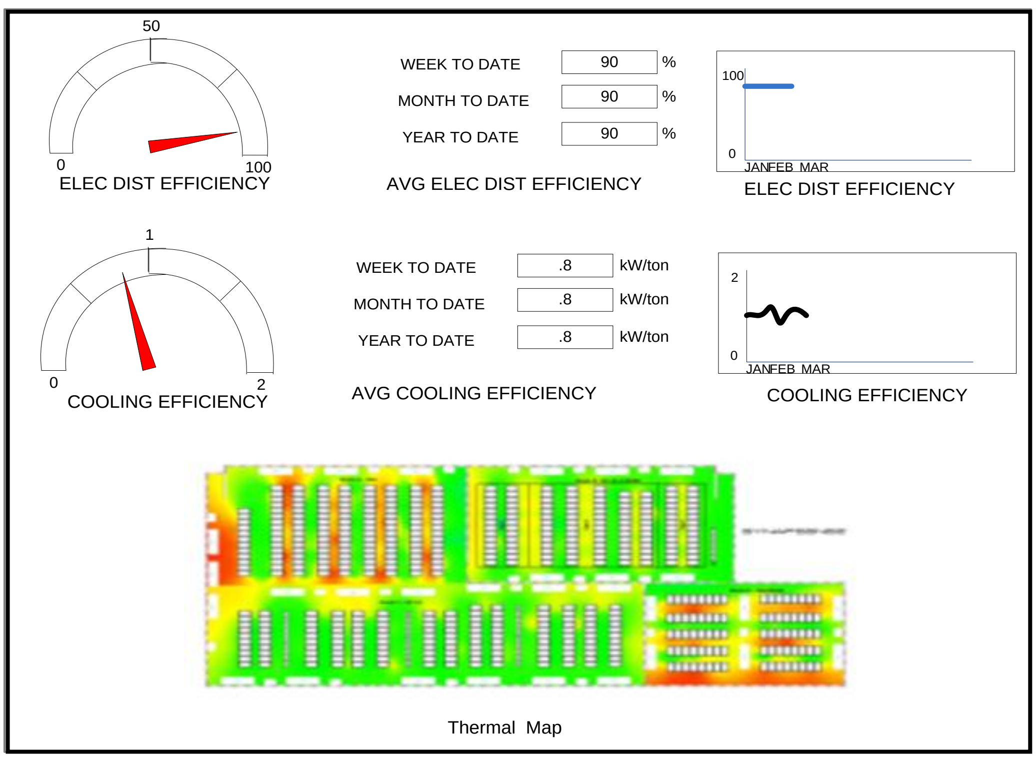

Figure 6. Facility Manager's Specific Dashboard Using Level 3 Tools

Examples of Commercial Energy Management Dashboards

Dashboard technology exists to provide customized visualization of various energy metrics. This section shows sample dashboards that illustrate how different vendors visualize different metrics. Different types and different levels of dashboards have been developed, from homemade versions, to packaged systems that cannot be customized, to packaged systems that are customized to meet specific user needs. Some vendors claim their dashboard can be customized according to customer needs.

Figures 7, 8, and 9 illustrate commercially available dashboard displays that show capacity management, PUE, and energy use by function.

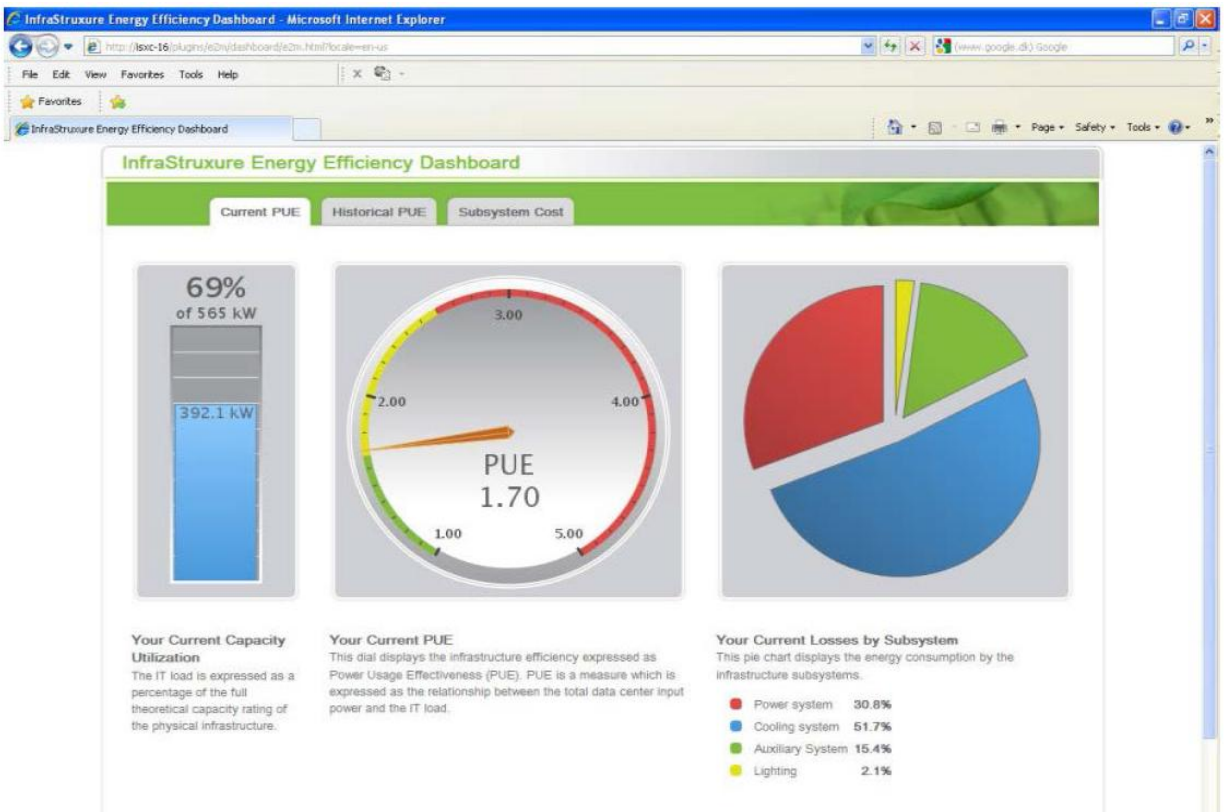

Figure 7. Dashboard for Capacity Management, PUE, and Energy Use by End Use (Courtesy of Schneider Electric)

Figure 8. Dashboard for PUE, and Energy Use over Time and by End Use (Courtesy of Modius)

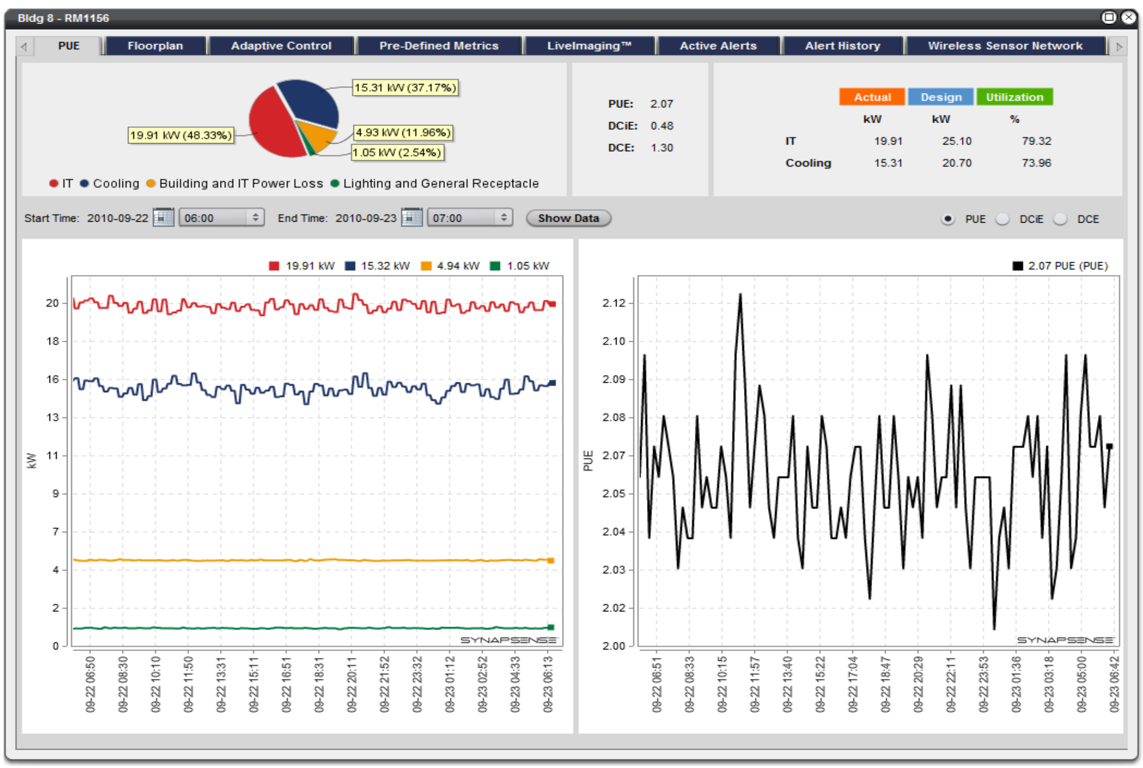

Figure 9. Dashboard for PUE, and Energy Use over Time and by End Use (Courtesy of Synapsense)

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