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General Recommendations for High Performance Computing Data Center Energy Management Dashboard Display

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***Abstract*— Within the past decade, there has been an increasing focus on improving energy efficiency in High Performance Computing (HPC). Improvements have been forthcoming, especially in the last 5 years, but there remains a strong need for continued if not accelerated progress. Much of this progress has been and will continue to be driven by market demands and the private sector. Some of the progress has been achieved by government-funded agencies and academic research. There are other mechanisms beyond these formal institutions; these mechanisms include volunteer and non-profit organizations that promote dialogue, analysis, best practices, standards and community activism. The Energy Efficient HPC Working Group (EE HPC WG) is such an organization and this paper describes an effort by the EE HPC WG to drive more rapid improvements in development and implementation of energy management dashboard displays.**

Keywords-component; energy; management; dashboard

I. INTRODUCTION

The objective of this paper is to provide general recommendations to help select or tailor the energy elements or parameters of an HPC data center infrastructure dashboard.

With increasing HPC energy consumption and the rising cost of energy, it has become important for the stakeholders to be able to monitor and manage energy consumption. Dashboards will monitor and display energy consumption of various physical data center components in or near real time as well as trend data. The dashboard will display monitored, measured, and calculated parameters.

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 single screen so that the information can be monitored at a glance. The fundamental philosophy behind a dashboard information system is that it provides quick access to actionable visual data. [1,2,3]

Some of the key characteristics of a dashboard are:

- Displays the most important performance indicators and performance measures that are being monitored; these are usually user defined, user friendly and easy to understand.
- Displayed content includes different kinds of charts, measured or calculated numbers presented in a graphical manner.
- Provides information for all stakeholders (workforce, middle management and executives).
- Visual data fits on a single computer screen. Different screens would display different energy parameters.
- Displayed data automatically updates without any assistance from the user.
- Supports interactivity – filtering, drilling down, or customizing the screens to meet the needs of the various stakeholders.
- The ability to store and generate reports on various aspects of energy, as needed or defined by the stakeholders.

Data centers consume 10-100 times more energy than commercial buildings. Users are constantly looking for strategies to reduce the power needs of these data centers, but they can't manage what they don't measure. Hence, monitoring and continuous fine tuning of energy consumption is a necessity, and a dashboard energy information system can play a key role in managing (reducing, optimizing) HPC data center energy use. Based on dashboard readings or trends, the operator can further drill down for more detailed data and can then initiate energy efficiency actions.

Most HPC data centers are just starting to gather and use dashboards for energy management. A survey conducted by the EE HPC WG [9] of the major United States Department of Energy (DOE) National Laboratory HPC data centers was

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completed in early 2012. There was an overwhelming positive response that the EE HPC WG should develop and document best practices relative to energy performance dashboards. Only a few DOE labs reported having energy performance dashboards (LBNL, LLNL and NREL) and those were described as partial, piecemeal and under construction. The results of that survey motivated the development of these guidelines.

II. OBJECTIVES AND STAKEHOLDERS

The objectives of these recommendations are to:

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

The following were identified as key stakeholders in an HPC data center who will be interested in the energy dashboard displays and reports:

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

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

III. STAKEHOLDERS DISPLAY CONTENT LISTS

A set of energy parameters for HPC data centers was developed for each target stakeholder. This is a candidate list of dashboard display elements. An interest level (or priority) for each item as it applies to the stakeholders is also proposed. Not all the items are applicable to every site. For example, percent renewable energy would only apply to a site with a renewable energy system.

This is an initial requirements list for dashboard displays, and it is subject to changes and updates by the user after further review among HPC stakeholders. The high and medium priority energy parameters for each of the three stakeholders are shown below.

TABLE 1 is a list of dashboard metrics for the data center director.

TABLE 2 Is a list of dashboard metrics for the data center facility manager.

TABLE 3 is a list of dashboard metrics for the data center IT manager.

A. Director's Dashboard Items List

Here only high level energy information is provided.

TABLE 1 DIRECTOR'S LIST OF DASHBOARD METRICS

Item	Primary Information	Unit	Priority
1	Total power & energy	kW & kWh	High
2	Energy cost	$	High
3	Average IT utilization-Compute System	Percent	High
4	Power Usage Effectiveness – Power	Index	High
5	Power Usage Effectiveness-Energy	Index	High
6	IT efficiency [a]	Work output/W*	High
7	Energy Cost per square feet	$/sq.ft	Medium
8	Energy Cost per data processing unit	$/unit	Medium
9	Carbon emission	Tons	Medium
10	IT Power & energy	kW & kWh	Medium
11	Chart of total energy use HPC vs. other IT vs. site		Medium

a. Depends on how each HPC defines its work output.

B. Facility Manager's Dashboard Items List

Here interest is more toward infrastructure energy use and related metrics while efficiency parameters were also of interest.

TABLE 2 FACILITY MANAGER'S LIST OF DASHBOARD METRICS

Item	Primary Information	Unit	Priority
1	Total power/energy	kW & kWh	High
2	IT Power /energy	kW & kWh	High
3	Power Usage Effectiveness - Power	Index	High
4	Power Usage Effectiveness-Energy	Index	High
5	Cooling Efficiency	kW/ton	High
6	Cooling Energy Use	kWh	High
7	Data center IT equipment cooling diagram	degF/C	High
8	Temperature (map)	degF/C	High
9	UPS input / output power /Energy	kW & kWh	High
10	Data center electrical distribution diagram		High
11	CRAC/CRAH/AHU RAT (avg, min, max)	degF/C	High
12	CRAC/CRAH/AHU SAT (avg, min, max)	degF/C	High
13	Average use of renewable energy	kWh/percent	Medium

Item	Primary Information	Unit	Priority
14	IT efficiency	Workoutput/ W[a]	Medium
15	District cooling Energy Use	kWh	Medium
16	Humidity (map)- dewpoint	degF/C	Medium
17	Subfloor/duct pressure (map)	in-wc	Medium
18	Outdoor drybulb and wetbulb temperatures	degF/C	Medium
19	IT fan power /Energy	kW & kWh	Medium
20	PDU input/output power /Energy	kW & kWh	Medium
21	Transformer input/output power /Energy	kW & kWh	Medium
22	Total CRAC Compressor power /energy	kW & kWh	Medium
23	Total CRAC/CRAH/AHU fan power /energy	kW & kWh	Medium
24	Total CRAC/CRAH/AHU Humidifier power /energy	kW & kWh	Medium
25	Total CRAC/CRAH/AHU Reheat power /energy	kW & kWh	Medium
26	Rack cooling index (RCI)Hi	Percent	Medium
27	Chiller plant load	Btuh or Ton	Medium
28	Chiller power /energy	kW & kWh	Medium
29	Lighting power/Energy	kW & kWh	Medium
30	Water cooling supply water temperature	degF/C	Medium
31	Water cooling plant efficiency	kW/ton	Medium
32	Water cooling plant load	Btuh or ton	Medium
33	Power factor	Percent	Medium
34	Pie chart of energy end use HPC vs other IT vs site	Percent	Medium

a. Depends on how each HPC defines its work output.

C. *IT Manager's Dashboard Items List*

Here interest is more toward IT related attributes such as IT utilization, power use, and related metrics.

TABLE 3 IT MANAGER'S LIST OF DASHBOARD METRICS

Item	Primary Information	Unit	Priority
1	Energy Cost per data processing unit	$/unit	High
2	Total power/energy	kW & kWh	High
3	IT Power /energy	kW & kWh	High
4	Average IT utilization-Compute System	Percent	High
5	Power Usage Effectiveness – Power	Index	High
6	Power Usage Effectiveness-Energy	Index	High
7	IT efficiency[a]	Work output/W*	High
8	Data center IT equipment cooling diagram	degF/C	High
9	IT Compute system Power /energy	kW/kWh	Medium
10	IT Storage Power /energy	kW & kWh	Medium
11	IT Network Power /energy	kW & kWh	Medium
12	Server Virtualization Percent[b]	Percent+	Medium
13	Temperature (map)	degF/C	Medium
14	UPS input / output power /Energy	kW & kWh	Medium
15	PDU input/output power /Energy	kW & kWh	Medium
16	Data center electrical distribution diagram		Medium

a. Depends on how each HPC defines its work output.

b. May not apply to certain HPCs.

IV. EXAMPLES OF COMMERCIALLY AVAILABLE ENERGY MANAGEMENT DASHBOARDS

Several vendors provided examples of their energy dashboards. The dashboard screenshot examples typically have more than one data element displayed. We are not necessarily matching dashboard lists with priority or stakeholders, but are providing them to illustrate how a number of metrics can be displayed.

FIGURE 1 shows PUE (power usage efficiency), energy use, and carbon emission.

FIGURE 2 shows PUE (power usage efficiency) and some other parameters. [6,7,8]

FIGURE 3 shows the power usage for individual components of the data center such as lighting, heating, and plug loads.

FIGURE 4 is a three-dimensional temperature map of a data center facility. [4,5]

FIGURE 5 is also a temperature map. This figure shows a two-dimensional slice of the temperature at selected levels in the data center. [6,7]

V. SUMMARY AND NEXT STEPS

Key energy elements or parameters were identified for display in an energy management dashboard in HPC data centers. The parameters were prioritized, for each of three data center stakeholders, namely: Director, Facility Manager and IT Manager. These lists can be used as a starting point in specifying a dashboard for a specific site. Samples of dashboard screenshots from vendors and National Labs are included to give a sense of what is available.

As HPC data centers begin to more actively deploy and use energy management dashboards, potential uses of the information collected are vast. Some possibilities include longitudinal data analysis, cross-site comparison and six-sigma continuous improvement.

Figure 1 PUE, ENERGY, AND CARBON – SCREENSHOT COURTESY OF SYNAPSENSE

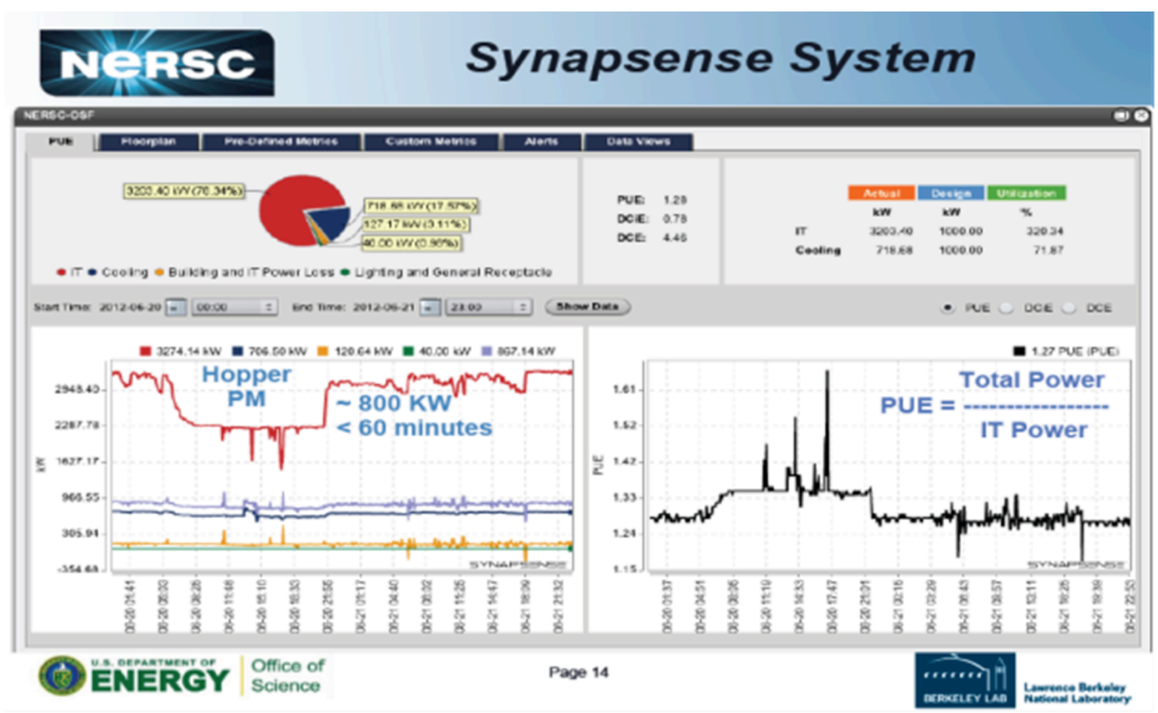

Figure 2 PUE AND OTHER PARAMETERS – SCREENSHOT COURTESY OF SYNAPSENSE, NERSC

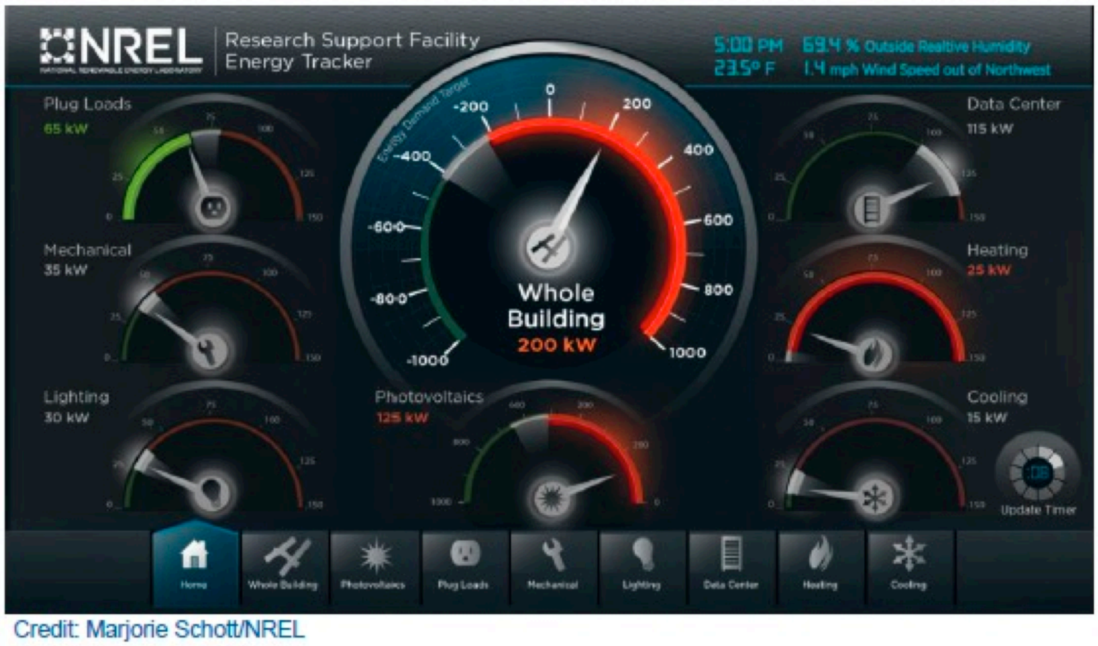

Figure 3 POWER USAGE BY USE – SCREENSHOT COURTESY OF NREL

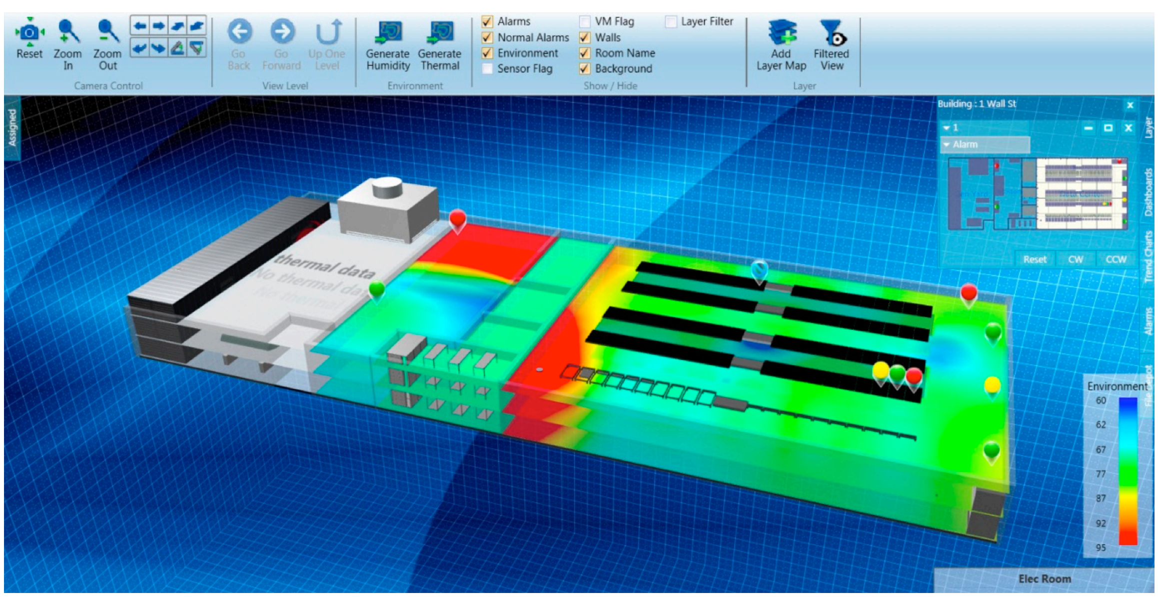

Figure 4 3D TEMPERATURE MAP – SCREENSHOT COURTESY OF CA TECHNOLOGIES

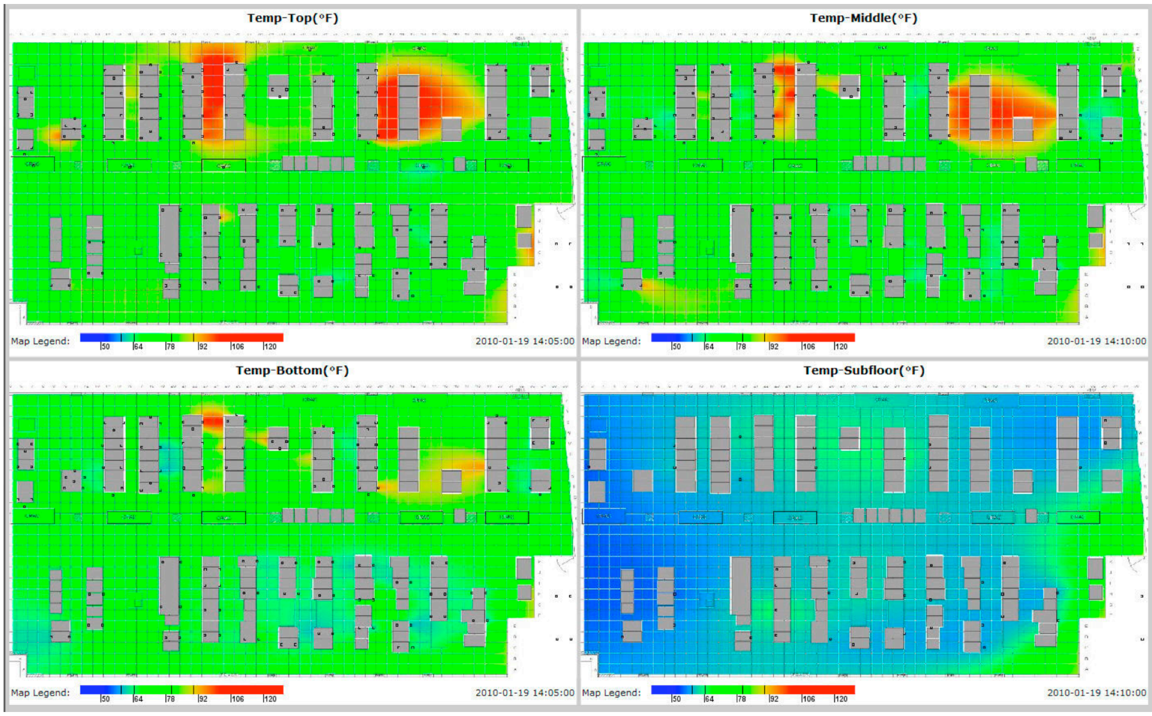

Figure 5 TEMPERATURE MAP – SCREENSHOT COURTESY OF SYNAPSENSE

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LEGEND

AHU – Air Handler Unit
A – Ampere
CRAH – Computer Room Air Handler
CRAC – Computer Room Air Conditioner
IT – Information Technology
kW– Kilo Watt
PDU – Power Distribution Unit
PH – Phase
PUE – Power Usage Effectiveness
SAT – Supply Air Temperature
UPS – Uninterruptable Power Supply
V – Volt
VFD – Variable Frequency (Speed) Drive
W – Watt

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