Data Center Energy Efficiency Measurement Assessment Kit Guide and Specification

Prepared For Federal Energy Management Program

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DRAFT

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I. SUMMARY

The purpose of this document is to provide structured guidance to data center owners, and operators, to empower them with information on importance of energy assessment and how a portable and temporary wireless mesh assessment kit can be used to speed up the process and reduce the costs of a data center energy use assessment and overcome the issues with respect to shutdowns. This kit is suitable only for data centers with air-cooled IT equipment.

The assessment kit is comprised of temperature, relative humidity, and pressure sensors. Also included are power meters that can be installed on computer room air conditioners (CRACs).

The assessment kit produces data required for a detailed energy assessment of the data center. Its design incorporates the following considerations:

- Measurement of environmental parameters (temperature, humidity, pressure) and power through a non-intrusive, non-interruptive process.
- These parameters (temperature, dew point) at server intakes are recognized by ASHRAE for standardization of server cooling performance.
- Air management improvement will provide grounds for increasing data center temperature closer to ASHRAE recommended or allowable numbers.
- Graphical reports (maps) for different parameters provide an accurate understanding of data center operation
- Ease of installation limits the duration of the test.
- Assessor can decide on the length of data collection based on the site needs.
- The way the data is recorded gives the assessor a chance to review and analyze the collected data later.
- Meanwhile some simple and quick energy efficiency measures can be implemented and the impact can be observed real time and documented.

II. GUIDE/SPECIFICATION SCOPE

TARGET AUDIENCE

This guide is primarily intended for owners and personnel including IT and facilities managers who are responsible for managing data center energy use.

WHAT THIS GUIDE DOES

This guide Introduces a assessment kit for data center assessment and its advantages and limitations, describes the assessment kit’s components, specifies the requirements of the assessment kit and its components, guides the user through the assessment kit’s installation, and lists and describes the data required for computing the proposed metrics used to determine power usage effectiveness (PUE).

WHAT THIS GUIDE DOES NOT DO

This guide does not address IT efficiency and productivity metrics. While the energy efficiency measurement approach described in this guide can be used to identify potential efficiency opportunities in HVAC and electrical systems, this guide does not constitute a detailed energy audit procedure or checklist. However, the results may be used by a trained energy auditor as part of an energy audit procedure, or to help prioritize areas for more in-depth audits. This guide does not describe the opportunities that result from the assessments or how to calculate savings from the potential actions identified. The owners of data centers are encouraged to hire trained energy auditors with data center experience to conduct their audits. The Department of Energy has established a data center energy practitioner program to train and certify such auditors.

III. Data center Monitoring

BACKGROUND

Monitoring data centers for energy efficiency is an important factor in their efficient operation. Environmental monitoring can provide a map of the cooling system performance that can be used to help detect and address deficiencies. Other monitoring can segregate the power used by various components and systems, as well as reveal data center power distribution losses. Many sensing points are required to create a reasonable map of data center energy usage performance. This is a granular monitoring approach that monitors both environmental parameters such as temperature, dew point, pressure, and power in the data center at many locations and levels.

Granular monitoring should help data center stakeholders accomplish the following:

- Identify baseline energy usage and improvement opportunities
- Measure real-time power usage and estimate PUE, which is calculated by dividing total estimated annual energy used by estimated IT equipment annual energy use
- Interpret temperature, humidity, and sub-floor pressure differential data from hundreds of sense points into intuitive live imaging maps
- Monitor environmental conditions to stay within specified recommended and/or allowable ASHRAE ranges and provide alerts when boundaries are exceeded.

This monitoring should consist of three basic components: the wireless network, a console application, and a browser-based user interface.

The principal objective of this work is to use the assessment kit capability, to improve the robustness of the assessment. This process helps to create an accurate understanding of data center operation, evaluate air management in the data center, and calculate PUE.

Principal Parameters, what to measure?

As described in *Self-benchmarking Guide for Data Center Infrastructure: Metrics, Benchmarks, Actions,* issued in 2010, the principal parameters in measuring/affecting energy use include (list is modified for this guide):

- Power Usage Effectiveness (PUE), percent of total used energy to IT used energy
- Air Temperature at IT intake
- Relative Humidity Range at IT Intake
- Return Temperature Index (RTI) at each rack .
- Data Center Cooling System Efficiency
- Airflow Efficiency
- Data Center Power Distribution System Efficiency

Principal Parameters, why to measure?

- PUE is the most recognized metric for tracking the data center infrastructure energy performance. All the efficiencies are addressed with this one metrics except IT efficiency.
- Air temperature at IT intake which is a measure of the cooling effectiveness of the IT equipment to ASHRAE levels
- Relative Humidity Range at IT Intake is a measure of the cooling effectiveness of the IT equipment to ASHRAE levels
- Return Temperature Index (RTI) at each rack is a measure of air cooling efficiency; it provides data on bypassed and recirculted air which is a measure of air management performance.
- Data Center Cooling System Efficiency measures cooling efficiency related to chilled water/DX plant. It measures power used for each unit of cooling.
- Airflow Efficiency measures the amount of air vs power used by fans. It measures power used form moving of each unit of air mass.
- Data Center Power Distribution System Efficiency measures losses in electrical distribution systems from main entry to UPS, PDU, and IT equipment.

Principal Parameters, where to measure?

Power Utilization Effectiveness(PUE)

- PUE can be computed by measurement or estimation of the basic components of the power utilization including IT power, cooling power, other infrastructure losses, and lighting.

  In most cases, UPS output is assumed as IT power (PUE level 1 according to TGG publication, “PUE™ : A Comprehensive Examination of the Metric”). Table 1 illustrates the Green Grid guidance as to which measurement points and intervals are required and recommended for each PUE measurement level (courtesy of TGG).

Where do I measure? How often do I measure?		Level 1 (L1) Basic	Level 2 (L2) Intermediate	Level 3 (L3) Advanced
IT Equipment Energy	Required	UPS outputs	PDU outputs	IT equipment input
Total Facility Energy	Required	Utility inputs	Utility inputs	Utility inputs
	Additional recommended measurements*		**UPS inputs/outputs** **Mechanical inputs**	**PDU outputs** **UPS inputs/outputs** **Mechanical inputs**
Measurement Intervals	Required	Monthly	Daily	15 minutes
	Additional recommended measurements*	**Weekly**	**Hourly**	**15 minutes or less**

Table 1: Guidance on Measurement Points and Intervals for Each PUE Reporting Level

- Air temperature at IT intake should be measured using thermometers, thermistors, infrared, or RTDs. The more sensing points are used, the more accurate the data gets. This is where mesh network monitoring is cost effective.
- Relative Humidity Range should be measured using humidity sensors. The more sensing points are used, the better the data gets. should be measured using thermometers. The more sensing points is used, the better the data gets. Here the advantage of mesh network measurement becomes clear.
- Return Temperature Index (RTI) at each rack is a derived metric. It is calculated by dividing CRAC's supply and return air temperature differential by rack intake and exhaust air temperature differentials. In lieu of airflow measurement that is rather difficult to do, temperatures are measured which can deliver the same result as to air is bypassed around the rack or recirculated. The more sensing points is used, the better the data gets. Here the advantage of mesh network measurement becomes clear.
- Data Center Cooling System Efficiency is another derived metric and is calculated by dividing the total power used by all the components of cooling systems (chiller, tower, DX systems, pumps, fans, etc.) by total cooling that was provided.
- Airflow Efficiency, a derived metric, is calculated by dividing total fan airflow to the power used by fans' motors. Usually, airflow is not measured and fan nominal capacity is used. This can reduce accuracy of this metric. Poor accuracy can be expected if the fans are on VFD motors. Here the fan curves should be used and many times, it is difficult to get one.
- Data Center Power Distribution System Efficiency is measured by by dividing the power that has reached the IT equipment by the power that is measured at entry to data center for IT equipment. It can be upstream of UPS(less accurate) or at switchgear (better accuracy). Usually this metric is calculated by reading the numbers off the switchgear and UPS and/or PDU display.

Data Center Visual Trending

Visual trending should provide thermal, pressure differential, humidity, and dew point mapping using real-time data at multiple levels of the data center.

With the amount of the sensors in a wireless mesh network monitoring system, operators will be able to see hot spots and direct airflow to avoid over-heating or air mixing. Also, pressure mapping should enable operators to balance the sub-plenum/ductwork pressure differential. Visual trending should provide:

- An integrated view of the data center environment, and a record of anomalies
- Real-time visibility of the impact of data center changes
- Information to assist in identifying data center energy efficiency improvement opportunities such as rack intake and exhaust
- Information to assist in identifying available data center cooling for increased CPU density and footprint reclaim
- Information to assist in identifying potential energy savings, operational savings, and data center resiliency
- Data center cooling capacity management by depicting real-time impact of changes

IV. Wireless Network Specification

WHY WIRELESS?

The two primary motivations for choosing a wireless network over a wired approach are the flexibility and the cost-savings associated with eliminating cables and wires. With no wires or cables to route, a wireless monitoring system is inherently more flexible than a traditional network. You are not locked into a fixed network topology or system setup, leaving open the possibility for additions, upgrades, extensions, and so on. This convenience means there is less overhead associated with setting up a measurement, and less overhead means more opportunity for taking additional measurements for added insight into your system. Wireless also extends the portability of your data acquisition. Field measurements can be time-consuming and costly. With wireless sensors, setup time is significantly reduced. The flexibility of wireless remote monitoring systems can translate into large cost savings. Cost savings can be achieved at two levels: reduced downtime and installation labor. Table 2 illustrates a summary of benefits and features. (Courtesy of Wireless Sensors)

Driver	Benefit	Feature Required to Deliver Benefit
Reduce Op Ex	▪ Optimize cooling distribution system	▪ Granular temp measurements at low deployment costs
	▪ Optimize CRAC	▪ CRAC supply and return temperature ▪ CRAC chilled water supply return temp ▪ CRAC thermal performance
Reduce Cap Ex	▪ Wireless devices non-invasive installation reduces TCO of monitoring systems	▪ Scalable, low cost, easy to deploy with long battery life ▪ Stand alone system or integrate with existing third party systems and applications
Prevent Failures	▪ Alert excessive ambient conditions	▪ Granular temperature measurements
	▪ Alert access intrusion	▪ Sense room access
	▪ Alert anomaly in air distribution system	▪ Granular temperature measurements

Table 2: Summary of The Benefits and Features of Wireless Monitoring

DESCRIPTION

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways, which may but need not connect to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes. Wireless mesh networks can be implemented with various wireless technology including 802.11, 802.15, 802.16, cellular technologies or combinations of more than one type.

ARCHITECTURE REQUIREMENTS

Wireless mesh architectures infrastructure is, in effect, a router network minus the cabling between nodes. It should be built of peer radio devices that do not have to be cabled to a wired port. Mesh architecture should sustain signal strength by breaking long distances into a series of shorter hops. Intermediate nodes not only should boost the signal, but also cooperatively make forwarding decisions based on their knowledge of the network, i.e. perform routing. Architecture should provide high bandwidth, spectral efficiency, and economic advantage over the coverage area.
Wireless mesh networks should have a relatively stable topology except for the occasional failure of nodes or addition of new nodes. The path of traffic, generated from a large number of end users, should change infrequently. Practically all the traffic in an infrastructure mesh network should either forwarded to or from a gateway.
The sensor nodes should collect temperature and other environmental parameters and power readings. The manager (gateway) should coordinate routing, aggregates packets of data, collect network statistics, and handle all data transfers. Again, gateway communication with its mesh network is required to be wireless. The server should communicate with the gateway through an Ethernet connection. A typical mesh network is illustrated in figure 1. (Courtesy of Wireless Sensors)

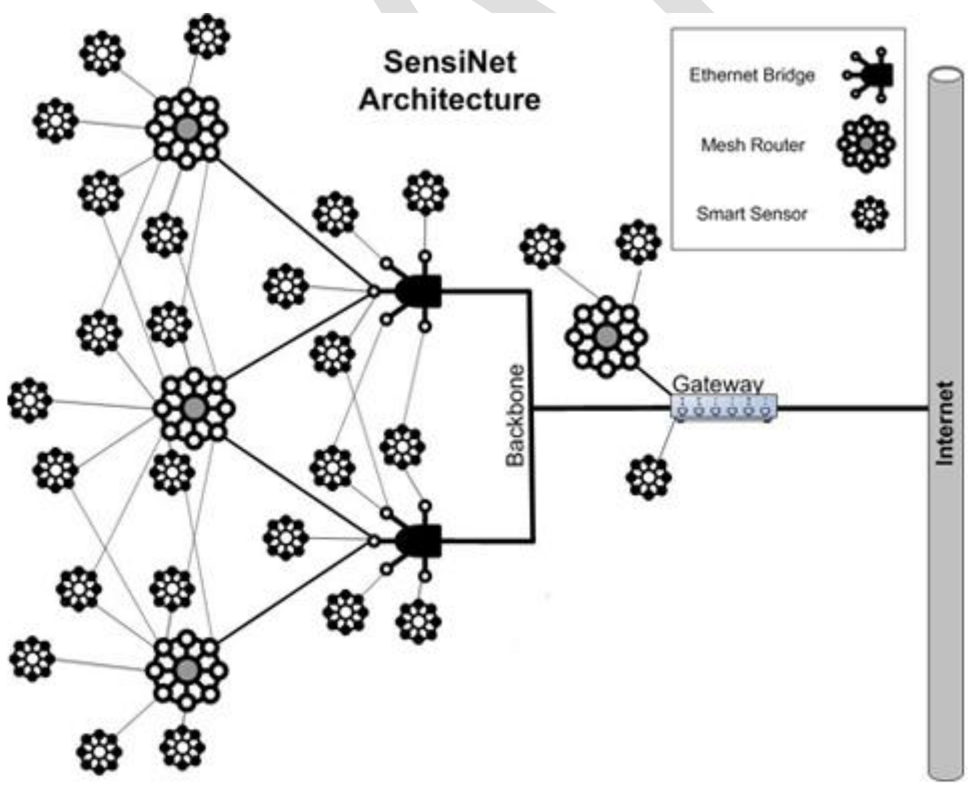

Figure 1: Typical Mesh Network

COMPONENTS AND FEATURES SPECIFICATIONS

The monitoring and metering shall be a microprocessor-based, fully integrated, modular, wireless granular mesh network. The system shall include, but not be limited to, the following features:

- The system shall be easily expandable by the user in both capacity and functionality.
- The network shall be fault tolerant.

Following are requirements for typical components:

Gateway

While main power supply is the house 120V. The gateway shall have a minimum of 72-hour battery back-up in case of power failure. It should have lights showing if it is powered by battery. In addition, lights should demonstrate if the gateway is communication with the nodes. The system shall have complete alarm handling, logging, prioritizing, and acknowledge capabilities. It shall include data logging, storage, dashboard, and trending.

Rack thermal node

Temperature node shall gather data from multiple sensors installed on the air intake and air exhaust of the racks and transfer temperature and humidity data to the nodes. Temperature nodes wired to those sensing points should communicate with the gateway through wireless mesh network. It is preferred that the same node collect relative humidity data from sensors without need for additional nodes. Accuracy of equal or better than ±0.6°F is required. The time between each data release (communication with gateway) should not exceed 5 minutes. Nodes should have lights showing that they are on, communicating, or initializing.

CRAH/C Thermal

Each unit comes with two thermal nodes, one for supply air and one for return air. Having multiple sensors at the return, usually a 3 foot by 8 foot area, will provide a more accurate temperature reading but is optional. Accuracy of equal or better than ±0.6°F is required. The time between each data release (communication with gateway) should not exceed 5 minutes. Nodes should have lights showing that they are on, communicating, or initializing.

Dew point Sensors/ Transmitters

These can be integrated parts of the rack and CRAC thermal nodes listed above to make the installation faster and easier or provided separately. Required accuracy is ±0.9°F. The time between each data release (communication with gateway) should not exceed 5 minutes. Nodes should have lights showing that they are on, communicating, or initializing.

Differential Pressure Transmitters

Differential pressure transmitters should be provided as necessary to meet the control tolerances specified. Differential Pressure Range should be from -1.0 to 2.0 in H_2O. Zero point accuracy should be equal or better than: ±0.002 in H_2O. The time between each data release (communication with gateway) should not exceed 5 minutes. Nodes should have lights showing that they are on, communicating, or initializing.

Current Transmitters

AC current transmitters should be a self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 milliamp (mA) two-wire output. Full-scale unit ranges shall be 10 amps (A) to 1000 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at a 500 ohm maximum burden. The transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized. The unit shall be a split-core type, for clamp-on installation on existing wiring. Nodes should have lights showing that they are on, communicating, or initializing.

Voltage Transformers

AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection. Transformers shall provide ±0.5% accuracy at 24 Vac and 5 VA load. Windings (except for terminals) shall be completely enclosed with metal or plastic.

Other Components

There might be requirement for other components such as btu meter (combination of water flow meter and two temperature sensors) for chilled water system, or others. These meters are not part of wireless mesh network but should be able to communicate with the monitoring server through Modbus, Bacnet, SNMP or other communication protocols.

Battery Life

The network should let battery powered devices sleep for minutes at a time, reducing battery use. The duty cycle of battery powered nodes within a network should be designed to be very low, offering even more energy efficiency and greater battery life. Batteries should last for four years at a minimum.

Operational Interference

Data center environments typically have a large amount of radio frequency (RF) noise. This noise is created by servers, UPS inverters and building systems, and other wireless communications, such as Wi-Fi and mobile phones, all of which create interference that can significantly degrade network performance. To overcome operational interference (noise), the network nodes should be ultra low-power wireless transceivers that transfer data to and from integrated sensors or controllers, using an on-board radio to send the packets to neighboring nodes. Each node should pass the packet on to other nodes, in a series of “hops” that deliver data to their destination. Preconfigured nodes should be able to be added to or removed from the network without disrupting communications. In addition, wireless monitoring devices should not cause any problems with the operation of the existing communicating devices in the data center; therefore, they should have low-power transmissions (< 3 mW), low data transmission rate (< 3%), and non-overlapping frequency range.

Security

Wireless sensor, router, and gateway devices should not support any Internet-protocol (IP)-based protocols. To avoid any security threats, they should not provide any support for IP connection initiation, connection establishment, data initiation, or data transfer. In addition, the wireless networks shall use encryption, to ensure that external agents cannot snoop the context of the communication on the network.

Data Latency

Wireless network providers should identify their data latency in their bid. This includes propagation, the time that it takes for a packet to travel between one place and another, and transmission speed, considering the medium itself introduces some delay.
The data reliability of the wireless network should be on the order of 99.999%, at least. The wireless network also should be able to accommodate feedback (i.e., data flow from upstream back).
If communication with a vendor's server is necessary, the mechanism, ease of use, and security features need to be defined and approved by the data center managers.

SCOPE OF WORK

The following bullets outline the scope of work. Note that the responsibility for each item should be well defined in the contract between the owner and contractor(s).

1. Provide all of the design, labor, equipment, and materials that are required to result in a complete and properly operating monitoring and metering installation.
2. Furnish all remote field devices (sensors, gateways, transmitters, power supplies, etc.) to assure a complete and operating system.
3. Provide a server for the monitoring and metering contractor to install their operating program(s) on. The contractor is responsible for coordination of software versions and implementation.
4. Provide complete start up, check out, and commissioning of related monitoring and metering systems.
5. Provide complete on-site instruction to the Owner in the proper operation of the system and all devices.
6. Provide all wiring, terminations, enclosures, network devices, software installation, and commissioning for monitoring of typical electrical systems such as CRAH or/and CRAC units.

V. ASSESSMENT KIT

WHY ASSESSMENT KIT?

Benchmarking is the first step in process of improving data center energy performance. Most federal data centers lack monitoring and measurement systems so for getting an idea on how the data center energy use performance is compared to the peers, an energy assessment is performed. A conventional energy assessment usually consists of a snap shot power measurement. An actual power measurement by installing meters requires shutdown and shutdowns in data centers are usually not possible. So the next option is reading power from different electrical equipment display if they have one. The result is not an accurate evaluation of the performance although it still can result in some useful recommendation as how to save energy. The biggest shortcoming of such assessment though is that air management is not addressed. Experience has shown that the easiest and most cost effective energy efficiency measures are those deal with improvements in air management. Assessment kit gathers continuously data related to air management for duration of the test. The data is reliable considering number of sensors (7 per rack, 4 per CRAC). The assessment kit provides an easy to understand visualization of the air management data through graphs and maps. Data is accessible real time and later when the report is being generated. Another benefit of assessment kit is real time observation of improvements as the result of EEMs implementation. Real time observation of environmental data eliminates worries about possible failure of equipment or interruption to data center operation as the result of implementation of measures. It builds up operators' confidence in applying such measures.

Examples of such EEMs are listed below:

1. Install missing blanking panels in the IT equipment racks to address the data center's hot spots.
2. Cover openings within and between racks. Investigate openings on top of the racks and ways to contain them. Hot aisle containment should address those openings.
3. Seal any remaining cable penetrations.
4. Rearrange the perforated floor tiles, locating perforated tiles only in cold aisles and matching tile flow rate with the IT equipment airflow rate.
5. Evaluate the air path (under the raised floor and in the ceiling space) and rearrange the cables, wires, and pipes to address possible congestion in the cooling air path.
6. Plan to contain hot aisle or cold aisle.
7. To separate cold and hot air, the most effective way is to contain the hot aisle and create a hot air return path (which can be ceiling space and chimney connecting the CRACs to the ceiling).

The very important benefit of the assessment kit is that the installation of CTs for measuring power use by CRACs is not interrupting to the data center operation. CTs can be installed in junction boxes that have CRAC bound cables. If junction box is not employed or it is not accessible then CTs have to be installed inside the CRAC. Usually there is enough redundancy in number of CRACs that one at time they can be turned off. One at atime, CRACs can go through the process turned off, CTs installed, and then turned back on. An opportunity to verify the impact of such measure as increasing the CRAC supply air temperature to increase cooling efficiency, turning off some of the CRACs to optimize power use by fan motors and compressors (if applicable), or reduce the fan speed to minimize power use by the fan motors if CRACs equipped with VFDs.
In summary, a portable and temporary wireless mesh assessment kit can be used to speed up, reduce the costs of a data center energy use assessment, and overcome the issues with respect to shutdowns.

ASSESSMENT KIT COMPONENTS

The following sections outline the specifications of the equipment that comprises the assessment kit that was used by LBNL. The components for the kit came from one manufacturer. Similar equipment from different manufacturers/vendors should be considered as well.

Thermal rack nodes and temperature sensors – 20 units
Each node comes with seven temperature sensors and one humidity sensor.

Thermal rack nodes and 6 row temperature sensors set – 3 sets
For network and other low-density racks, a thermal node with six intake and six exhaust sensors is included. It makes the work easier and more racks are covered by each node.

CRAC thermal nodes measuring temperature and humidity – 10 sets
Each unit comes with two thermal nodes, one for supply air and one for return air. Having multiple sensors at the return, usually a 3 foot by 8 foot area, will provide a more accurate temperature reading.

Dew point sensors/ transmitters – 40 units
These are integrated parts of the rack and CRAC thermal nodes listed above to make the installation faster and easier.

Differential pressure transmitters – 6 units
The assessment kit has six pressure sensors capable of covering 3,000 square feet of white space.

Current transmitters – 8 sets
The assessment kit can be complemented by more current meters if there are more than 8 CRAC units in the zone of the data center that being assessed. Note that for constant speed fans CRAH units, continuous monitoring is not required since the power use is the same throughout the day. This is assuming there is no reheat in place.

A typical monitoring nodes and sensors is shown in figure 2. On the left a thermal node, a pressure node, and gateway are shown and on the right the green dots identify the placement of the sensors.

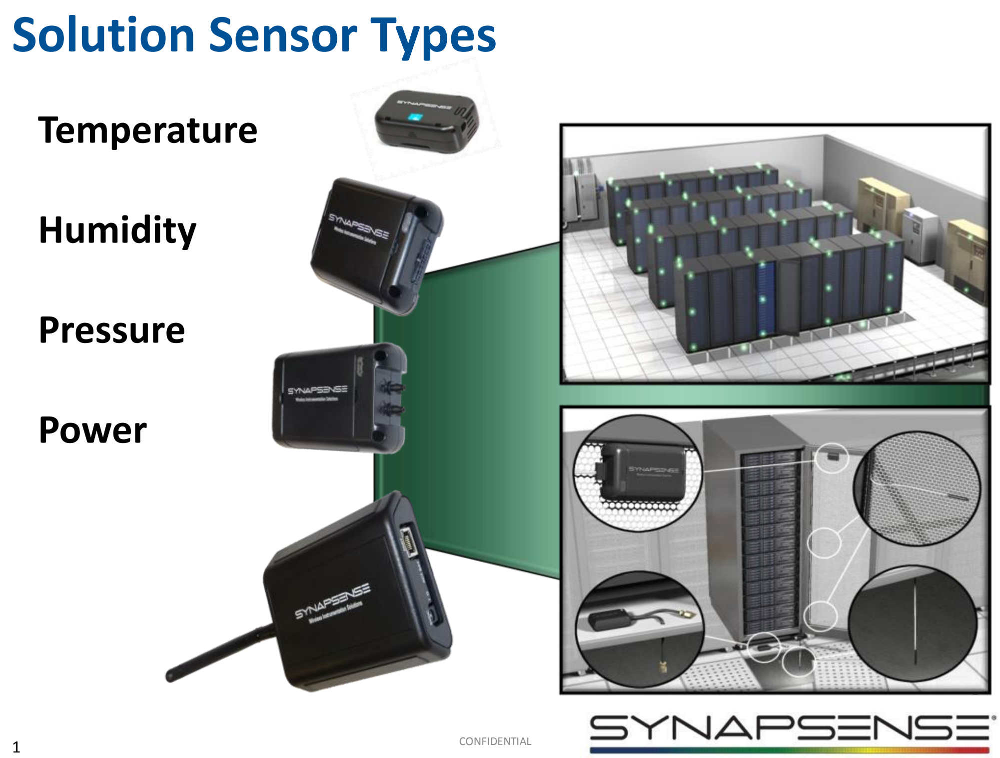

Figure 2: Typical monitoring nodes and sensors

VI. ASSESSMENT KIT INSTALLATION and COMMISSIONING

PURPOSE

The main purpose of this work is to use the monitoring to improve the robustness of the energy efficiency assessment. The main goal of introducing the assessment kit was to combine the measured data with calculations and produce meaningful information that otherwise would have required a lot of equipments. The results are close to those from more extensive alternatives that cost more and take longer to install and commission. This application helps to create a relatively accurate understanding of data center operation, evaluation of air management in the data center (locating hot and cold spots, locating the air leaks, etc.), and calculating PUE. Air flow distribution can be optimized through trial and trending (sealing openings, floor tile tuning, etc.). After each trial, trending can immediately show the impact of the changes, which can encourage additional trials. The purpose of the trials is to identify the effect on the separation of cold and hot air, potentials for increasing room temperature set point, and expanding relative humidity set-point range or disabling humidity control.

PROCESS

The process begins with installation of the system, including sensors, routers, and a gateway for environmental monitoring. The following bullets outline the steps necessary to install and operate the system.

1. Arrange access to the data center and coordinate the activities. Many centers have extensive change control and access procedures, and it is critical that these procedures be followed and accounted for in the assessment plan. Observe all safety procedures in order to maintain the safety of personnel, protect equipment, and ensure continuous operation of the data center.
2. Generally, the installation of the environmental sensors is not intrusive and does not interrupt data center operations. However, this is not the case if power meters are planned for installation because shutdowns are required to install power meters on panels, and those will interrupt the data center operation. It can take a long time to install the meters, and it can be costly. This is the reason the assessment kit estimates power usage in lieu of metering in those instances.
3. Set up the equipment. First, the server and the gateway need power. The gateway needs to be set up in a central location in white space with good access to wireless components such as thermal nodes, with no major obstruction (such as a full height walls) between the gateway and the nodes. After the gateway and server are set, the nodes and sensors need to be installed as planned. When all of the equipment is installed, the software can be activated to start the data-logging process.
4. Where consistent with the plan, start logging the computer room conditions of the computer room air conditioners, computer room air handlers, or other air-handling units serving the data center. This may be either through energy management control systems (EMCS) or with assessment kit power meters. The supply and return air conditions (both temperature and relative humidity) are monitored over time. Be aware of stratification at the point of measurement; it is possible for the air temperature to vary several degrees between the top and bottom of supply air ducts. To meter the power, an amp meter and volt meter should be installed. Note that power is required for these meters, and the communication between these meters and gateway is wireless. The meters are especially useful for metering CRAC units, since the power use is variable (i.e., the compressor stages on and off). For a constant volume CRAH unit while the humidification/dehumidification is disabled (that is, neither reheat nor electronic humidifier are in operation), calculation would be easier than measurement.
5. Measure pressure by locating the differential pressure sensor tubes under the raised floor and above (or inside the ductwork and the data center space). Here data can be presented by a pressure map or different tables or graphs. Reducing pressure to around 0.03inch can result in reduced airflow, thus saving energy.
6. Measure rack air intake and exhaust temperatures and relative humidity by installing sensors in the front and back of the racks. Considering the coverage of each node, usually thermal node installed on every third rack in the row.
7. To monitor the fan power for constant speed fans, nominal cfm from the equipment data sheet can be used along with the estimated pressure loss. The preferred option is to do a spot measure of the power using the kit current/voltage meters. This may require the shut down of one unit, installation of the meter, and turning the unit back up. Shut down then should be repeated when meter needs to be removed. The better way, if it is possible, is to track the power cables serving the CRAC unit back to the junction box, which is usually located under raised floor or in the ceiling space. The figure xx shows the installation in the CRAc as well as in the junction box. The benefit of installation in the junction box is that there will be no need for shutting down the CRAC unit in most facilities. Figure 3 shows installation of CTs on the CRACs (left) and installation of CTs in the junction box (right).

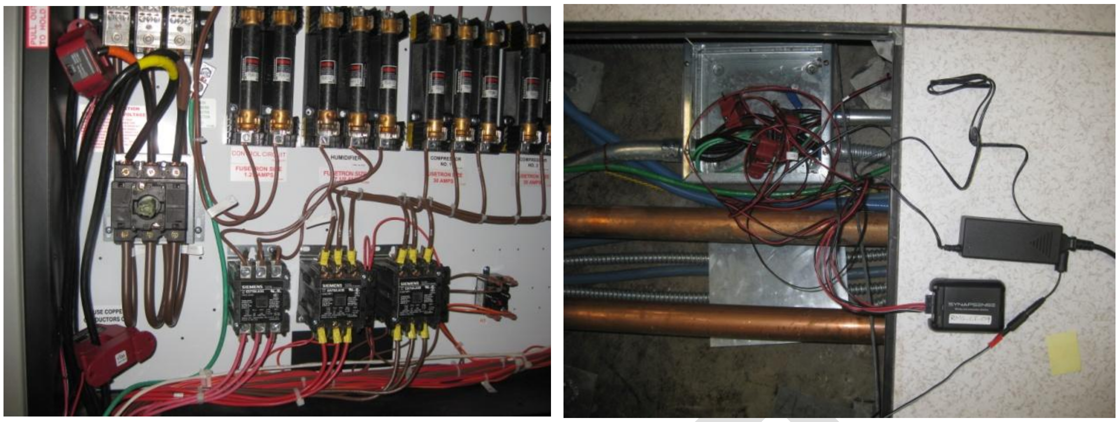

Figure 3: Typical CT Installation on CRAH (Left), in JBox (Right)

For CRAC units and CRAH units with VFD, power meters need to be installed on all the operating units. If not enough power meters exist then the meters should be installed on shared basis and move from one unit to another during the test until all the CRACs units are covered.

To calculate PUE, the cooling needs to be estimated since the assessment kit does not include flow meters and power meters for chiller plant or other cooling systems monitoring. Knowing the IT load, one can estimate required cooling (0.285ton per kW). By estimating the other cooling loads such as electrical equipment cooling, lighting, and possible envelope loads one can then calculate total cooling in tons. The power needed to provide that amount of cooling then depends of the cooling system components and their efficiencies. For example a good chilled water system with water cooled variable speed drive (VSD) chillers and waterside economizer will present more energy efficient central plant.

SYSTEM DATA PRESENTATION

The important data should be accessible through a server interface in the form of dashboard, snapshots, maps, tables, and graphs. Rack temperature and humidity, supply air pressure, and CRAC power use should be accessible directly. Data bases of information should be created that can be utilized by the user to create different reports for diagnostic, management, or planning purposes. For example, user should be able to superimpose rack air intake temperature on the data center map, or tabulate it to compare with other data, or graph it to exhibit the changes of the parameter in a pre defined period of the time. Power usage effectiveness is not expected as a direct output of the assessment kit. It is computed using electrical component readings, estimation of power use by cooling system assuming certain efficiencies, estimation of lighting power use, and information resulted from CRAC power measurement.

SAMPLE PRESENTATION

Following figures are samples of a real project. The assessment took just 4 days. Few air management EEMs including sealing the floor, relocating perforated tiles to the cold aisles and removing those in hot aisles and access paths, sealing the racks (using card boards), and increasing set point of CRAHs supply air temperature.

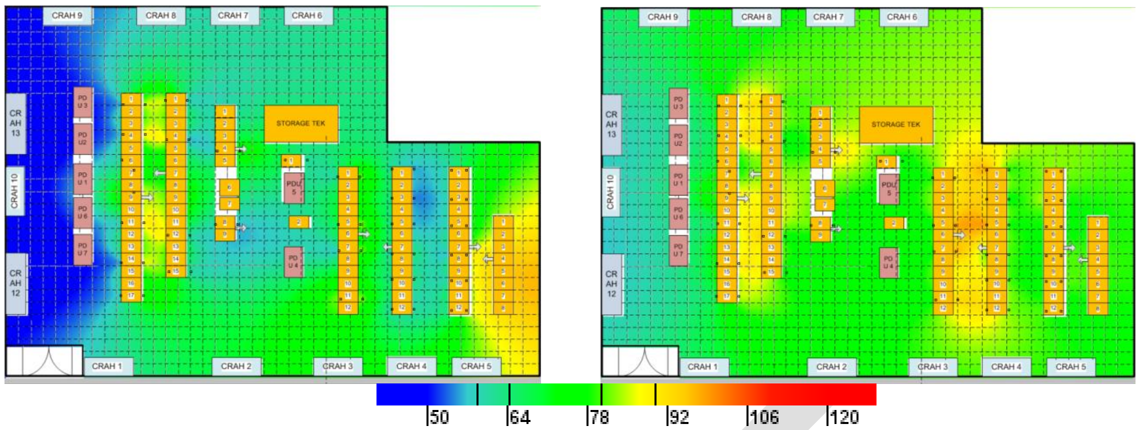

Figure 4: Data Center Thermal LiveImaging™ Map Before (Left) and After (Right) Air Management EEMs Were Implemented

Figure 5 illustrates average rack intake air temperature. After air management EEMs were implemented, this temperature was safely increased. The main benefit was that the chilled water temperature could be increased which resulted in major power savings.

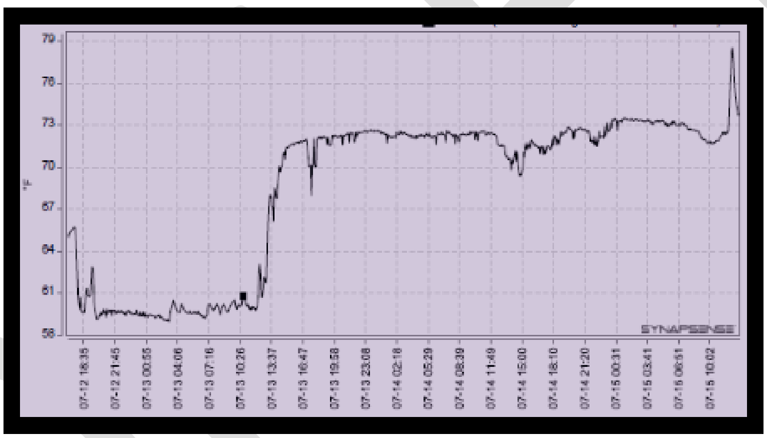

Figure 5: Average Air Intake Temperature Increase After Air Management EEMs Were Implemented

VII. REFERENCES

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