SCTE · ISBE

STANDARDS

Energy Management Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 213 2020

Edge and Core Facilities Energy Metrics

NOTICE

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1. Introduction

1.1. Executive Summary

SCTE 213 provides procedures that help cable operators measure at the critical facility level, how effective changes in the service impact energy consumption from both high level and functional work perspectives. It enables cable operators the ability to craft a uniform baseline, and ultimately measure wins and improvements against that baseline using the agreed upon metrics. It also improves tools to communicate with executive management a set of common and consistent reports comparable across regions, by measurement against energy KPIs. This document also enables prioritization of energy efficiency spend during budget cycles.

1.2. Scope

This document provides a metric to help operators measure how changes in the service impact energy consumption at the critical facility, from both a high level and functional work perspective.

The metric is designed to:

- Drive the energy strategy and direction of the organization
- Provide a focus of energy for an operator
- Help make decisions regarding energy
- Drive performance operationally, financially and environmentally
- Measure energy change and within the organization
- Produce good internal and external public relations regarding energy impact

The scope of the energy metric standard includes edge and core network facilities servicing the customers. Excluded from this standard are labs and testing facilities, people space, parking lots, parking garages, warehouses, and customer premise equipment (CPE). Please refer to SCTE 211, Energy Metrics for Cable Operator Access Networks, for similar metrics for the access portion of the network.

1.3. Benefits

SCTE 213 provides operators a uniform way to assess and rank edge and core facility inventory for energy efficiency and productivity, creating ability to allocate capital budget/projects efficiently to facilities most in need. It also provides operators with a quantitative way to capture and show energy data, tracking improvements and translating those improvements to real operational and financial gains to support/validate business cases for energy improvement projects.

1.4. Intended Audience

Cable operator critical facility professionals and procurement teams.

1.5. Areas for Further Investigation or to be Added in Future Versions

Impact of DAA on core and edge facilities and their metrics.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- ISO/IEC 30134-2 2016 Information technology — Data centres — Key performance indicators — Part 2: Power usage effectiveness (PUE)
  https://www.iso.org/standard/63451.html

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

[i1] SCTE 184 2015, SCTE Recommended Practices for Cable Facilities

[i2] SCTE 211 2020, Energy Metrics for Cable Operator Access Networks

[i3] SCTE 210 2015, Performance Metrics for Energy Efficiency & Functional Density of Cable Data Generation, Storage, Routing, and Transport Equipment

3.2. Standards from Other Organizations

[i4] ETSI ES 205 200-2-1 ATTM Energy management; Global KPIs;, Operational infrastructures; Part 2: Specific requirements; Sub-part 1: Data centres

3.3. Published Materials

[i5] “PUE^{TM}: A Comprehensive Examination of the Metric”, ASHRAE Datacom Series Book 11
[i6] “Harmonizing Global Metrics for Data Center Energy Efficiency”, Joint Statement of The Green Grid Taskforce, March 13, 2014

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineer
ATS	automatic transfer switch
ATTM	access, terminals, transmission and multiplexing
BDFB	battery distribution fuse bay
CATV	cable television
CB	consumed bytes
CMTS	cable modem termination system
CPE	customer premises equipment
CRAC	computer room air conditioner
CRAH	computer room air handler
DC	direct current
DCeP	data center energy productivity
DX	direct expansion [air handler unit]
e.g.	for example (exempli gratia)
EMS	[SCTE] Energy Management Subcommittee
EPCB	energy per consumed bit
ES	ETSI Standard
ETSI	European Telecommunications Standards Institute
FEC	forward error correction
GB	gigabyte
Gbps	gigabits per second
hr	hour

HVAC	heating, ventilation, and air conditioning
i.e.	that is (id est)
IT	information technology
KPI	key performance indicator
kV	kilovolt
kVA	kilovolt ampere
KVM	keyboard-video-mouse
kWh	kilowatt hour
kW	kilowatt
Mbps	megabits per second
MHz	megahertz
MPEG	Moving Picture Experts Group
MSO	multiple system operator
MW	megawatt
PC	personal computer
PDU	power distribution unit
PUE	power usage effectiveness
RDU	rack distribution unit
SCTE	Society of Cable Telecommunications Engineers
STS	static transfer switch
TB	terabyte
TGG	The Green Grid
TS	transport stream
UPS	uninterruptible power supply
V	volt

5.2. Definitions

access network	Utilized to transport information between a service provider and a plurality of users. Includes all active and passive equipment between the headend or hub and the demarcation point at the user premises.
core facility	Structures responsible for backbone traffic and edge to edge connectivity of services to large pools of customers
critical facility	Any structure that if non-functional, impacts customer experience and would generate greater than 250 calls to call centers
critical load	Equipment, if turned off or not operable, greatly impacting customer experience
customer	Invoiced/complimentary consumer of network service(s)
DC power plant	Batteries, rectifiers, charge controllers, power bays, primary and secondary distribution equipment (BDFB/fuses), converters and inverters supporting load.
downstream	Information flowing from the hub to the user
edge facility	Structures servicing neighborhoods where an outage would be contained to a specific pool of customers and not impact greater customer base
meter	Equipment able to measure amount of energy in kWh or power in kW consumed over time

metric	Mathematical calculation aiding in the intelligent decision making process
outside plant	Outside plant refers to all of the physical cabling and supporting passives (including cables, connectors, taps, cabinets, poles) and actives (including fiber nodes, remote PHY devices, remote MAC-PHY devices, amplifiers, line extenders) located between a demarcation point in a head-end or hub facility and a demarcation point in a customer premises.
people space	Building whose primary function is to enable people to perform activities such as meetings, calls, computer work, and all other non-critical facility activities
power distribution	Moving of power in a controlled manner from utility service entry to load
uninterruptable power supply (UPS)	Power protection device helping to prevent equipment power down during primary source of power failure
upstream	Information flowing from the user to the hub

6. Overview

6.1. Energy Productivity Metric (Energy Per Consumed Bit - EPCB)

The development of productivity metrics for facilities has been taken up by other forums. TGG [i6] has developed a framework approach to productivity called data center energy productivity (DCeP). DCeP is an equation that quantifies useful work that a data center produces based on the amount of energy it consumes. “Useful work” is a sum of tasks that are completed in a specified period of time. DCeP allows each user to define useful work and the weighting for various forms of useful work (if measuring more than one type) that apply to that user’s business. For example, a retail business *may* use the number of sales as its measure for useful work, an online search company *may* use the number of searches completed, and so on. The definitions can get as granular as necessary for the entity using the equation: web pages served, database transactions executed, emails served, etc.

In keeping with TGG approach outlined previously of leaving it to the users to define what “useful work” is, either useful work shall be consumed bitrate or consumed bytes. The resulting metric, to be detailed in the sections following, is “Energy per consumed byte,” or EBCB.

6.2. Energy Efficiency Metric (Power Usage Effectiveness - PUE)

Metrics can help operators better understand and improve the energy efficiency of their existing critical facilities. The PUE metric provides a useful tool for evaluating and measuring the energy usage and efficiency of the infrastructure equipment that supports the IT equipment within a critical facility. SCTE 184 [i1] specifically mentions PUE as a metric operators track for critical facilities. Operators can use PUE results to address and reduce the energy usage related to the supporting infrastructure within their critical facilities.

Mathematically, PUE can be used to illustrate a data center’s energy allocation. A PUE of 3.0 indicates that the critical facility’s total-energy usage is three times greater than the energy usage for the IT equipment alone. Or alternatively, that $1/3^{rd}$ of the facility energy is used for the IT equipment, and $2/3^{rd}$ of the energy is used for items in the facility other than that IT equipment providing service. PUE is a number that is always greater than 1, and the closer to 1, the more energy efficient the critical facility.

PUE as a metric has been measured and reported by a number of different data center and critical facility owners across the world over the years. In general, best in class data centers perform with PUE <1.5 and approaching 1.15-1.2. Typical data center/critical facility PUE performance is in the 1.8-1.9 range [i5].

PUE as a metric is best applied when looking at trends in an individual facility over time and measuring the effects of different design and operational decisions within a specific facility. Assuming consistency in the measurement of PUE with-in their own company, operators can use PUE measurements from the facilities with-in their own footprint to compare facilities for the purpose of targeting investment in energy efficiency properly. PUE *should not* be used to compare facilities across operator, or to compare to facilities of companies in other industries, as such comparisons are meaningless and potentially misleading and harmful.

7. EPCB Methodology

7.1. Facility Energy Definition

Critical facilities are responsible for the housing of the equipment required to deliver the products to the cable subscribers. Equipment is typically staged in racks. Equipment requires proper power, airflow management, and backup power to support everyday operations. Total critical facility energy is defined as the energy dedicated solely to the facility (e.g., the energy measured at the utility meter of a dedicated facility or at the meter for a facility or equipment room in a mixed-use facility). Total facility energy includes all IT equipment energy, plus everything that supports the IT equipment-using energy, such as the following:

- Power-delivery components, including UPS systems, switchgear, generators, power-distribution units (PDUs), batteries, and distribution losses external to the IT equipment
- Cooling system components, such as chillers, cooling towers, pumps, computer room air-handling units (CRAHs), computer room air-conditioning units (CRACs), and direct expansion air-handler (DX) units
- Other miscellaneous component loads, such as data center lighting

7.2. Determining Total Facility Energy

ISO/IEC 30134-2 2016 provides methodology and guidance for measuring. Facility energy shall be determined using ISO/IWC 30134-2, specifically section 6.1.

7.3. Critical Facility Data Throughput

The purpose of the critical facility is to house equipment used to transport and manipulate information as it transits the network to and from subscribers. In general, this information consists of video, voice, and data. For most of the history of television, the video content was carried as analog modulated radio frequency (RF) signals. However, most of the video transiting the facility today is carried as digitally modulated signals that contain video information. All of the voice and data in the network is also carried as digitally modulated signals.

The equipment in the critical facility is deployed to service the cable subscriber (customer). The IT equipment in critical facilities supplies those customers with services, services which are composed of digital bits that transit the critical facility. As such, in the context of energy metrics, the sending and receiving of digital bits is considered a fundamental work output of a critical facility.

7.3.1. Definition of Consumed Bit

The concept of consumed bit has been introduced for cable access networks in the document SCTE 211 2015 [i3]. In that document, consumed bits in an access network were summed to determine total bits delivered over a period of time.

For the purpose of critical facility energy metrics, a consumed bit customers ***shall*** be defined as follows

- In the downstream, all bits leaving the critical facility and transported to subscribers are considered consumed bits.
    - All data or telephony bits delivered to a user or device are defined as consumed.
    - All video on demand or switched video bits are defined as consumed.
    - Because of its size and scale, it is assumed that for a critical facility, all linear broadcast bits transported to customers in the access network from the critical facility are consumed.
    - Linear broadcast MPEG transport streams utilizing a full 6 MHz channel shall be defined to have a bit rate of 42.88 Mbps (approximately 38 Mbps payload + overhead), consistent with 256-QAM transport on the channel. *Should* other QAM types be used, operators *should* make adjustment to the bitrate accordingly. Consult [3] for examples on how this can be done.
    - With respect to linear broadcast analog channels emanating from the critical facility, any analog video channel being carried ***shall*** be defined to have an equivalent bitrate of 3 Mbps in the downstream direction from the facility to all subscribers. All bits from analog channels broadcast from a facility ***shall*** be considered consumed.
- In the upstream, all bits coming into the facility from subscribers are defined as consumed.
- Data overhead bits such as bits used in packet headers are considered to be consumed bits, because they are part of the information that is delivered to the user or device.
- Forward error correction (FEC) bits or other bits added to the data stream which are used to enable transmission across the access network ***shall not*** be considered to be consumed since the information is not delivered to the user or device.
- In addition to bits that transit the facility to and from customers, all bits which ingress and egress the facility via backbone network are also counted as consumed bits.

7.4. Determining Consumed Bits/Bytes

7.4.1. Consumed Bitrate

Measurement of consumed bits typically does not occur in the field at the bit or byte level directly. Instead, measurement devices typically measure the transport of bits as a consumed bitrate. For the purposes of determining consumed bits for a critical facility, the consumed bitrate ***shall*** be defined as the rate of consumed bits per second, C_{BR}.

7.4.2. Consumed Bytes

As opposed a bit rate, which measures a rate of transport of bits in and out of a critical facility, certain metrics require measurement of an absolute number of bytes transported over a period of time. For this, the concept of consumed bytes (CB) is introduced. To calculate consumed bytes, C_{BR} must be multiplied by the amount of time ΔT in seconds, and divided by 8 (as there are assumed to be eight bits per byte). Mathematically, this is shown in Equation 1.

$$\boldsymbol{C_{BYTE} = C_{BR} * \frac{\Delta t_c}{8}}$$ **Equation 1**

where
C_{BYTE}= consumed bytes

C_{BR} = consumed bitrate in bits/second

Δt_c = time in seconds

As C_{BYTE} is a function of C_{BR}, there is no separate measurement of C_{BYTE}. Measurement of C_{BR} is performed as indicated in Section 7.4.3. C_{BYTE} is calculated per Equation 1 from that measurement.

7.4.3. Measurement of Consumed Bit Rate in a Critical Facility

To measure the total number of bits consumed in a critical facility, operators must sum up all the different consumed bitrates of traffic which go to and from subscribers, as well as the consumed bitrates of traffic which enter and leave the facility as part on the backbone network. Two types of sources exist in the facility, variable and fixed bitrate sources. Variable bitrate sources vary in time based on subscriber demand. Typical points in the network where measurement of consumed bitrates for variable sources can be taken include:

- CMTSs
- Edge and core routers
- Switches

As the consumed bitrate for each of these sources by definition varies over time, for variable source of traffic in the facility, the average value of C_{BR} over a period of time ***shall*** be used as the consumed bitrate C_{BR} in metric calculations. The amount of time C_{BR} is averaged over for the bitrate streams *should* be consistent with the timeframe associated with metric frequency and/or frequency of other data in the metric (e.g., if metric is bytes/watt, and the energy information is calculated across a month, then the consumed bitrate for variable sources *should* be averaged across the month). Additionally, if within any of the source bitrate streams duplicate bits are transported over redundant links for reliability purposes, they *should* also be counted as consumed bits for the purposes of this calculation.

Fixed consumed bitrate sources, such as those that emanate from broadcast services, *should* use the assumed consumed bitrate as detailed in Section 7.3.1. for C_{BR} for those source streams.
To determine C_{BR} for a critical facility, operators ***shall*** sum all individual C_{BR} measurements for the facility. Mathematically, this is summarized in equation below:

$$\textbf{Total Facility } C_{BR} = \sum_1^n C_{BR(n)} \qquad \textbf{Equation 2}$$

where
$C_{BR(n)}$= Consumed bitrate for the nth stream in the facility

n = number of consumed bitrate streams in the facility

7.5. Measurement Example: Calculating C_{BR} and C_{BYTE} for a Critical Facility

Assumptions:

Monthly average measured bit rate into facility: 3.1 Gbps
Monthly average measured bitrate out of facility: 39.6 Gbps
Digital broadcast TS: 73
Analog channels: 0

$From\ Equation\ 2, C_{BR}$ for the facility would be:

$$\boldsymbol{Total\ Facility\ C_{BR} = \sum_{1}^{n} C_{BR(n)}}$$

$$Total\ Facility\ C_{BR} = 3.1\ Gbps + 39.3\ Gbps + ((73 * 42.88) Mbps * \frac{1\ Gbps}{1000\ Mbps})$$

$$Total\ Facility\ C_{BR} = 3.1\ Gbps + 39.3\ Gbps + 3.1\ Gbps$$

$$\boldsymbol{Total\ Facility\ C_{BR} = 45.5\ Gbps\ (\text{averaged across the month})}$$

Knowing C_{BR}, C_{BYTE} can then be calculated across the month from Equation 6

$$\boldsymbol{C_{BYTE} = C_{BR} * \frac{\Delta t_c}{8}}$$

$$C_{BYTE} = 45.5\ Gbps * \frac{1\ Byte}{8\ Bits} * \frac{60 * 60 * 24 * 30\ sec}{Month}$$

$$C_{BYTE} = 45.5\ Gbps * \frac{1\ Byte}{8\ Bits} * \frac{60 * 60 * 24 * 30\ sec}{Month}$$

$$C_{BYTE} = 14{,}742{,}000\ GB\ transported\ in\ the\ month$$

OR

$$C_{BYTE} = 14{,}742\ TB\ transported\ in\ the\ month$$

OR

$$\boldsymbol{C_{BYTE} = 14.7\ PB\ transported\ in\ the\ month}$$

7.6. Calculating EPCB

As noted in Section 6., data throughput coming into and leaving a facility is fundamental indicator of work performed by the facility. In fact, as all services provided from the facility are digital in nature, with amount of work performed by the facility directly related to the bits transiting to and from customers and the facility, a DCeP based metric utilizing data throughput of the facility to/from customers would be considered a high quality indicator as to the productivity of the energy used in a facility.

7.6.1. EPCB Definition

For the purpose of individual operator site performance comparisons and evaluation, an operator can calculate a power to data throughput metric by the following formula:

$$\boldsymbol{EPCB = \frac{Total\ Critical\ Facility\ Data\ Thruput}{Total\ Critical\ Facility\ Energy}}$$

It *should* be noted that this metric is the inverse of the DCeP metric as defined in [i6], with energy in the numerator, and work product in the form of throughput in the denominator. This flip of numerator and denominator has quantitative impact on the metric itself, but allows the metric to be consistent in units with the Energy per consumed byte metric as defined in [i2].

In mathematical terms, this is

$$\boldsymbol{EPCB_{FAC}} = \frac{\boldsymbol{E_{TF}}}{\boldsymbol{C_{BYTE}}} \qquad \textbf{Equation 3}$$

where
$EPCB_{FAC} = energy\ per\ consumed\ byte$

C_{BYTE} = consumed bytes in TB (as defined in Section 0.)

E_{TF} = total facility energy in kWh in time period

It *should* be noted that for this metric, the timeframe Δt_pused to calculate P_{TF} as per Equation 3 in this section MUST equal the timeframe Δt_c used to calculate C_{BYTE} as per Equation 1 in Section 7.4.2.

A sample calculation of $EPCB_{FAC}$ using the assumptions from previous sections is shown below
Assumptions:
Total Facility $C_{BR} = 45.5\ Gbps$ (as per example in Section 7.5.)
Critical Energy Usage: 114,398 kWh (from utility bill)
Billing Days in the Month: 33 (from utility bill)

To calculate $EPCB_{FAC}$, one must calculate its two component parts, C_{BYTE} and P_{TF}. Starting with C_{BYTE}, using Equation 1 to convert to C_{BR} to Bytes,

$$C_{BYTE} = C_{BR} * \frac{\Delta t_c}{8}$$

For the metric, Δt_c must equal Δt_p. As per assumptions, Δt_p = 33 days, Δt_c must also equal 33 days, converted to seconds. As such, calculation becomes

$$C_{BYTE} = 45.5\ Gbps * \frac{1\ Byte}{8\ Bits} * \frac{60\ sec}{minute} * \frac{60\ min}{hour} * \frac{24\ hrs}{Day} * 33\ Days$$

$$C_{BYTE} = 16{,}216{,}200\ GB\ transported\ in\ the\ billing\ period$$

OR

$$C_{BYTE} = 16{,}216\ TB\ transported\ in\ the\ billing\ period$$

From the assumptions

$$E_{TF} = kWh\ in\ the\ period\ \Delta t_c = 114{,}398\ kWh$$

Therefore:

$$\boldsymbol{ECBS_{FAC}} = \frac{\boldsymbol{E_{TF}}}{\boldsymbol{C_{BYTE}}} = \frac{\mathbf{114,398}}{\mathbf{16,216}} = \mathbf{7.1}\ \boldsymbol{kWh/TB}$$

8. Critical Facility Efficiency Metric - PUE

8.1. Definition of PUE

PUE is defined in ISO/IEC 30134-2 Section 5 as the ratio of total critical facility energy to IT equipment energy.

8.2. Measurement of PUE

PUE ***shall*** be measured as defined in ISO/IEC 30134-2 Section 6.

8.3. Use of PUE

Much has been written about the use of the PUE metric in helping operators to improve critical facility energy efficiency. TGG, in particular, has written extensively on use of PUE for such purposes as noted in [i3] and [i4]. As with any metric, PUE is only useful if it is properly used. The PUE metric is associated with the critical facility infrastructure. PUE is not a data center productivity (DCeP) metric, nor is it a stand-alone, comprehensive efficiency metric. PUE measures the relationship between the total facility energy consumed and the IT equipment energy consumed. When viewed in the proper context, PUE provides strong guidance for and useful insight into the design of efficient power and cooling infrastructure architectures, the deployment of equipment within those architectures, and the day-to-day operation of that equipment.

Proper use of PUE to improve energy efficiency in a critical facility is accomplished through a process of measurement of the metric performed for each facility. This includes:

- Taking initial snapshot PUE measurement of all critical facilities in an operator's geographic footprint. Whilst not constituting a full baseline PUE profile, an initial snapshot PUE can identify obvious outliers with respect to energy efficiency, for immediate attention.
- Creating an initial baseline profile of a facility with respect to PUE. For a critical facility, it is RECOMMENDED that a critical facility baseline be created using a full years' worth of PUE measurements, so that facility variations due to weather/environment can be included in the baseline. Such data can aid operators in targeting energy efficiency improvement appropriately to critical facilities
- Continuing measurement of PUE as energy efficiency improvements are implemented, so that the impact of those improvements can be judged against the baseline.
- Continuing measurement of PUE also allows operators to quickly see anomalies in energy efficiency that might occur, and to deal with them quickly.

In segmented facilities that have multiple data halls, use of partial PUE could be leveraged to help identify areas in the building to target for efficiency projects. This enables the operator to measure portions (data halls) of the facility vs. the overall structure energy performance in large scale environments.

9. Using PUE and DCeP together to characterize facilities

In its whitepaper "Harmonizing Global Metrics for Data Center Energy Efficiency" [i6], TGG specifically identifies PUE and DCeP as important metrics for characterizing critical facility performance with respect to energy efficiency, and recommends characterization of data centers using these two metrics.

As noted previously, the two metrics provide different but complementary information with respect to the performance of the facility. PUE as a metric specifically focuses on the efficiency of the facility itself. It is a measure how energy efficient the facility is with respect to maintaining the environment the IT equipment uses to produce capabilities and service needs of the business. DCeP, on the other hand, focuses on how efficiently the energy is used to produce the capabilities and service needs of the business.

Improvements in PUE generally manifest themselves in making HVAC and other support systems in the facility more energy efficient. Improvements in DCeP come from making the energy used better at producing real work output from the facility per unit energy.

One can characterize facilities by plotting these two metrics for facilities a quadrant grid. As shown in Figure 2 below, using operator target PUE and DCeP to set the center points on the graph for splitting into quadrants.

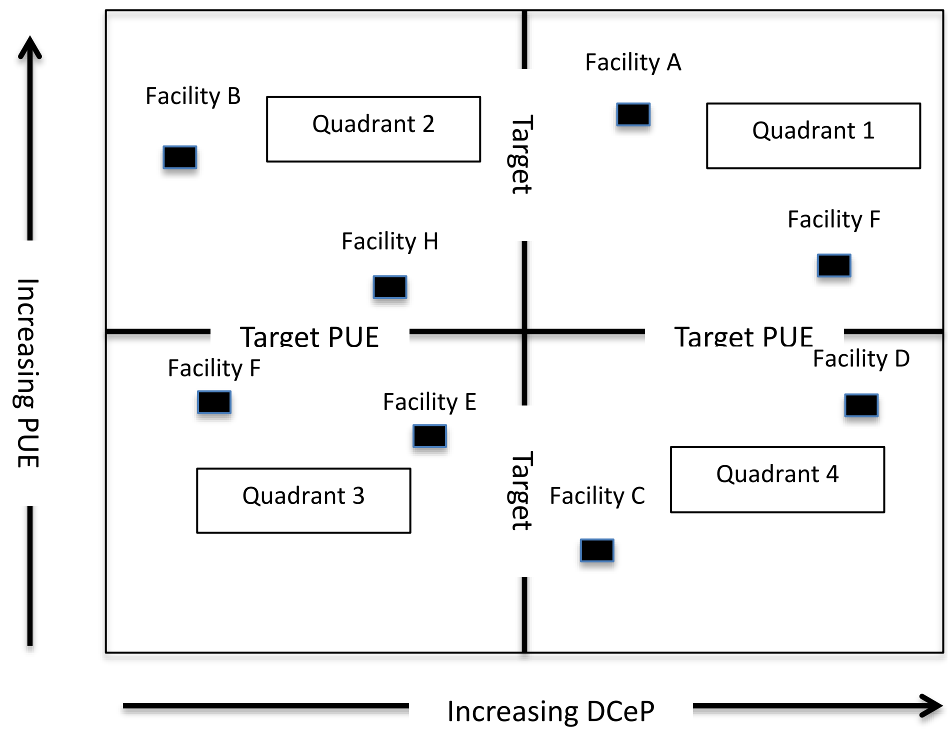

Figure 1 - PUE vs DCeP Quadrant Grid

Placement of the facilities in this grid based on their performance in these two metrics allows an operator to quickly characterize facilities with respect to energy efficiency and energy productivity. Facilities landing in the lower right-hand quadrant (quadrant 4) are better than target in both metrics – these facilities are the operators best in class with respect to energy performance. These are facilities from which best practices for facility operation *should* be taken. And if consolidation in the area around these facilities is to be done, from an energy perspective, these are the facilities that *should* be consolidated into, not consolidated away.

Facilities landing in quadrant 1 are making productive use of the energy, but are not efficient as facilities themselves. Depending on how poor the PUE is, operators would want to look at facilities in this quadrant for potential energy efficiency/HVAC/cooling improvements first over other facilities, as doing that could potentially move them in the direction of quadrant 4 and best practice. Facilities in quadrant 3 are performing efficiently as facilities, but are not productive. As they are efficient, facilities in this quadrant *may* be candidates for being consolidated into, as in theory they have available capacity for adding work units to better use the energy that is there. But the low PUE means that any power added to support the new work units would be added efficiently.

Facilities in quadrant 2 represent an operator's worst performers. Not only are they energy inefficient in their ability to create the proper environment for the IT equipment, the energy they are using is not productive. From purely an energy efficiency and productivity perspective, facilities in this quadrant *should* be looked at first for potential consolidation and/or elimination. Failing that, these are the facilities where presumably the most opportunity exists for improvement work. Characterizing facilities in this manner gives operators the ability to quickly and easily categorize and track facilities with respect to energy performance, as well as to integrate energy performance into the equations used to determine facility consolidation as well as facility improvement projects.