Critical Facility Metrics – Data Center Energy Productivity (DCeP) in a Cable MSO World

A Technical Paper prepared for the Society of Cable Telecommunications Engineers
By

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Overview

You can't manage what you don't measure. With respect to energy efficiency in critical infrastructure facilities, operators are searching for "what to measure." Specifically, operators are looking for:

- The best metric and/or set of energy efficiency metrics to compare and rank facilities.
- How those rankings can be used to prioritize facilities for potential abatement opportunity.

Power Usage Effectiveness (PUE) is a facility standard for measuring energy efficiency that many in the datacenter industry understand and use as a metric for benchmarking energy efficiency performance. SCTE 184 "Recommended Practices for Cable Facilities" recommends that operators regularly measure and actively work to reduce (optimize) PUE in critical facilities as good energy efficiency practice.

But PUE as a metric and comparison tool has limits. In particular, PUE provides no indication on the relative productivity of the IT load with respect to the energy it uses. Although certainly still worth measuring and reporting, PUE may not by itself be the best metric for determining relative energy efficiency for critical facilities, nor prioritizing those facilities for improvement.

This paper explores the use of energy productivity measures specifically as they relate to CATV critical facilities. The Green Grid recently proposed a measure, Data Center Energy Productivity (DCeP), which quantifies useful work that a data center produces based on the amount of energy it consumes, but leaves for each industry/organization to determine what constitutes work in facilities to make the metrics more applicable. The paper outlines DCeP metrics focused on energy productivity specific to the cable industry's critical facilities. Additionally, the paper addresses how SMS-003 APSIS™ and SMS-004 Energy Benchmarks and Metrics (active SCTE standards projects) tie into the DCeP metric.

The author would like to acknowledge the contribution of Kendall Whitney, former Broadband Product Specialist at Alpha Technologies. Kendall provided important research and support in the initial work associated with development of this before, before his move from Alpha in May 2014.

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1 Introduction

It takes electrical power for Cable Television Multi-system Operators (MSOs) to build and deliver services to their customers. To power the outside plant (OSP) network of nodes and amplifiers, industry uses distributed power supplies connected to the electrical grid. These connections largely mirror in size a typical grid connection to a residential home. It is estimated there are currently greater than 500,000 of these distributed grid connections for outside plant power across North American cable television networks.

To power critical facility hubs and head-end equipment space where the all important voice, data, and video hardware is located for those services, the industry uses larger commercial grade power connections from the grid. These are typically in the mid to high 10s of kWs in requirement. There are roughly 10,000 of these types of facilities in North American cable television (hubs and head-ends). Power is also required for the non-critical facility people space which MSOs use to house staff, warehouse equipment, etc. This power is similarly connected to the grid using standard commercial connections. Operators have fewer of these than critical facilities, with power requirements in these sites generally lower than at critical facility locations.

According to Coppervale estimates, electricity usage by North American Cable Television Operators totals 10 GWhr annually, costing operators greater than $1 Billion per year. Typical split of electricity usage across the industry is detailed in chart below

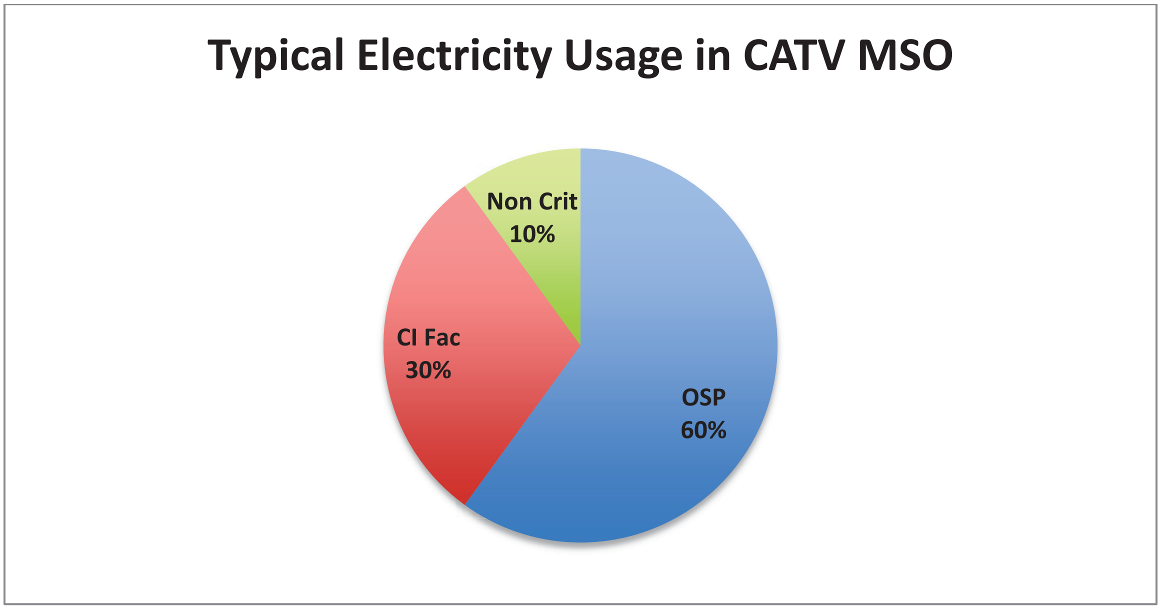

Figure 1 - Typical Electricity Usage in CATV MSO

1.1 Growth in Energy Usage

Even though this energy profile seems tilted today towards outside plant, year-on-year it is changing. OSP energy has been reasonably stable since the completion of the industry's upgrade phase a decade or so ago. As with other parts of the business, OSP energy is impacted by industry developments in services and capabilities including:

- continuing node splits and movement of fiber closer to customers. In the field, this tends to trade out actives for optics. Power impact of this movement from 500 homes passed N+6 architecture to a 30 homes passed N+0 architecture is estimated increase in power of about 20%[1]. Operators still are in the early days of this transition, so that increase is accruing slowly.
- addition of Wi-Fi capability to the distribution network, which by some estimates more than doubles OSP power if full ubiquitous Wi-Fi in residential areas is built[1]. But the depth of Wi-Fi deployment is still un-known, and Wi-Fi deployment is a multi-year process spread out over the next 2-5 years. Again, power increase from this is happening, but slowly.
- evolution of new equipment (Nodes, Amplifiers, Power Supplies) becoming more energy efficient then previous versions. As upgrade and attrition replaces devices, this helps off-set increases in other areas.

Although MSOs need to still actively manage and drive energy needs in OSP lower through programs like APSIS, OSP power needs on the whole have been fairly stable over the last decade, and look set to continue to stay stable and/or with-in a manageable growth rate going forward.

Over the last decade, though, the power profile in critical infrastructure (CI) facilities has been changing. According to industry executives, data usage has been increasing over the last decade in the range of 40-50% per year, as correlated to Operators growing subscriber base, increasing data speeds with the use of DOCSIS 3.0, and pushing more interactive and demand oriented video products to the market.

This combination data and service growth has specific impact on critical facilities. Subscriber growth, higher data rates, and development of new services:

- drive more optics in the facility to accommodate node splits and fiber going deeper in the network.
- drive additional CMTSs and supporting data transport hardware.
- push more servers and QAM modulators plus other supporting transport infrastructure into facilities to support these services.
- expand equipment needed to support growing business customer base, particularly in the local hubs those customers are connected to.

The consequence is the energy usage profile of a typical MSO is changing. What may look like a 60/40 split between OSP/facilities today, with current trajectories may be

50/50 in the next year or two; ultimately tilting towards CI energy being the greater energy contributor over time.

Although cable operators are becoming more aware and doing significant work to try and reduce electricity usage, available data indicates it is still going up on a year-on-year basis. As an example, Belgian Operator Telenet in its 2013 sustainability report discusses significant efforts they are making in the areas of energy efficiency and conservation in their facilities. But even with these efforts, their total electricity usage increased over 10% in a 2-year period from 2011 to 2013[2]. This is not because they are doing a poor job in this area – they have significant focus on reducing electricity consumption, and in fact metrics show they are improving energy efficiency. This is because service and data growth is driving electricity needs faster then they can offset with their conservation and abatement efforts. And with studies showing that there is no expectation growth in data hunger from subscribers slowing anytime soon, this growth in CI facility electricity need is expected to continue into the foreseeable future, even as companies continue to work to offset it through renewal and replacement of existing equipment with more efficient devices .

1.2 Why is this Important?

It is fair to say that electricity usage and power costs have seldom been a focus of operators as usage and costs frequently took back seat to capacity and performance. As noted, electricity is a requirement for development of the network and services on it – operators can't live without it. But because electricity bills are distributed across a variety of cost centers in companies, and generally haven't in the past added up to be a significant expense or business issue, the only "focus" afforded electricity in the network is the focus to make sure the bills are paid each month so the network stays up and working. Operators don't generally track any other metrics related to electricity usage or electricity efficiency in their business KPIs. Power is a necessary expense companies in general pay with little or no question.

Operators might have been able to continue to manage electricity usage in this manner going forward, except the increasing electricity demand profile driven by data growth comes at a time when cost of electricity is increasing. Additionally, in some cases lack of access to the amounts of electricity required from the grid to power these locations could affect subscriber and service growth in future. Many of the critical facilities in the industry were set up and sized 20+ years ago for arguably a different business, not intended to handle the amount of equipment being deployed, along with the electricity to power it. As such, the industry is facing real issues in continuing to grow these locations, as well as potential issues with the grids' ability to provide the power needed to meet that growth in a timely and cost effective manner.

So the industry has reached the point where paying more attention to growing electricity requirements in critical facilities makes sense not only because it is becoming an increasing cost to the business, but also because it has the potential to hinder growth going forward if there is not a way to meet future service and data growth with-in a reasonable electricity footprint. As John Schanz of Comcast noted in the 26 June 2014

SCTE Press Release on Energy 2020 Program, *"Ensuring both the availability and the efficient use of energy for cable's needs are operational and financial imperatives".* How will cable operators deliver value to their customers given energy constraints?

1.3 What Next – Where to Start?

Ensuring availability and efficient use of energy is a big task – so the question is where to start? Improving energy efficiency is no different than any other process improvement the cable industry has sought for its business. The industry knows from the management world that once the commitment to improve and/or do better has been made, the next questions that need to be answered are:

- Do better than what?
- How to measure progress?

Process improvements require relevant metrics measured and quantified on a periodic basis. Quantitative metrics allow the ability to create starting point benchmarks, develop targets, and measure progress against those benchmarks towards targets over time. In other operational areas, the cable industry has used metrics and KPIs to do this. When the industry wanted to understand and improve technical network performance, metrics derived from fault data showing network availability were used. Improvement in customer service drove metrics around call answering efficiency and MTTR.

To effectively attack the issue of making CI facilities more energy efficient, the industry must find a way to quantify energy performance in these locations. Gathering of important energy related data from facilities on a real-time and/or periodic basis is an important part of doing this. Additionally, creation and tracking of appropriate energy related metrics are equally important in determining energy efficiency and finding real issues before they become problematic to the business and/or expensive to remedy.

2 Energy Metrics for Data Centers

With respect to energy efficiency, the cable industry has made a start in determining metrics for operators to use for critical facilities. In its document "SCTE Energy Management Recommended Practices for Cable Facilities", published in 2012 as SCTE 184[3], SCTE suggests best practices operators should consider for their CI facility base. With the respect to metrics for measuring energy efficiency, SCTE 184 references work done by the Green Grid. The Green Grid is an industry consortium organized specifically to develop and harmonize energy efficiency metrics. Its mission is "to become the global authority on resource efficiency in information technology and data centers", and in attempting to fulfill its mission, it has published a number of documents and standards related to energy and energy efficiency in data centers.

Recently, the Green Grid completed work on updated recommendations for datacenter metrics. This recommendation was developed and agreed by an on-going taskforce sponsored by the group over the last three years specifically focused on metrics for Data Centers. The goal of this taskforce, taken directly from Green Grid literature[4], was

Share global lessons and practices with an objective of arriving at a set of metrics, indices, and measurement protocols that can be formally endorsed or adopted by each participant organization to improve data center energy efficiency and GHG emissions globally. This objective includes the following specific goals:

1. Identify an initial set of metrics.
2. Define each metric.
3. Define the process for measurement of each metric.
4. Establish an ongoing dialog for the development of additional metrics.

In its recommendation, the taskforce put forth a beginning set of initial metrics for data centers the group recommends should be tracked. These metrics were

- Power Usage Effectiveness (PUE), the measure of total data center energy divided by just the energy needed to power the IT equipment in the data center
- Green Energy Coefficient (GEC), the portion of the facility's energy that comes from Green sources
- Energy Reuse Factor (ERF), the portion of energy that is exported for reuse outside the facility
- Carbon Utilization Effectiveness (CUE), the total carbon of the facility divided by the carbon just for the IT equipment. In essence, the carbon equivalent of PUE
- Data Center Energy Productivity (DCeP), the ratio of work performed by the energy, divided by the total amount of facility energy

SCTE 184 provides details on PUE, as well as recommending that operators "determine site PUE and strive to lower it by eliminating energy waste due to poor and less efficient power distribution and cooling". SCTE 184 also mentions CUE in its section on "Future Planning", as well as discussing a DCeP like metric for carbon intensity in the same section.

In a perfect world, operators would be in a position to report and track these metrics across their own CI facility footprints, but given the industry is really starting today from ground zero (particularly with respect to head end (HE) and Hub facilities), and the fact that the industry issues with energy today are related more to managing growth of electricity requirements in facilities, the continued focus of this paper will be on the metrics of PUE and DCeP as initial metrics for operators, as they relate directly and specifically to electricity usage. GEC, ERF, and CUE in and of themselves are important metrics operators should think about in future, as positive performance in these areas has potential to bring benefit in a number of ways. However, given the growing electricity footprint in CI facilities, the greatest immediate benefits would come from understanding and improving performance in relation to PUE and DCeP.

2.1 Collecting Facility Data – The Starting Point for Metrics

SCTE 184 identifies best practices for operators to track and manage key information related to the facility itself in its chapter on Environmental Monitoring and Building Management. This provides good direction as to how operators might look to monitor and manage all their facilities; before beginning the process of developing and quantifying any metrics, characterization of all the facilities should be documented. Success of this activity will hinge on the having the basic facility data for ***ALL*** facilities (including HEs and Hubs) easily available in a ***CENTRAL LOCATION*** and kept ***UP TO DATE***. If as an operator, that the information is available today, then that is a great start; else, it is time to get begin that exercise.

Some of these items are included in SCTE 184, and although certainly not an exhaustive list, (and more is better) the information to be contained for each facility should include as a minimum:

- Facility name, location (GPS coordinates if possible), and square footage
- Power bill information for the last 12 months on a monthly basis, and the 2 years prior on yearly basis (this should give total CI facility electricity usage each month, in addition to cost. This is helpful in seeing load-factors for facilities, if not tracked already).
- Information as to whether the facility is CI only, or shared with people space, and if shared, are there separate meters and bills. Not knowing this can lead to errors and/or inaccuracies in metric calculations.
- Information as to where facility is fed from on the grid, what is the capacity of that feed, and are there any known limitations associated with growing the feed (if it is not tracked already, % of power used as a percentage of transformer feed capacity is a simple metric to keep ahead of potential growth related issues).
- Power characteristics of the site (i.e. AC/DC, UPS size, Generator Size, etc.).
- Detail on cooling (i.e. A/C in place, free-air cooling used, etc.).

In addition, other characteristics that would be useful to have and track on each facility would be:

- Any renewable and/or off-grid capacity the facility is using (useful for future calculation of Green Grid CUE and GEC).
- Rack/Equipment layout, total racks installed in the facility, plus total rack capacity available (if not tracked already, racks placed as a % of total rack capacity is another simple metric to stay ahead of space issues).
- Equipment detail with-in the racks (potentially helpful for future equipment level DCeP measurements).

As mentioned earlier, before even thinking about looking at metrics for facilities, it is important to have this basic information on each facility in a central location readily available and useable by the operator. With this basic information in place to characterize each facility, an operator can then begin to think about which metrics for energy efficiency make sense, and what additional measurements might be needed to provide those metrics going forward.

2.2 PUE and why it's important

Metrics for critical facility equipment locations are traditionally driven by the computer industry, the likes of E-bay, Google, and Facebook, all of which have need for quite large datacenters to house the immense quantity of servers and storage needed to support their business ventures. These companies are Green Grid members, and have been involved in helping to shape the current Green Grid set of recommendations.

The industry standard metric used today to benchmark and compare large datacenter energy efficiency is Power Usage Effectiveness (PUE) – it is why it is first on the Green Grid's list of metrics for data centers. As the cable industry has a few data centers of its own, and cable industry HEs and hubs may be considered to be similar to data centers (just smaller), PUE is an appropriate metric to look at for cable operator critical infrastructure.

As noted earlier, SCTE 184 "Recommended Practices for Cable Facilities" advocates using PUE as a measurement that can help operators characterize facilities for energy efficiency. Mathematically, PUE is determined by dividing the amount of power entering a datacenter by the power used to run the computer infrastructure (defined as the equipment that is used to manage, process, store, or route data), with a perfect score being a 1, translated as 100% efficiency or all power being used purely for computing activities.

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

Total Facility Power = the power measured at the utility meter — the power dedicated solely to the data site (and not offices). Includes cooling systems and power delivery units.

IT Equipment Power= the load associated with all of the IT equipment, such as compute, storage, and network equipment, along with supplemental equipment such as switches, monitors, and workstations used to monitor the datacenter.

Figure 2 PUE = Power Usage Effectiveness

Though hard to gauge for certain because it does vary around a number of factors, typical PUE for most data sites across various industries is thought to be around 1.8-2.5[5], meaning for every 1.8-2.5 watts of energy entering the facility, 1 watt is used to meet business computing needs.

SCTE 184 discusses the merits of using PUE to quantify energy efficiency in CI facilities; and we see evidence the cable industry is starting the process of measuring PUE, at least for more power hungry data-center locations. Going back to the Belgian Operator Telenet, in its 2013 Sustainability Report, it reported average PUE numbers for its datacenters for both 2012 and 2013, providing an initial benchmark for 2012 along with follow-on comparison from 2013. There is evidence that other operators, although not reporting results publically, are measuring PUE for their datacenters on a regular basis.

There is little evidence, though, that operators are measuring and tracking PUE today for the more numerous and widely spread HE and Hub locations. A desirable next step for operators is to add continuous measurement and tracking of PUE for ALL facilities to the CI facility characterization database, as PUE is an important and useful first metric to use for all CI facilities when trying to achieve an energy efficiency focus.

PUE is generally simple to measure in a facility, requiring power measurements that in many cases are available today manually, or if not available, can be easily obtained. Facility power can be found at a meter or on a power bill for stand-alone facilities. For mixed facilities, if critical and non-critical spaces are not separated, although not perfect, approximations exist based on square footage to allocate CI energy usage split from meters/bills. IT equipment power in many HEs/Hubs can be found by looking at UPS power measurements (AC Powered equipment) and/or rectifier loads (DC powered equipment).

PUE allows managers to get a baseline view of the energy efficiency of the facility itself. Assuming an operator measures PUE in a similar manner across facilities, it also allows for potential comparison of facilities to identify poor performing facilities for potential improvement, as well as good performing facilities that can be studied for best practice. The table below shows an example of facility measurements of PUE.

	Total Power (kW)	IT Power (kW)	PUE
Building 1	29.3	14.6	2.01
Building 2	20.2	8.4	2.40
Building 3	43.0	17.8	2.42
Building 4	34.3	17.4	1.97
Building 5	24.1	12.6	1.91
Building 6	43.0	11.4	3.77
Building 7	66.4	31.9	2.08
Building 8	23.6	12.1	1.95
Building 9	47.4	24.3	1.95
Building 10	61.1	14.0	4.36

Table 1 - Example PUE Measurements

With these two pieces of data and one calculation for each facility, an operator could see very quickly which facilities are performing efficiently from an energy standpoint, and which are challenged. For this example, one can see clearly that Buildings 6 and 10 would be worth a closer look, as PUEs over 3.0 generally are best "low hanging fruit" for paying back work necessary to bring PUE in line with other buildings. Facilities could be ranked in order of efficiency, and calculations could be made as to what potential opportunity for operational savings exist if investment is made in improvements. When improvement projects are completed, continuing to track these measurements would help in proving if the investment provided the benefits expected.

PUE as a metric has its flaws. On the surface, total facility power and total IT power seems relatively straightforward to define. Beware using PUE for PR advantage as lines of definitions can and do get blurred. A common issue centers on equipment/rack fans, which technically should be part of the non-IT power as they provide cooling, but typically get counted as part of IT, as it is just difficult to do otherwise. The inefficiencies of UPS and back-up power add to non-IT power, as well, an issue that impacts the cable and telecoms operators more than others because of the amount of backup typically used in telecom and CATV facilities. Additionally, PUE is not static or snapshot measurement, but varies with time. In many climates, PUEs in summer can be very different from PUE measured in winter, owing to use of less cooling and/or more free cooling. What time of year PUE is reported can and does impact the number.

The fact that PUE has these issues does not make it un-usable in assessing energy efficiency in CI facilities. Operators need to take care that PUE is used consistently and in a productive manner as one of the metrics to fully characterize energy efficiency in a CI facility. In particular, when using PUE as a metric for CI facilities, operators should insure:

- Initial measurements shouldn't be used for benchmarks, but can be used to identify outliers. A snapshot PUE greater than 3 or 4 is going to warrant examination for opportunity even after a full cycle of measurement. In the above table, for example, it is likely that even if the issues above were taken into account, Building 6 and Building 10 would still warrant a close look for efficiency improvements.
- For a fuller and proper benchmark, facilities should be measured over a period of time. In a perfect world, tracking a full year would be recommended, as in theory, that would constitute a full seasonal cycle. (Shorter periods, as long as they cover important weather extremes can work.)
- They standardize what is measured and where measurements are taken across their own facilities. Although this may not completely eliminate discrepancies, it will at least make comparisons more valid in an operator's own footprint.
- PUE as a metric is a tool to improve energy efficiency in own facilities, and so stay focused on using it as such. Don't get caught up in the PR side of comparing facilities across operators, and certainly not across industries. Because the number can vary depending what is measured, when it is measured, etc., an operator's focus should be to use PUE to compare with-in what you control.

3 PUE = Starting Point. But what else?

Although PUE is an important number to help in characterizing a CI facility, it is at the end of the day, one number. No single measure is sufficient to fully characterize a subject as complex as energy efficiency in a critical facility site. As such, PUE by itself does not provide complete characterization of the energy efficiency of a site, no more than peak data throughput by itself characterizes completely the performance of a data service. Other factors are needed to more fully characterize energy efficiency in a CI site – the question is what other factors and metrics?

PUE has helped data site managers identify opportunity to greatly reduce energy usage on the facilities side of the equation. However, working to make facility non-IT infrastructure components, like lights and air conditioning, marginally more efficient, when the driver of data center power consumption is the increasing numbers of servers, CMTSs and QAMs, misses the root cause of data center energy consumption growth. A PUE of 1.1 does not mean much if the facility is not being fully utilized – is not performing useful work and creating value for customers.

3.1 Energy Productivity =Work per Watts ($s)

To achieve efficiency in a system optimized for energy efficiency, the equipment should do the maximum amount of work possible with the minimum amount of electricity. More so than PUE, a measure of energy productivity gets closer to the idea of how much value an MSO is delivering to customers per given amount of energy consumed. Although PUE as a ratio helps characterize efficiency of non-IT load, the question is how do you best characterize the energy productivity of the IT-load? For this purpose, the Green Grid put forth a Data Center Energy Productivity (DCeP), a metric that measures the productivity of the IT load.

Mathematically, DCeP can be expressed as:

$$DCeP = \frac{\text{Useful Work Produced}}{\text{Total Data Center Source Energy Consumed Producing this Work}}$$

Where:

$$\text{Useful Work Produced} = \sum_{i=1}^{M} V_i * U_i(t,T) * T_i$$

M is the number of tasks initiated during the assessment window
Vi is a normalization factor that allows the tasks to be summed numerically
Ti = 1 if task *i* completes during the assessment window, and *Ti* = 0 otherwise
Ui(t,T) is a time-based utility function for each task

t is elapsed time from initiation to completion of the task
T is the absolute time of completion of the task

A fairly complicated equation, but in reality a somewhat simple concept. To simplify the equation, you need to look at it like this

$$DCeP = \frac{\text{Work Units Produced by the Facility}}{\text{Total Energy used in Producing this work (in Watts)}}$$

Notice the DCeP denominator, Total Data Center Source Energy Consumed Producing this Work, is identical to the PUE numerator. Moving towards such a metric requires making only one other measurement, productive work units. The challenge is what constitutes "productive work units" in a telecoms and cable television environment?

Green Grid in its wisdom has not gone any further than to produce the above equation summing all the elements of productive work and dividing it by the power needed to produce it for the metric. The Green Grid says that because "what constitutes work" is very user and industry specific, they leave it to the user to decide. Quoting the Green Grid Appendix on DCeP

> *"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."*

Although the concept of DCeP is still relatively new, there are a few examples where users have put definitions to what constitutes useful work for them, and made the calculation. E-bay is one company that has embraced DCeP and defined it for their company. Useful work for them is number of URL's, and hence they see DCeP as "URL's per kWh". They provide a quarterly measure of the metric on their web-site (http://tech.ebay.com/dashboard). Verizon provides a telecom example – as part of their carbon emissions reporting they have used Terabytes of data on their network as the unit of work, and provided the measure in past Corporate Responsibility reports of their company-wide carbon intensity using Metric Tons of carbon per Terabyte transported[6].

Both of these examples have a common theme – a metric defining the ratio of work and energy, to drive to get a true sense of energy efficiency specific to the business the company is in. It allows them to continually compare performance on a going forward basis over time as they develop their infrastructure, and see if in fact any improvements they are performing are making efficiency better as it relates to the work performed by the energy used. But as opposed to PUE, which tells them about the efficiency of the non-IT parts of their facilities, these measures give them a view as to whether the energy they are using is actually producing more or less work than they have in the past (i.e. more URLs for E-Bay, or more Terabytes for Verizon). As stated earlier, this metric is not meant to replace PUE, but with PUE to help in constructing the total energy efficiency picture of the CI facility infrastructure.

3.2 What Constitutes Useful Work?

The key question is - what does the cable industry see as ***measurable useful work*** done by CI facilities that can be used in this metric? The first point in this is that any metric must really relate to what a cable operator might see as ***"output"*** in the real sense produced by the CI facility. The second key point is that as noted in the opening sentence of this section, the work unit must be ***"measurable".***

Whatever metric the industry and/or an individual operator might choose as unit of work for its DCeP metric, must be the best balance of these two criteria above – truly an ***output*** of the facility, and ***measurable***. The best metric for output is of no use if it cannot be easily measured. Similarly, just because it is easy to measure does not mean it will necessarily help in providing information management can use to drive better efficiency in CI facilities. PUE as a metric is not perfect, as noted earlier, but it has become the industry standards for measuring energy efficiency in CI facilities in many ways because it provides a useful characterization of a facility, and is relatively simple to measure and calculate.

With respect to what works for work output, in simplest terms, one could say the business expects CI facilities and the equipment in them to produce revenue. Companies do use revenue metrics to characterize ***whole company performance*** with respect to energy. Telenet reports a revenue metric in its sustainability reporting, and E-Bay's dashboard has a metric for company-wide revenue per MWh of power. These metrics are fine at the company level, where revenue is routinely calculated and reported; however to characterize an ***individual facility*** per facility revenue, may be difficult and problematic for most companies to measure.

So the challenge is to find an acceptable proxy for total revenue, that is easier to measure and track by facility. As revenue itself is a function of the number of revenue generating units (RGUs) connected to the facility, and RGUs are a function of subscribers connected to the facility, it is possible that one these can be more easily gathered in a facility. Hence it may make sense for an operator to look at a DCeP metric using RGUs and/or subscribers. In carbon work at Coppervale, we have used watts/subscriber as a metric to look at the aggregate facility performance to allow comparison of different regions for the purpose of looking for outliers. We have always thought that watts/subscriber would be a good way to characterize and compare individual facilities, as well. It is not necessarily because we see "subscribers" as the perfect measure of "work units" per se; but back to the start of this section, watts per subscriber seems to balance well being useful, as well as potentially easier to measure for individual facilities. To make this metric match Green Grid's DCeP mathematical convention, the energy term "watts" must be flipped to the denominator of the equation. As this yields a number significantly less than 1, instead of watts, kilowatts (kW) should be used. Therefore the final subscriber work metric would be "subscribers per kW" fed by the facility. This would be defined as

$$Subscribers\ per\ kW\ IT\ (SPkWIT) = \frac{Total\ Subscribers\ Connected\ to\ the\ Facility}{kW\ of\ IT\ power\ used\ by\ the\ Facility}$$

One final point on this – because we are trying to keep the focus of DCeP on improving efficiency of IT power, we would propose use of IT Power as the denominator of DCeP, not the larger total power for the facility. PUE provides ability to identify outliers with respect to overall facility efficiency, and where improvements in cooling, etc. can be best targeted. As DCeP is really a metric about efficiency of IT power, it is right to use that as the denominator for this metric, not the larger total facility power.

For the purpose of example, sample subscriber numbers have been added to the table shown previously with the PUE information on it.

	Total Power (kW)	IT Power (kW)	PUE	Subscribers	Sub/kW IT
Building 1	29.3	14.6	2.01	7853	538
Building 2	20.2	8.4	2.40	3645	434
Building 3	43.0	17.8	2.42	5025	282
Building 4	34.3	17.4	1.97	15134	870
Building 5	24.1	12.6	1.91	2400	190
Building 6	43.0	11.4	3.77	6861	602
Building 7	66.4	31.9	2.08	6510	204
Building 8	23.6	12.1	1.95	2191	181
Building 9	47.4	24.3	1.95	15464	636
Building 10	61.1	14.0	4.36	11695	835

Table 2 - Example Subs/kW IT with PUE

As with PUE, subscriber per kilowatt IT (SPkWIT) also varies. What is important, though, is the different and additional information it provides an operator trying to characterize facilities. Buildings 4 and 9, for instance, have a relatively low PUE and high SPkWIT, and hence would be considered good facilities that appear to be low priority for efficiency opportunities. Buildings 5, 7, and 8 provide examples where the facility itself is functioning well from a PUE perspective, but with low SPkWIT appears under-utilized and/or wasteful with respect to doing productive work. These might be good candidates for equipment and/or facility consolidation if it can be done (or for more subscribers!). As noted earlier, Buildings 6 and 10 are examples of facilities where a

PUE focus makes sense – with high SPkWIT these facilities are using their IT energy efficiently, these facilities just need to improve how they are cooled.

4 Work defined as Bytes – a better way?

SPkWIT is but one method to measure DCeP. We suggest it for operators because it provides a good metric of work performed by the facility, and in theory at least for operators may be simpler to measure. We presume operators have a view as to number of subscribers connected to a facility, or if they don't, might be able to at least adequately estimate it through a number of means. If summing STBs, CM', and eMTAs makes calculating RGUs per facility simpler, then RGUs per kW would provide similar information on the facility. However it is done by operators, a metric which uses some sort of subscriber based number as the unit of work for the facility divided by power is a good addition as a metric to help in characterizing CI facilities.

Whilst this type of metric can be a simpler way to characterize DCeP for a facility, there are views to using one of the more basic things a facility produces for DCeP metric, bytes. As noted earlier, Verizon has in past made a measurement like this, but on a company-wide basis specifically for carbon intensity. In the cable space, Belgian operator Telenet has reported a metric like this for its non-data center CI facilities. Their report sums the information from their 53 Head-end locations, and looks something like this:

Electricity Consumption per Gigabyte in Head Stations (HE Buildings)

Year	**2010**	**2011**	**2012**	**2013**
Annual average in GWh	1079	977	864	801
Percentage reduction over previous year		10%	12%	13%

Table 3 - Telenet Consumption per GB for Head-ends

As can be seen in table, they have reported this DCeP metric for the last 4 years. Although it too is a company wide view looking at annual average, the implication is that measurement is being made of Gigabytes transported by each of the CI facilities themselves. This means in theory, at least, this metric is available on a per facility basis, and would allow for facilities to be compared using this metric.

As Telenet shows in this example, use of a metric like this can make sense and be used by operators to characterize overall energy performance of their CI facility infrastructure. Continuing to improve this metric year on year shows an operator is getting more work from their CI facility infrastructure. The question is, would it be fairly simple to calculate this metric on an individual facility basis, and if that was done, would the information be any different and/or better than using watts/subscriber as a DCeP metric?

To the first question as to simplicity, this is a question operators themselves need to answer. Operators are set up in today's world to have a good sense as to the data thru-put at each facility location. The CMTSs, Edge-QAMs, servers, routers, and transport equipment located at these facilities all provide operators with data thru-put information that could be used for such a metric. We have seen that information can be aggregated to provide companywide total data through CI facilities to make calculations as illustrated in our Telenet model. It seems, then, a simple step for operators to dis-aggregate this data and collect it on a per facility basis to provide bytes transported through that facility on a daily, weekly, or monthly basis. Operators should be able to relatively easily gather and track data thru-put on per facility basis if there is a good reason to do it.

As to the 2nd question, "would it really be worth doing," this centers around whether the differences in subscriber transaction habits create meaningful differences in CI facility electricity usage. The SPkWIT metric makes the assumption all subscribers are the same; in reality, that is not the case. Subscribers differentiate themselves on internet services based on consumption and usage habits, and differentiate in the video world through differences in on-demand transactions they perform.

A byte per watt type DCeP metric captures how the equipment in a facility deals with those differences in relation to energy efficiency. Characterizing individual facilities in this way highlights both energy differences in facilities related to subscriber numbers, AND differences associated with the different levels of data rates and transactions customers connected to those sites might have. Two sites with similar SPkWIT could have different "bytes/watt" measurements owing to the differences in data usage and transaction rates at the sites. Even though the two would have the same SPkWIT measurement, the site with the higher "bytes/watt" measure would be more efficient, as it is truly getting more real work (i.e. "data thru-put") done per unit energy. More investigation could be done to target specific action on facilities with poor "bytes/watt" measurements, to improve throughput per unit of power.

4.1 Bytes/Watt and APSIS™ – a connection?

Characterizing individual facilities using a DCeP metric based on "bytes/watt" would highlight both energy differences in facilities related to subscriber numbers, AND differences associated with the different levels of data rates and transactions customers connected to those sites might have. Two sites with similar SPkWIT could have different "bytes/watt" measurements owing to the differences in data usage and transaction rates at the sites. Even though the two would have the same SPkWIT measurement, the site with the higher "bytes/watt" measure would be more efficient, as it is truly getting more real work (i.e. "data thru-put") done per unit energy.

Why might this additional DCeP metric be important? The SCTE's APSIS ™ (SMS-003) working group is working to define a methodology, working with suppliers to interface equipment in CI facilities, with the intent of allowing operators to run applications over the interface that actively manage energy use and could reduce energy consumption. At the time of writing (July 2014) identification of use cases and applications is still in its very early days for the SMS-003 work, one potential application is to use the interface to power down and/or power off lowly utilized equipment where possible. This metric has the potential, at a facility level, to identify facilities where such an application might be most useful, and target its use to those locations.

One potential use case includes using the situation noted above where the two facilities have similar SPkWIT numbers, but different “bytes/watt” measures. When such a situation arises, in the best case, it highlights for an operator where there might be opportunity to potentially look at taking equipment and/or capacity out of service, as what is there is not working to full potential. Because data usage and transaction rates vary and are time-of-day dependent, equipment is typically sized to meet the old telephone equivalent of a “busy hour”, to insure the majority of customer needs are met during the time resources are in demand the most. This may lead to a situation where even though data and transactions inefficiently fill the resources most of the time, they need to be kept in place as they are needed in the busy hour to meet peak demand. Operators are then forced to run the facility inefficiently to insure customer service needs are maintained. In the case of APSIS™, another option might be available. Using the APSIS™ interface, lowly utilized equipment could be powered down, or even powered off periodically, to reduce electricity load and run the facility more efficiently (think of a dimmer switch example in lighting). APSIS™ also introduces the concept of Traffic Based Energy Control or TBEC, which allows energy to be adjusted based on the activity on the network.

4.2 Digging Further – from Facility to Equipment level

This “bytes/watt” metric characterizes the facility for work in a more specific and detailed way than SPkWIT – an important milestone in allowing operators to better target facilities for abatement opportunity using APSIS™. The cable industry can get smarter and more targeted with energy efficiency by moving to look at the rack and equipment level. SCTE SMS-004 – Energy Metrics and Benchmarking, is working to define equipment density metrics for the individual pieces of equipment in a critical facility. Examples of metrics defined to date include CMTS and E-QAM related metrics around power per downstream, and VOD server metric around power per video stream, to name a few. Whilst the SMS-004 work is aimed at helping operators be able to compare and contrast manufacturers equipment in terms of density and energy efficiency, the fact is that the SMS-004 density metrics could also be used as equipment level DCeP metrics for operators to compare implementation of equipment in CI facilities for energy efficiency.

Digging deeper in this way would allow Operators not just to know which facilities might benefit from APSIS™ apps, but how energy efficient their real implementations of the equipment might be using the SMS-004 metrics as a DCeP like model. For instance, an operator could look at actual implementation of a CMTS and E-QAM and see what it’s power per downstream is, to allow comparison of different CMTS and E-QAM implementations, looking for more and less efficient ones directly at the equipment level.

Current CI facilities and equipment are not set up and/or optimized to gather and/or provide information at this level of granularity. And even if it was, operators more than likely aren't in a position today to look at and/or analyze such data to make full use of it. With the development of SMS-004, the groundwork is being laid for equipment suppliers to incorporate such metrics into the equipment they supply, and for operators to potentially start collecting and using such data. The SMS-004 work provides the "unit of work vs. power" metric to use when comparing implementations in field for operators to better understand how energy efficient they have been in implementing equipment in the field, and where opportunity to improve might lie.

4.3 Facility Energy Dashboard

We have identified a lot of ideas as to how to best quantify, monitor, and manage energy. Ultimately, though, to be useable this data must be organized and presented in a form that leaders and workers in the company can use to drive investment and behavior. To that end, we see development of a ***facility energy dashboard***. A dashboard can start simple, with easy to track metrics on a facility-by-facility basis like:

- Basic facility items such as total power used in a month, power used as % of total facility capacity, % rack space utilization, etc.
- PUE
- SPkWIT

Initially tracking of these metrics would allow operators to stay ahead of potential business impacting issues, as well as the ability to identify outliers and target investment on energy efficiency improvement where most needed. Operators could even develop and use geographic and company-wide KPIs like "% of facilities with PUE < 2.5", or "% of facilities with SPkWIT > 500", if appropriate and helpful in driving company behavior and awareness. An important fact is that tracking is a starting point for getting the data to manage the energy part of the business at the fingertips of those who need it.

Over time, more detail could be added to the facility dashboard related to "bytes/watt" measurements, attempting to peel the onion further and get to next level of detail on facility efficiency. Whilst useful initially, this measure becomes more relevant as APSIS™ is completed and APSIS™ related apps appear. As with SPkWIT, this can be done on a facility-by-facility basis, allowing aggregation of the data by region and company-wide for the purpose of KPIs like "% of facilities with GB/GWHr > 800", if appropriate as an end target.

And finally, with full development of equipment metrics through SMS-004, dashboards at the individual facility level could be added for specific equipment performance. This would allow the ability to identify specific equipment (CMTS, E-QAM, etc.) in the facility running less efficiently. As with "bytes/watt", completion of APSIS™ makes this a more useful and relevant measurement to track on the dashboard. The possibility of SMS-

004 type measuring capability implemented in equipment could simplify reporting of these metrics, making them easier to add into the dashboard. The other metrics, in addition to identifying outliers, allows potential areas for aggregated KPIs around "% of E-QAMs with Downstreams/Watt > X.X", and other equipment type KPIs by region aggregated to company-wide.

Ultimately, it is all about quantifying energy usage and managing it. But you can't manage what you don't monitor and track – an energy dashboard that starts with what is important and easy to do today, and evolves as equipment capabilities and standards in this area develop, is an important strategy for operators to have if they want to insure they can keep energy availability and costs under control for their businesses.

5 Conclusion: A Starting Point

The fact that energy availability and cost in relation to business growth and success has become a part of the discussion going forward at all is an indication operators are starting to at least take seriously the idea that quantifying and managing energy risk. And operator's CI facilities are "ground zero" of this battle, as they continue to grow demand for power in line with service and data growth. To get a handle on CI facility energy, operators need to start by summarizing and track what they have in place. For those operators who haven't already done it, just simply gathering key data and information for each facility, and keeping it up to date, would be a great starting point.

Once an operators' facilities are properly characterized, the next step is to measure and track key metrics. This paper has made the case for PUE as a metric for all facilities, to provide operators a view as to the efficiency of their own facilities. PUE information across all facilities is a good starting point to allow an operator to target capital for energy efficiency where it can make the most sense, and have the shortest payback. Reporting across all facilities would also allow operators to set and track internal PUE targets, like "percentage of facilities with PUE under 2.5" or something similar, to further focus staff efforts on driving energy efficiency. As noted earlier, PUE can be abused as a metric, but a common and defined measurement regime, combined with a sensible target for your own operator business could be helpful in driving an energy efficiency "attitude" into the groups managing CI facilities.

The paper has also made the case for DCeP metrics of "subscriber/watt" and "bytes/watt" to be used over time by operators to provide information how efficient the facility is in producing real work from the energy it uses. In addition to PUE, operators should track today the DCeP metric "subscriber per kW IT power" (SPkWIT) to allow a fuller characterization of the facilities energy performance. With these metrics, facilities can be compared and contrasted to find outliers and low-hanging fruit from an efficiency standpoint to attack for improvement. The metrics can also provide clues as to potential facility consolidation candidates, although certainly factors other than energy involved in making such a move.

Adding a "bytes/watt" DCeP metric can be valuable, as well, in providing a better and deeper understanding of energy productivity, although it is understood that implementing such a metric may be more difficult in some cases. Such a metric might be useful in conjunction with implementation of future APSIS™ capability – it may be that implementation of such a metric can be done in line with APSIS™ evolution. With the evolution and development of SMS-004, new DCeP metrics at the equipment level will become possible and better known. Operators should look at these as appropriate.

In conclusion, the real message to operators is: however you do it, the time is now to start quantifying, measuring, and tracking energy efficiency as it relates to your CI facilities. It is not a hard or complicated thing to do, and as with all other metrics and KPI's the energy uses, can allow you to avoid future pitfalls, manage energy costs, and insure your CI facilities infrastructure is not energy constrained, and can meet the service, cost, and quality needs of the business going forward.

Abbreviations and Acronyms

A/C: Air Conditioning
AC/DC: Alternating Current/Direct Current
CI: Critical Infrastructure
CM: Cable Modem
CMTS: Cable Modem Termination System
CUE: Carbon Utilization Effectiveness
DCeP: Data Center Energy Productivity
EMTA: Embedded Multimedia Terminal Adapter
ERF: Energy Reuse Factor
GEC: Green Energy Coefficient
HE: Head-end
KPI: Key Performance Indicator
kW: Kilowatt
MSO: Multi System Operator
OSP: Outside Plant
PUE: Power Utilization Effectiveness
QAM: Quadrature Amplitude Modulation
RGU: Revenue Generating Unit
SPkWIT: Subscribers per kilowatt IT
STB: Set-top Box

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