Energy 2020 Baseline - Setting the Stage

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

Dr. René Spée

Consultant

Coppervale Enterprises Inc.
3767 Alpha Way, Bellingham, WA 98226
239-628-3470
rspee@coppervale.org

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Executive Summary

Energy 2020 is an ambitious program to curtail and reduce powering requirements and associated costs over the next five years. In order to measure system performance and quantify savings, it is instrumental to establish an accurate baseline. To this extent, the Society of Cable Telecommunications Engineers (SCTE) has developed a document (SCTE 212 2015) standardizing the methodology for facilities and access networks using utility bill information. This paper reviews the standard, outlines a data processing procedure for implementation and presents examples using actual operator utility data. Once established, baseline data can be used to establish metrics and track system performance as illustrated in this paper using practical examples.

1.2. Scope and Background

The SCTE established the Energy 2020 program to limit and ultimately reduce the powering requirements for cable systems. Given that we need to be able to measure what we want to improve, this has led to the establishment of a standard (SCTE 212 2015) to develop an energy and cost baseline. Implementation of this standard is not straightforward given the many permutations in access network utility billing and instrumentation (metered vs. unmetered, status monitored or not, etc.) and the requirement for allocating facility energy to critical vs. non-critical usage.

This paper uses data from audits of cable system utility expenses to illustrate the development of an energy baseline. The data presented was gathered for systems covering all geographic regions in the U.S. and represents an overall footprint of approximately 35 million homes passed. We will outline the basic approach to implementing SCTE 212 2015 in practical terms and then present a detailed example using a representative system of approximately 5 million homes passed. Our approach is to develop individual baselines for limited regions and then roll up the resulting data into an overall baseline. This not only limits the complexity of obtaining and manipulating overly large utility data sets, but it also preserves regional characteristics so that individual areas within an operator's footprint can be compared.

The paper is focused on the generation of the baseline in terms of energy, power and cost. With operator specific information such as data throughput, homes passed or customer count, the baseline data can be used to develop benchmarks and metrics. We will briefly review the technical metrics being introduced by the SCTE and present some secondary metrics, which may prove useful in understanding and improving system performance. Wherever possible with the data we have access to, we will provide practical examples.

Establishing the energy baseline from utility bill data is a daunting task given the large number of bills to be reviewed and processed. However, if the process of baseline development is used to concurrently identify and correct utility errors and overbillings, the result can be financially rewarding. Depending on utility environment and operator accounting practices, we have found systems to be overbilled between 2% and 11%.

Once a baseline is established and a mechanism for periodic updates has been implemented, baseline and metric information can be presented in a dashboard format suitable for technical, operational and financial interests within the cable operator community.

Finally, we will discuss our recent experiences with the cable utility environment and attempt to use the data we have gathered in establishing an estimate for an overall U.S. baseline.

2. Baselining Approach and Metrics

We recommend developing the energy baseline by geographic area, especially for larger operators. The overall, companywide baseline is then a rollup of the individual areas or systems. This will simplify the process, since it limits the size of data sets to be processed at any one time. Moreover, this approach allows for more granularity in evaluating certain areas of the footprint which may have characteristics setting them apart from the average. For example, this allows separate evaluation of high vs. low density systems, systems with different fiber penetration, or systems with a predominantly 60V plant architecture. If an operator has access to a complete national data base of utility bills, the overall baseline can be developed in its entirety and subsequent evaluations can drill down to subsets by e.g. state or zip code tags in the data.

SCTE 212 2015 outlines the requirements for developing the baseline from utility bills. In some instances, baseline information can also be derived by actual periodic measurements. In other cases, measurements are required to augment the utility bill information - for example when analyzing renewable energy installations or when a detailed breakdown of energy usage within a single facility is required.

In practical terms, the actual extraction of energy information from utility bills will depend on the structure of the available information. Some operators use utility bill extraction service companies to download complete billing details on a monthly basis; in this case, establishment of the baseline will be reduced to manipulating data already in electronic form. Other operators receive conventional bills from the utility and only extract the basic financial information required for the accounts payable process. In the latter case, detailed billing information for a twelve month period needs to be acquired from accounting records or from the utility itself. Subsequently, it is necessary to convert the raw data from its native format (e.g. hard copy) into an electronic format suitable for data manipulation; given that accounts will number in the 10,000's, this procedure can be quite resource intensive. Once an annual baseline has been established, ongoing updates are required to track changes in energy utilization and we recommend augmenting accounts payable processes to extract all baseline relevant items on a monthly basis.

If individual bills need to be collected and processed, the sheer number of utilities serving an operator may be a significant obstacle. The U.S. utility environment is such that next to large, investor owned utilities, there is a plethora of smaller utilities, such as co-ops and municipal systems. For a typical system of around 2-5 million homes passed, we often see the number of electric utilities in excess of 100. However, in our experience, the 10-15 utilities with the largest annual spend will cover 80% or more of usage and spending. The larger utilities usually represent the overall operator's footprint quite accurately and it is often sufficient to analyze these and use an extrapolation approach for the remainder. It should also be noted that the larger utilities often have more sophisticated billing systems and may be able to provide data in a suitable electronic format.

The standard requires the extraction of the data listed in Table 1.

Table 1 - Utility Bill Extraction per SCTE 212 2015

Bill Element per Standard	Discussion
How many days included in the utility bill (to calculate power from kWh)	Utility bills will only indicate kWh and will be for varying periods. Average power can be calculated as Power (kW) = kWh / days /24 hours. If desired, a kWh number for a normalized month can also be calculated as kWh (normal) = kWh (bill) / days in bill x 365 days / 12 months.
If applicable, bill demand power for peak power (kW), to determine load factor	Larger facilities are charged not only for energy, but also for the peak power required. This so called demand value can be used to establish the load factor, which is the ratio of average power to peak power.
kWh (sub metering should be performed by the cable operator not utility provider)	For mixed use facilities, sub metering may be required to establish the energy breakdown between building zones.
Billing rates and tariff charged	Not required to establish an energy baseline, but required to evaluate tariff based savings opportunities.
Meter number	Back up information for site address, if required.
Utility service address and utility account number	Required to match to operator's assets.
Total amount charged	Cost component of energy baseline.

The standard also requires supplementary data separate from utility bills. This includes generation by any non-grid connected means as well as power supply purchasing data to track access network growth.

Table 2 summarizes the metrics to be developed using the energy baseline. As illustrated, the single access network metric measures efficacy on the basis of total data throughput. Facility metrics are specific to individual facilities and are either based on data throughput or subscriber count. A third facility metric requires detailed knowledge of facility infrastructure as well as internal power distribution and determines how effectively the input power is routed to the information technology (IT) equipment.

Table 2 - Summary of Metrics Derived from Energy Baseline

	Metric	Calculation	Source
Access Network	Throughput Metric	Energy per Consumed Bit for Plant (kWh/TB)	SCTE 211 2015
Critical Facilities	Subscriber Metric	Total Number of Critical Facility Subscribers / Total Facility Power	SCTE 213 2015
Critical Facilities	Throughput Metric	Total Critical Facility Data Throughput / Total Critical Facility Power	SCTE 213 2015
Critical Facilities	Power Usage Effectiveness	Total Critical Facility Energy / IT Equipment Energy	SCTE 213 2015

In addition to the engineering metrics required by the SCTE standards, the baseline data from utility bills provides for additional information suitable for efficiency analysis and benchmarking. Some of these performance indicators are summarized in Table 3.

Table 3 - Supplemental Metrics

	Metric	Discussion
Access Network	Power supply load distribution and average load per power supply	Correlates usage to installed capacity for power supply efficiency analysis and load growth investigations
Access Network	Comparison of power supply averages for metered and unmetered accounts	Identifies possible overbillings on the unmetered sites
Access Network	Power per home passed	A traditional measure of hybrid fiber-coax (HFC) plant performance
Access Network	Power per miles of coax	Removes density dependence from the power per home passed metric
Access Network	Correlation with aspects of plant infrastructure	This can be used to evaluate plant segments with different characteristics (e.g. voltage, fiber penetration, coax impedance)
Facilities	Load factor	Performance indicator correlating average to peak power
Facilities	Seasonal load variations	Indication of building performance when correlated to climatic zone
Facilities	Energy or power per square foot of building area	Measures energy or power density; often used for administrative facilities but also useful for technical facilities
Facilities	Aggregate subscriber metric for technical and administrative facilities	Expanding the SCTE 213 2015 metrics to the overall facility population.

The following sections discuss the establishment of a utility bill derived baseline in more detail.

3. Baseline Development

3.1. Facility Baseline Development

There is no viable alternative to using utility data for the baseline for facilities. While some critical facilities may have operator provided hardware for measurement, many facilities will not. Also, while the standards focus on metrics for critical (technical) facilities, we still require data on non-critical (administrative) facilities, as they are part and parcel of overall energy usage.

Once utility bills have been obtained and the data has been processed into an electronic format, the first step is the extraction of facilities by matching addresses from utility bills to the operator's facility asset list. Facilities are very divergent in use, size and energy performance; thus, a sampling approach is not recommended. The matching process is a correlation of two data bases, operator and utility. If the operator database is set up with additional information such as detailed use description, floor area, installed air conditioning capacity, customers served, and data throughput, this will aid in the subsequent development of metrics per SCTE 213 2015.

For any large facilities outside of the service territory of the primary utilities, we recommend obtaining the appropriate billing history from the secondary utilities. For smaller sites, usage can be extrapolated if details on the nature of the facilities are available. For example, from the analysis of the largest utilities, we may have details on a large number of hub sites and can develop a kWh/square foot or kWh/customer relationship benchmark to be used in extrapolating the remaining facilities.

Facilities can be split into three categories: critical, administrative and mixed use, i.e. containing both critical and administrative components. Depending on the granularity required, facilities can also be segregated into more detailed categories, such as edge vs. backbone sites as discussed in the Energy 2020 community, offices vs. tech ops sites, etc. For this discussion, we will use the summary categories of critical (hubs, head ends, data centers etc.) and administrative (offices, warehouses, stores, etc.).

Not all facilities are single usage, but some may contain elements of both critical and administrative nature. For these mixed use sites, a utility bill for a single meter will not provide the breakdown into the appropriate categories. In these cases, operator installed sub-metering can be employed to determine the energy usage of various building zones. In the absence of this capability, the characteristics of "pure" sites can again be used to extrapolate the usage of the individual elements in a mixed use facility.

3.2. Access Network Baseline Development

Establishing the baseline for the access network from a utility bill analysis involves possibly 10,000's of bills. While the analysis can be streamlined somewhat by implementing a sampling approach, we still recommend an initial parsing of the utility bills to ensure data integrity.

3.2.1. Data Extraction and Preparation

As discussed in Section 3.1, as a first step in the analysis, the bills for facilities have been extracted from the bill population. This should leave the remainder of bills representing the access network. At this stage, we recommend a review of these remaining bills to make sure no obvious facilities are left. At times, operator data bases may be slightly out of date or smaller sites may not be represented on operator facility lists. The review should focus on accounts with kWh usage levels in excess of typical power supplies as well as accounts exhibiting non power supply characteristics, such as significant seasonal variations. Once these account issues are resolved, the remaining bills represent the access network power supplies. Given the volume of data, minor database errors (low usage, non power supply bills counted as power supplies) generally do not impact the accuracy of the final result significantly.

SCTE 212 2015 calls for a reconciliation of utility bill addresses with actual power supply locations. This is designed to aid in the correction of billing issues as well as establish a correlation between individual power supply ratings (e.g. 60V or 90V) and utility input power. In practice, even for smaller systems of 10,000 or so power supplies, we have found this process daunting and very resource intensive. Clean address matches between utility and operator data are usually only possible for half of the locations, if that many. Underlying causes include bulk billing of power supplies without address detail, missing addresses on bills or in operator data bases, wrong addresses or cross street address designations. Geographic information system (GIS) tools can be used to appropriately allocate a portion of the unmatched accounts. This still leaves a significant number of accounts for manual, item by item reconciliation, a very resource intensive task. Given our experience with utility overbillings on power supply accounts, we believe that this reconciliation and the subsequent correction of identified utility billing errors can be very rewarding from a financial audit point of view. From a baseline only perspective, while a full reconciliation may be desirable, we believe that significant analysis work is possible based on averages, with reconciliation performed on an as needed basis when required for follow on investigations.

Once any remaining non power supply bills are removed, the next step is to segregate the bills into metered and unmetered bills and extract the required information per Table 1. Prior to executing the baseline calculations, it is instructive to examine the metered power supply bills for outliers. Figure 1 illustrates the input power distribution of approximately 70,000 metered power supplies we have processed as part of our audit work.

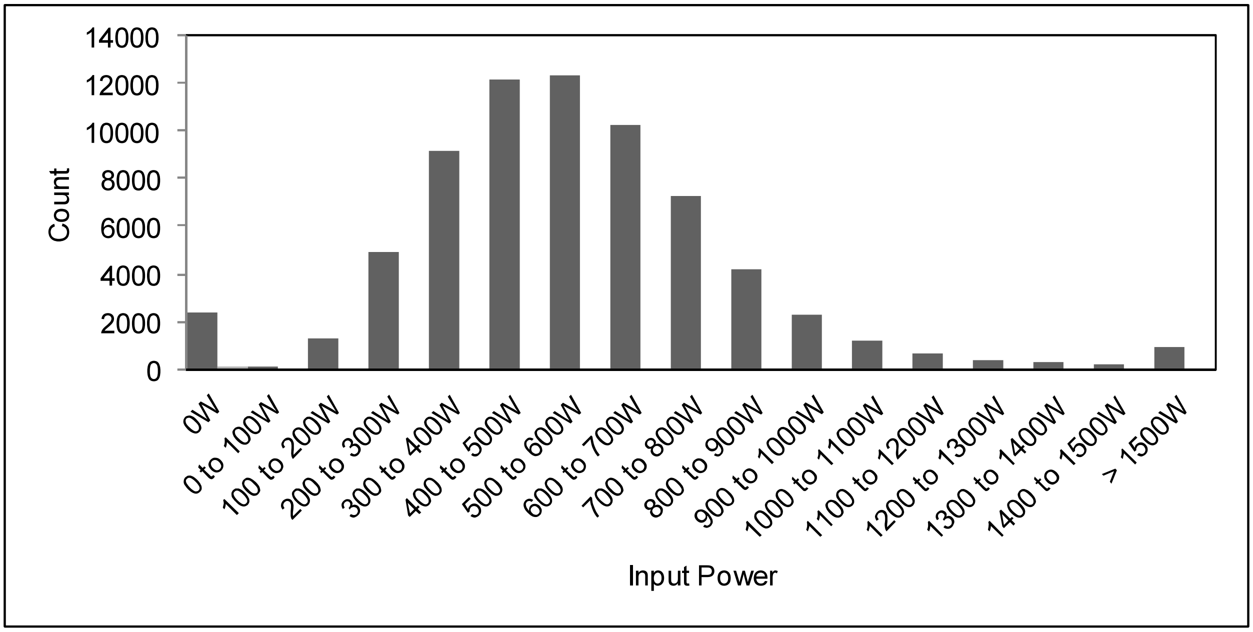

Figure 1 - Metered Power Supply Input Power Distribution

As shown in Figure 1, a significant number of power supply accounts are drawing no load. Some of these present savings opportunities if they are no longer needed, others are new accounts not tied into the plant yet. From an energy baseline approach, we recommend eliminating the zero usage accounts in order not to artificially lower the average load. The baseline should only consider active power supplies which are powering the plant.

High usage power supply accounts also bear some investigation in order to determine if a metering issue is leading to possible overcharges. However, in our experience, the majority of these represent central powering installations with multiple power supplies per cabinet.

Unmetered power supply bills should not be used for the energy baseline, as billed kWh in many cases are not a reflection of actual energy usage. Coppervale's nationwide billing data base indicates that the average unmetered supply is charged significantly in excess of an average metered power supply, indicating a potential for significant overcharges and consequently, savings. The distribution of unmetered accounts as well as utility billing practices are geographically very diverse. Consequently, we recommend addressing this issue at a local level with the appropriate utilities.

3.2.2. Baseline Calculation

If metered accounts are a good representation of the operator's geographic footprint, we can establish the average usage of all metered accounts, corrected for the zero usage accounts (see Figure 1). This average is then multiplied by the total number of power supplies to establish the overall baseline for the system under investigation.

Note that the average obtained from the distribution shown in Figure 1 will represent the average kWh load per utility connection. Due to the presence of a small percentage of power nodes with multiple power supplies, the actual average per power supply will be somewhat lower. On a global scale, as shown in Figure 1 (input power >1,500W), these power nodes represent just over 1% of all accounts. However, for systems with a large percentage of central powering installations, appropriate adjustments have to be made. In these cases, we recommend an adjustment based on the number of supplies used per node.

Unless significant construction activity has been ongoing in the access network (large number of node splits, additions to power supply loads), a brown field HFC system as a whole has a static load profile with marginal, temperature related seasonal variations. While we always examine a full year of bills, in such cases it is feasible to only examine a single month's bill for the metered power supplies.

For systems where metered accounts do not represent the plant geography well or where there is not a sufficient number of metered bills available, a different approach is required. This sampling based methodology is also applicable if it is desirable to establish the baseline without analyzing a very large number of billing records.

3.2.3. Sampling Approach to Baseline Establishment

A simple baseline can be developed using a sampling approach for metered power supplies. In order to be successful, this sampling approach requires that the metered bills are representative of the overall system in terms of average load and geographic distribution. If so, a random sample can be selected to model the overall plant.

Table 4 outlines the sample requirements for systems with a varying number of power supplies. As shown, larger systems require proportionally fewer samples than smaller footprints. The sample sizes given are for a 95% confidence level with a 5% margin of error. Larger sample sizes will improve on this. Note that the success of this approach is predicated on the sample selection being random.

Table 4 - Sampling Considerations

Population Size	Sample Size (95%/5%)
1,000	278
5,000	357
10,000	370

Once the average load of the sample is determined, overall network load is calculated by multiplying the sample average by the total number of power supplies. This approach models the actual access network powering requirement. Note that the same considerations regarding zero usage and power node accounts as discussed above apply to the sampling approach.

For systems where the predominant power supply billing is unmetered, a utility based approach will not work. In such cases, it is required to select a random sample per Table 4 from the population of power supplies and then obtain utility grade field power measurements at the input to the power supply enclosure.

Based on experience, we do not recommend using legacy transponder measurements to establish the baseline. Accuracy of these older model transponders is not sufficient to develop utility grade input data. Aside from accuracy concerns, transponders only measure output voltage and current but not the required output power factor. The latter is a function of the downstream architecture (actives, coax type and length) and can vary from location to location. Using power supply efficiency estimates to project output parameters to the utility side introduces additional error, as does the inclusion of battery charger requirements. It is possible to calibrate transponder data on a sample basis with utility grade input data to generate system specific input/output correlation factors. In this case, the correlating utility input data already establishes the baseline. Note that the reverse consideration also applies and calculation of output current based on utility input power is only possible as an approximation. Where a detailed correlation of input to output is required, utility input data should be matched on an individual basis to power supply output data.

While the baseline for the access network can be developed using a sampling approach, this method still requires the collection of all power supply bills in order to be able to select the random sample from the overall population of bills. However, for monthly baseline updates, only the bills for the sample have to be processed and evaluated.

4. Baseline Development - Example

As an example, we evaluate a system with approximately 5.2 million homes passed in accordance with the procedure outlined in Section 3 above. The system is served by 148 individual utilities, with the largest eight utilities accounting for 83% of spending. A review of the service territories of these eight utilities reveals that they offer good coverage of the entire operator's service area, with the remaining smaller utilities accounting for small, distributed pockets within the larger utilities' footprints. We use the billing data for these large utilities to develop the baseline and extrapolate the remaining 17%.

4.1. Sample System - Facility Baseline

Matching utility bills to a list of facilities, we are able to allocate just under 80% of the floor space to utility bills, in line with the percentage of total spend being analyzed. Table 5 summarizes the energy and cost numbers for the three classes of facilities as extracted from the utility bills and matched to an operator asset list.

Table 5 - Sample System Facility Data Matching

	Annual kWh	Annual $
Critical Facilities	24,058,205	$2,255,615
Administrative Facilities	14,580,842	$1,432,162
Mixed Use Facilities	33,868,338	$2,978,943

As a next step, we need to allocate the data for mixed use facilities to critical and administrative uses. In this example, we have access to facility floor area by functionality (hub, office, etc). This allows us to develop density factors (kWh/sq ft, $/sq ft) from the data shown in the first two rows of Table 5. These factors in turn are used to segregate the mixed use data into the appropriate functional category. We note that the accuracy of this method is directly related to the quality of the facility data - if floor area or functional allocations are reported in error, any discrepancy will flow through to the final result.

Finally, the data needs to be adjusted for the remaining 17% of spending associated with the 140 utilities for which we do not have detailed data. This can again be based on an application of the density factors developed to the unmatched facilities. In many cases, we also find that a linear extrapolation based on spending and kWh offers a good estimate for the unmatched facilities.

Table 6 summarizes the final facility baseline for this sample system.

Table 6 - Sample Facility Baseline

	Annual kWh	Annual $
Critical Facilities	50,793,652	$4,762,239
Administrative Facilities	36,690,867	$3,281,560

In addition to the baseline derived from utility information, SCTE 212 2015 also calls for the breakout of any non grid-connected generation, such as solar plants or fuel cells. This will require operator installed metering and data collection. This effort is straightforward; for the sample system discussed here, no such systems are present.

The energy data obtained can now be used to develop metrics as discussed in Section 2. We do not have access to some of the elements required by SCTE 213 2015, such as facility data throughput or equipment details. In absence thereof, we analyze the data using alternate metrics to illustrate the analytical possibilities. Utilizing any metric related to cost or kWh will entail simple arithmetic.

4.2. Sample System - Facility Data Analysis and Metrics Development

Since the utility bill information is available on a monthly basis, we can chart the data to evaluate annual load progression and seasonal variations. Figure 2 shows the annual load profile for the sample system. This plot gives us information on load growth or lack thereof and provides an indication of seasonal performance. It also provides a basis for comparison with other systems.

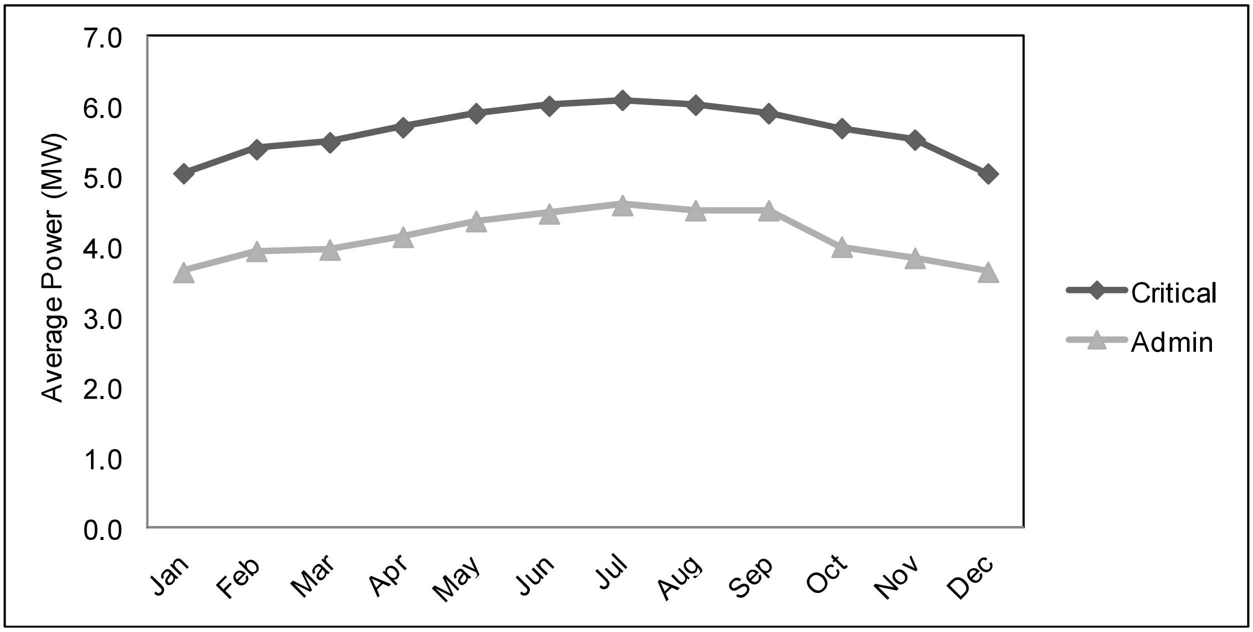

Figure 2 - Sample System Facility Average Load Profile

The facility baseline data can be used to develop system wide metrics. Table 7 provides an example of facility usage and cost when related to subscribers or revenue generating units (RGU).

Table 7 - Sample System Cumulative Facility Performance per Subscriber (RGU)

	Annual kWh	Power (W)	Annual $
Critical Facilities	19.9	2.3	$1.87
Administrative Facilities	14.4	1.6	$1.29
Total	34.3	3.9	$3.16

We can also evaluate individual facilities and look for possible low performers. For example, we can evaluate load factor, i.e. the ratio of average to peak power. For critical facilities, we expect high load factors, given that the load is constant throughout the day and is mainly impacted by heating, ventilation and air conditioning (HVAC) efficiency variations. Conversely, we expect facilities involving significant personnel activities to show a reduced load factor, given that peak loads coincide with business hours and lower loads outside of business hours will reduce the average power requirement. From a utility based analysis, this metric is only available for facilities on so called demand tariffs, which list peak power on a monthly basis.

Figure 3 summarizes the load factor distribution for critical facilities in our sample system. Note that any facility specific metric like load factor should only be investigated for facilities where actual utility bill information is available and not for sites that were extrapolated. As indicated in Figure 3, the majority of facilities exhibit good (80-90%) to excellent (>90%) performance, while the sites with poorer performance (<75%) are candidates for follow up investigations and possibly corrective actions.

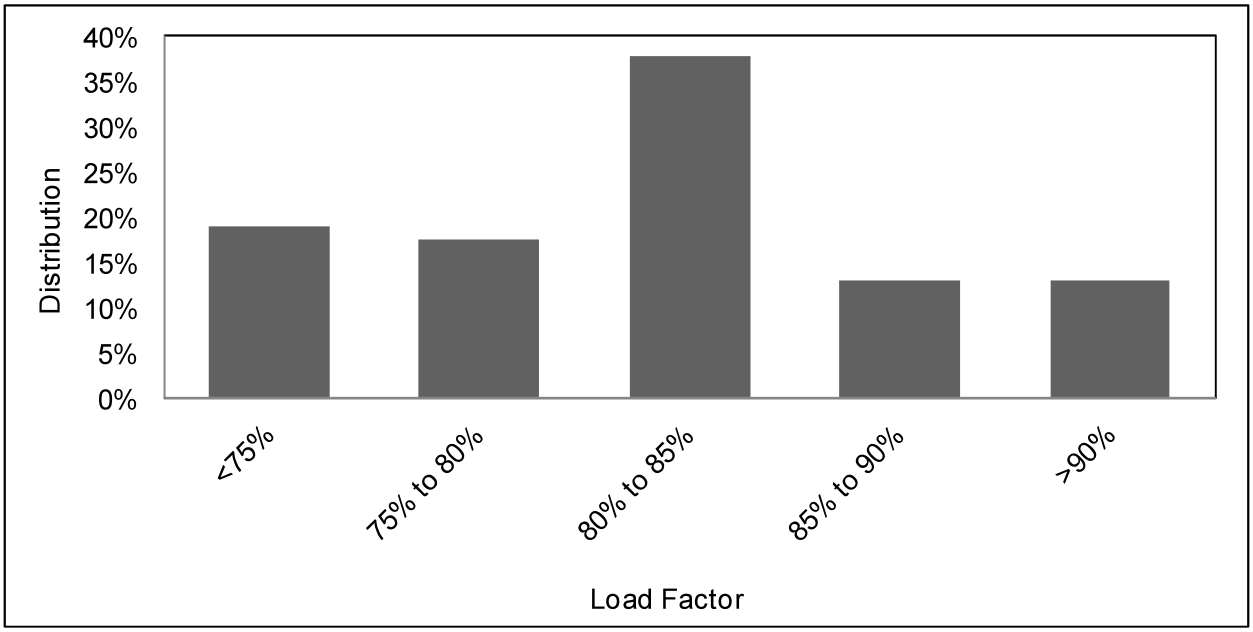

Figure 3 - Sample System - Critical Facility Load Factor Distribution

Load factors for administrative facilities are summarized in Figure 4. A load factor in excess of 70% indicates a load profile approaching that of a 24/7 operation and may provide opportunity for improvement via simple load management.

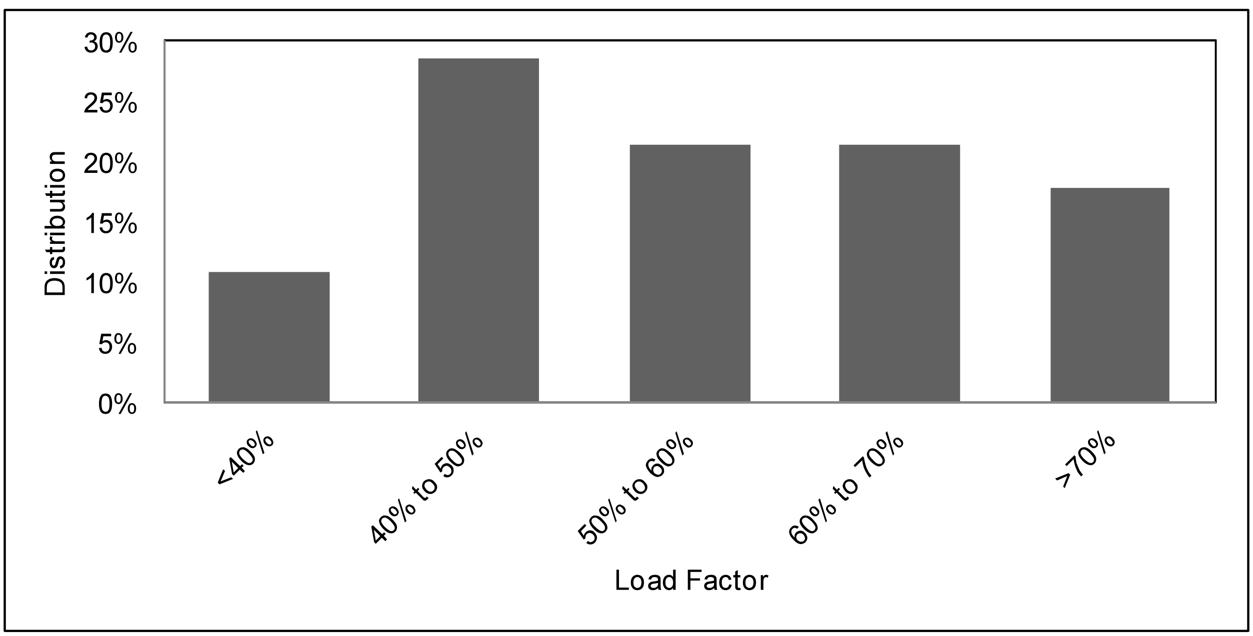

Figure 4 - Sample System - Administrative Facility Load Factor Distribution

As illustrated, the baseline data as collected for a relatively small system provides information on absolute performance and possible improvement opportunities. Once rolled up with other areas of an operator's territory, it can be used to rank order individual systems and identify which areas offer the best opportunity for high return on investment (ROI) improvement activities. This will be presented in Section 5.

4.3. Sample System - Access Network Baseline

Following the facility extraction discussed above, we are left with 21,008 billing accounts. In order to ensure that only valid metered power supply bills are considered for the baseline, these accounts need to be investigated for consistency. This account review results in required account actions for just over 2% of the accounts as summarized in Table 8. This reconciliation process not only ensures improved accuracy of the resulting baseline, but also saves approximately $135,000 per annum.

Table 8 - Sample System Access Network Bill Cleanup

Item	Count	Value	Discussion
Non-power supply bills identified	16	$46,613	Accounts wrongly billed to operator and closed
Obsolete zero usage metered power supply bills	355	$45,795	Additional 119 zero usage accounts identified as needed
Obsolete unmetered power supply bills	86	$42,400	

The remaining accounts represent the metered and unmetered network power supplies. Metered accounts number 16,983 and average 427kWh per month, equivalent to an average power draw of 584W. Using the total number of access network power supplies as reported by the operator, we can now determine the overall access network energy baseline as summarized in Table 9.

Table 9 - Sample System Access Network Energy Baseline

Average Metered Power Supply Load - W	Average Metered Monthly Power Supply Energy - kWh	Total Number of Installed Power Supplies	Access Network Annual Energy Baseline (kWh)	Access Network Power Requirement (kW)
584	427	24,756	126,849,744	14,458

While the energy baseline is based on actual energy requirements using metered power supply bills, the cost baseline requires actual spending numbers. Table 10 summarizes spending and establishes the access network cost baseline. The number of total metered and unmetered power supplies is extrapolated via the total number of power supplies and the percentage of bills analyzed.

Table 10 - Sample System Access Network Cost Baseline

	Number	Average Monthly Energy - kWh	Average Monthly Cost - $	Total Annual Cost - $
Metered Power Supplies	20,481	427	$53.97	$13,265,318
Unmetered Power Supplies	4,275	1,041	$103.95	$5,332,743
			Overall Cost Baseline	$18,598,061

Table 10 shows a big discrepancy between metered and unmetered accounts. The large unmetered value is due to one utility charging power supplies at UL/CSA nameplate rating, which for a typical 15A power supply is 16A at 120V or 1,920VA. Subsequent metering of the affected unmetered power supplies (2,200 in total) saved approximately $1,700,000 per year - this would be reflected in the following year's updated baseline. Incidentally, the average monthly actual load for these newly metered power supplies is 433kWh, or within 1.5% of the baseline average shown in Table 9.

4.4. Sample System - Access Network Data Analysis and Metrics Development

The access network baseline can now be used to establish metrics. Table 11 summarizes energy and cost data per subscriber and Table 12 illustrates some examples of metrics related to underlying system infrastructure.

Table 11 - Sample System Access Network Performance per Subscriber (RGU)

Annual kWh	Power (W)	Annual $
49.7	5.7	$7.28

Table 12 - Sample System Access Network Infrastructure Metrics

Metric	Value
Power per home passed (W/hp)	2.7
Power per mile of coax plant (W/mi)	215
Miles of coax per power supply	2.6

It can also be instructive to evaluate the system wide distribution of metered power supply loads as shown in Figure 5. This can be used to investigate the effects of possible load increases, evaluate power supply efficiencies as a function of load and capacity and investigate efficiency enhancement options for lightly loaded supplies (<200-300W input power).

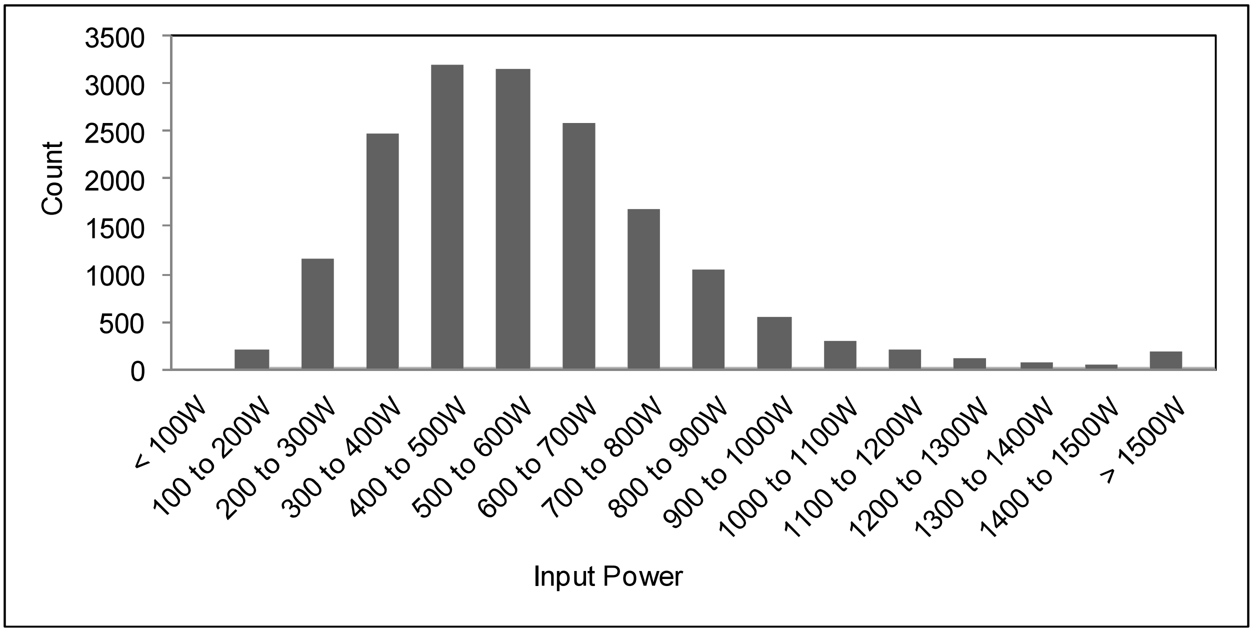

Figure 5 - Sample System Power Supply Load Distribution

The baseline and the metrics developed can also be correlated with other system characteristics, such as fiber penetration, number of nodes, coax type and impedance, and others. These investigations can shed light on the underlying causes for overall plant efficiency performance.

4.5. Sample System - Overall Baseline

Combining the results for facilities and access network, we arrive at the overall baseline for the sample system. The raw baseline data is presented in Table 13, while Table 14 provides the energy and cost metrics per subscriber.

Table 13 - Sample System Overall Baseline

	Energy (kWh)	Energy Contribution	Cost	Cost Contribution
Access Network	126,849,744	59%	$18,598,061	70%
Critical Facilities	50,793,652	24%	$4,762,239	18%
Administrative Facilities	36,690,867	17%	$3,281,560	12%
Total	214,334,263		$26,641,861	

Table 14 - Sample System Baseline Performance per Subscriber (RGU)

	Annual kWh	Power (W)	Annual $
Access Network	49.7	5.7	$7.28
Critical Facilities	19.9	2.3	$1.87
Administrative Facilities	14.4	1.6	$1.29
Total	84.0	9.6	$10.44

5. Baseline Rollup and Comparison

The example presented in Section 4 covers one of systems we have recently audited. It is instructive to roll up individual baselines into a single baseline and show some examples of system comparisons.

Figure 6 illustrates the energy and cost distributions for the combined systems analyzed representing approximately 35 million homes passed, while Figure 7 summarizes the overall energy and cost performance on a per customer basis.

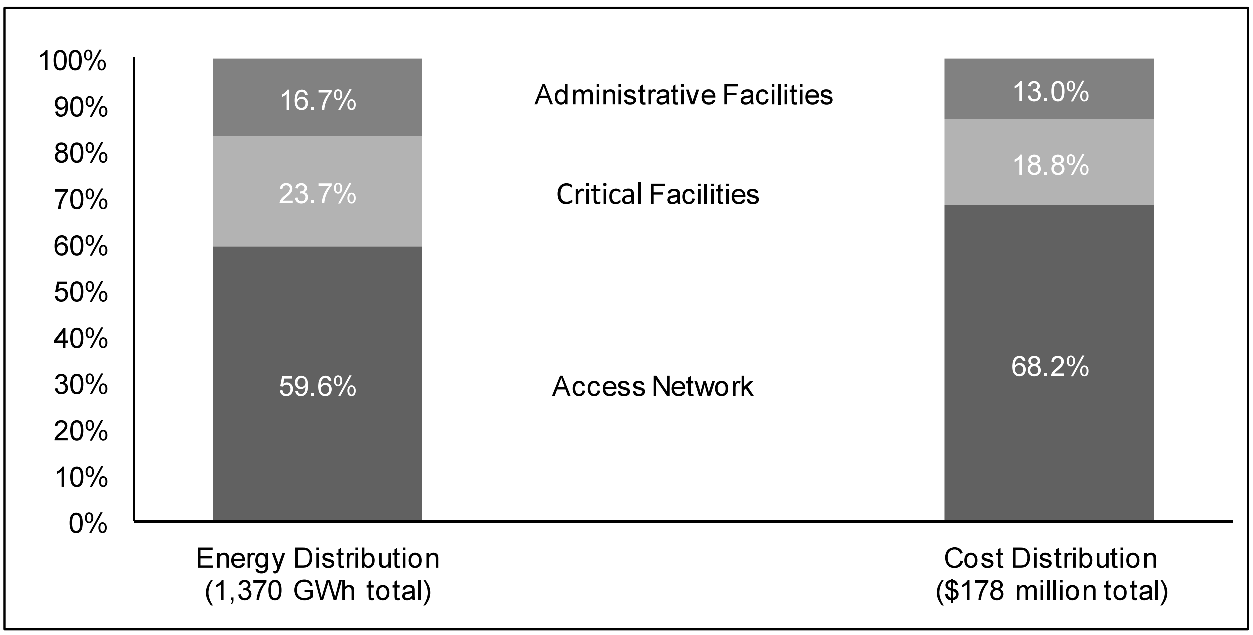

Figure 6 - Baseline Rollup Combining Individual System

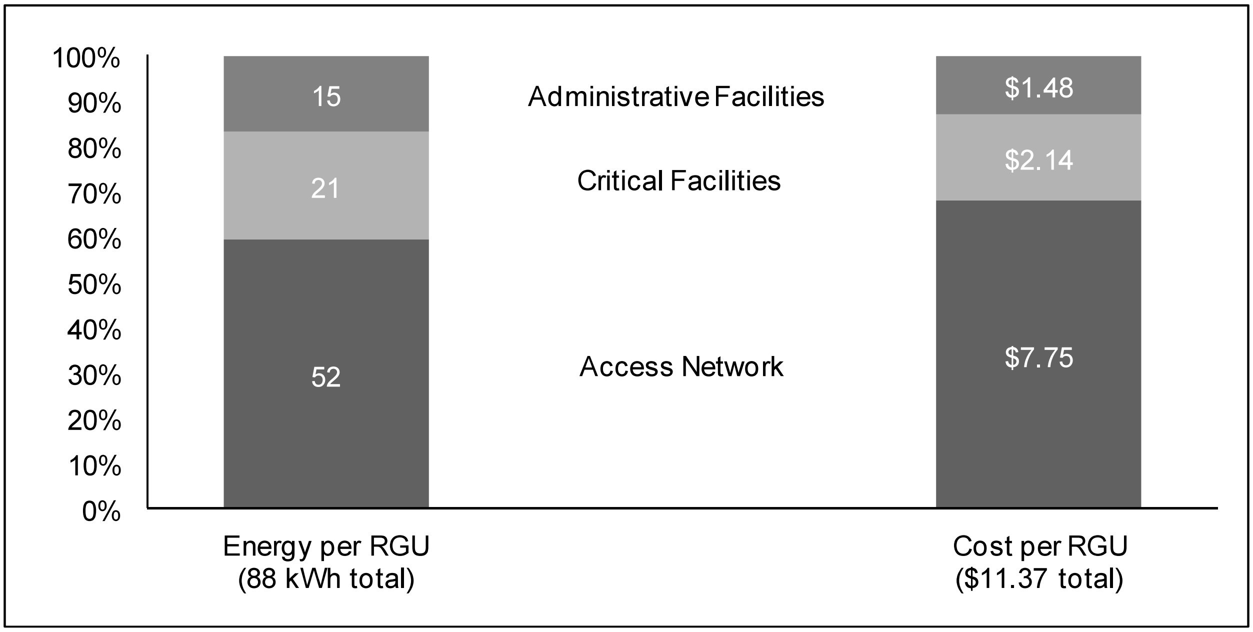

Figure 7 - Baseline Rollup Normalized to Customer Count

Having developed the overall baseline from individual systems, we retain the granularity to compare and rank order the members of the group. The following sections give some examples using the data set developed. Note that these examples are for illustration purposes only in order to highlight the capability of a baseline driven analysis. As discussed in Section 2, there are numerous metrics and benchmarks that can be applied to gain further insight into system performance.

5.1. System Comparison - Critical Facilities

Figure 8 breaks out the energy requirements for critical facilities per subscriber. The individual systems range from 16-26kWh.

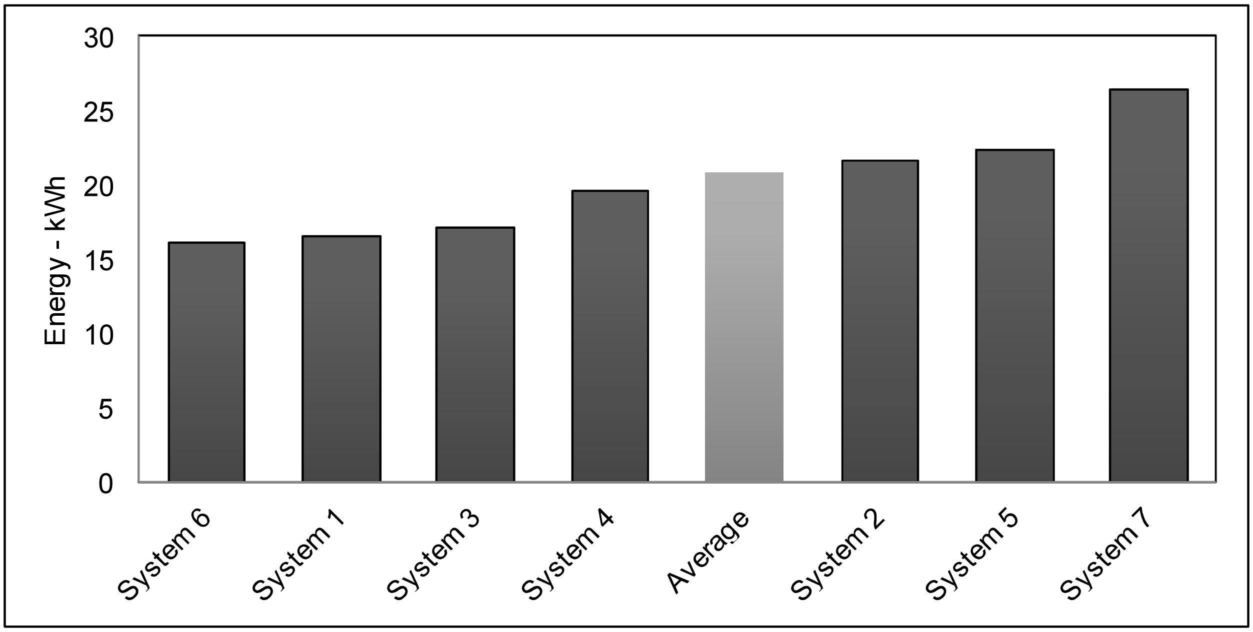

Figure 8 - Critical Facility Energy Requirements per Subscriber

We can now drill into the underlying data and explore individual facility metrics to evaluate outliers. Figure 9 tallies the critical facilities in the individual systems with load factors less than 80%. It is evident that the low and high performers correlate very well with this metric. From an improvement perspective, we can now focus on critical facilities in System 7.

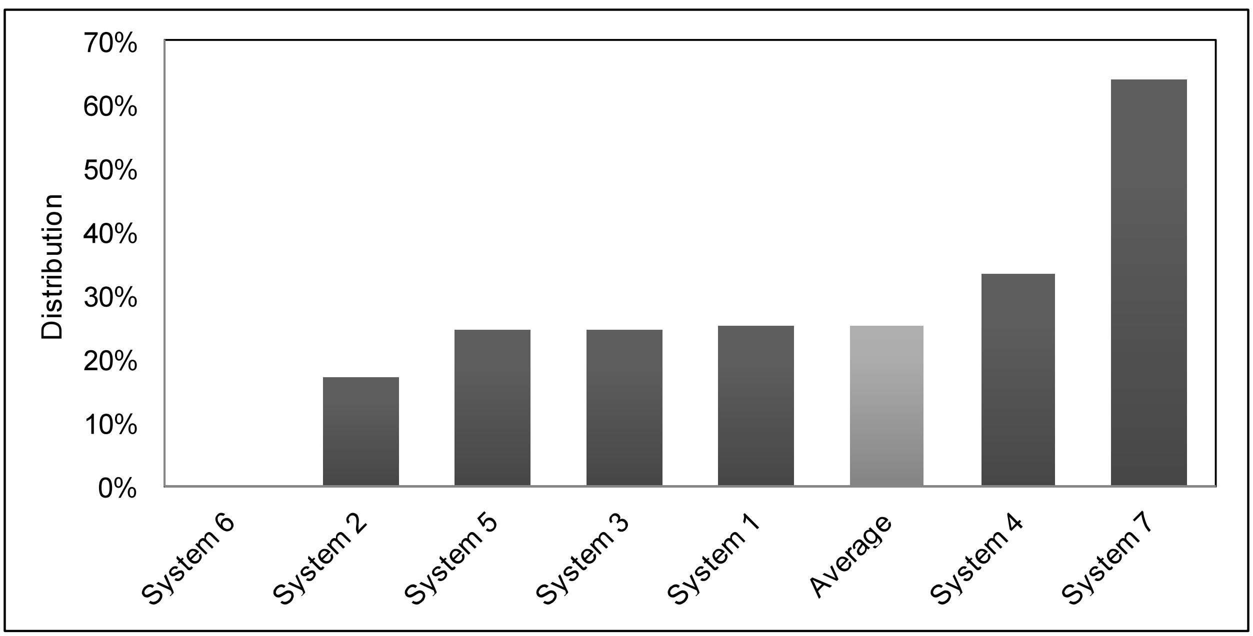

Figure 9 - Critical Facilities with Load Factor Less Than 80%

5.2. System Comparison - Access Network

The energy requirements of the access networks are a function of plant density. Lower densities require more power to deliver signal to a home passed and by extension, to a customer. This extends to data throughput as well, as it is more efficient to transmit a byte over shorter rather than longer distances. Figure 10 takes this into account as it compares the systems comprising our overall baseline.

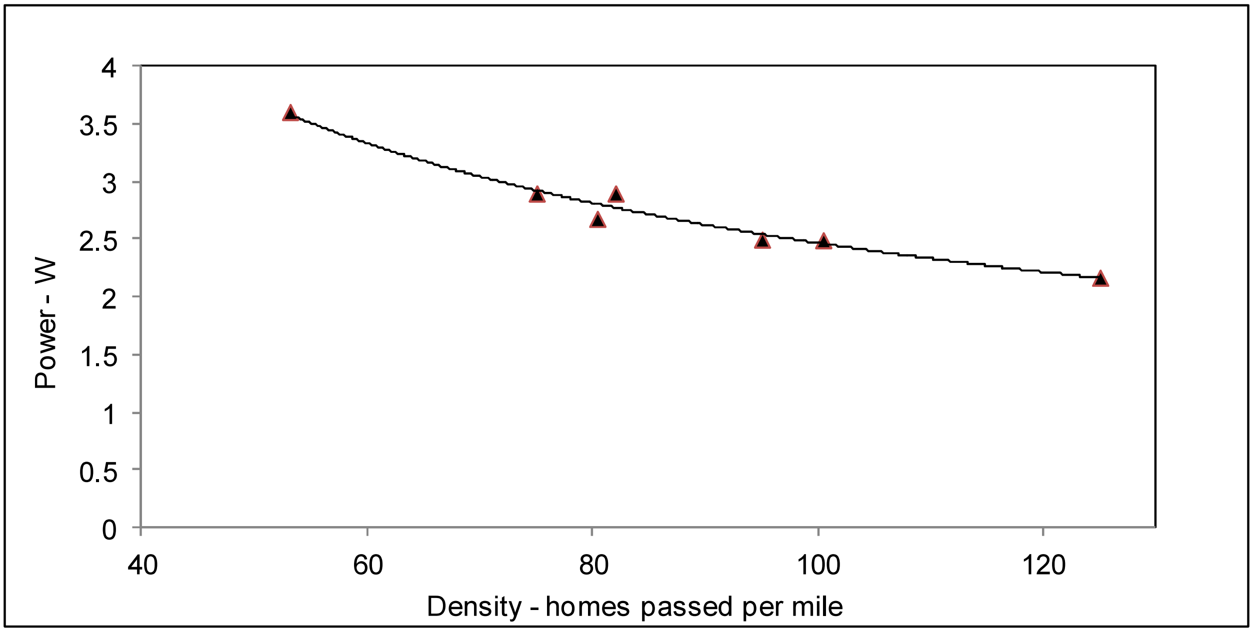

Figure 10 - Access Network Powering Requirements

We note two systems of very comparable density of around 80 homes passed per mile, yet exhibiting powering requirements differing by approximately 10%. A correlation with system architectural parameters is shown in Table 15. Average system voltages are comparable, yet one of the systems predominantly uses coaxial cable with a higher DC loop impedance, indicating a possible reason for the difference in efficiency performance.

Table 15 - Architectural Impact on Access Network Efficiency

	Homes Passed per Miles	Average System Voltage - V	Predominant Coax Type
System 3	80	73	875 and 700
System 5	82	75	625

ROI considerations generally limit short term, significant efficiency improvements for brown field access networks. However, the baseline data, associated metrics and correlation with system architectures allow for an understanding of current system performance. This in turn can provide valuable insight when planning expansions or rebuilds.

6. Recent History and Outlook

The data we use for the analysis presented was gathered between 2010 and 2014. We have not seen significant absolute powering variations within the data sets. Most system facility data sets we have examined in this time period have been relatively stable year over year, following the example of the sample system in Figure 2. While overall annual facility load changes in the time periods analyzed have been quite stable and within +/- 5% for the individual systems, underlying individual facilities can exhibit significant powering variations.

Figure 11 compares the average access network power supply loads over the past years. Again, while individual power supply loads may increase or decrease due to additional loads or node splits, the average has not evolved significantly. We also did not observe significant year over year increases or decreases in the number of power supplies fielded in the systems analyzed. Each year listed in Figure 11 is based on 25,000 or more power supplies analyzed; Figure 11 omits the year 2014, since we do not have sufficient data points available yet.

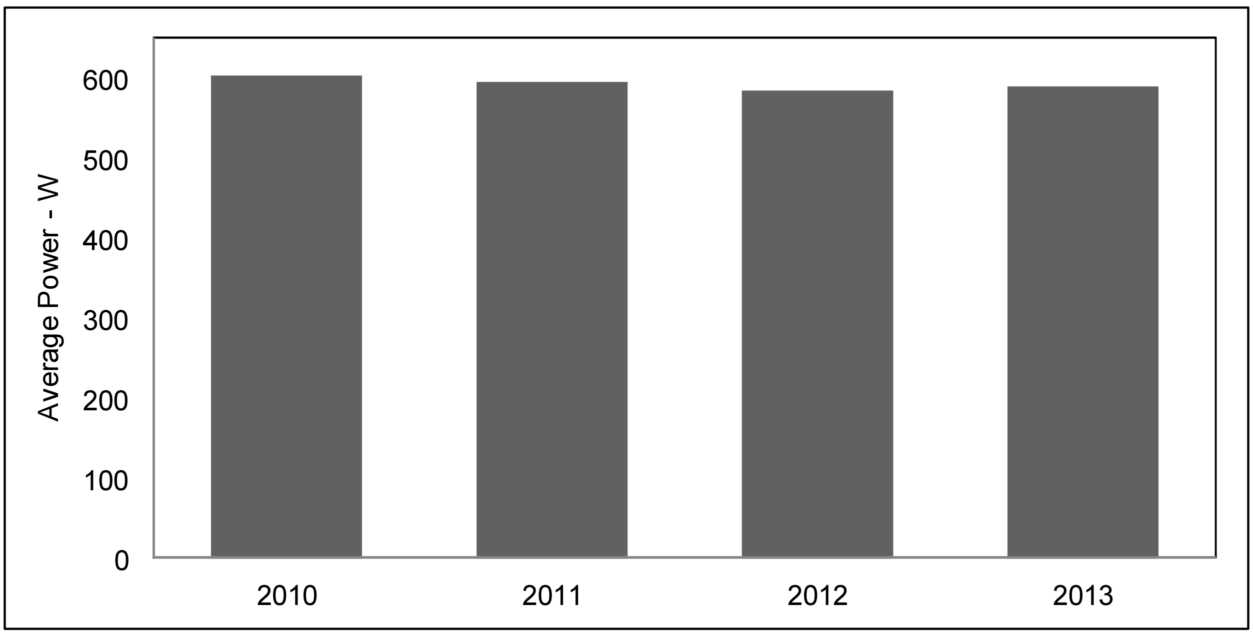

Figure 11 - Average Power Supply Load Development

As shown in Figure 12, retail electricity pricing has grown by approximately 2% per annum over the past few years and the short term outlook from the U.S. Energy Information Administration expects this trend to continue at least for the short term. This will keep cost growth per kWh predictable for the near future.

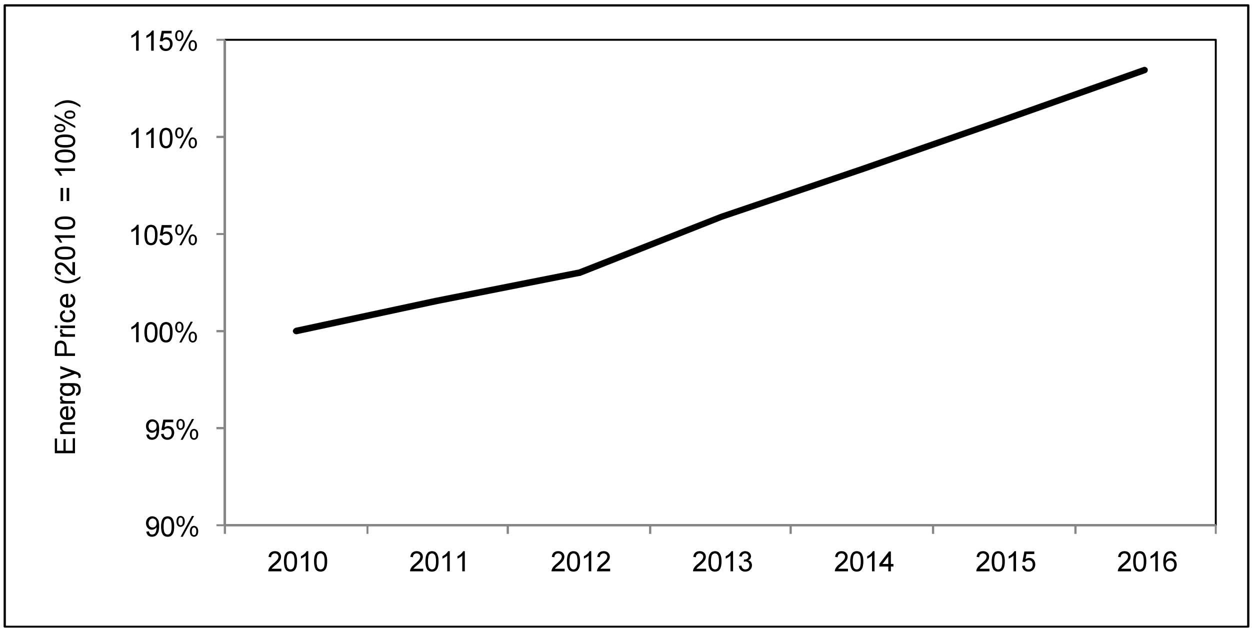

Figure 12 - Retail Energy Price History and Short Term Outlook

The data we have presented covers a wide range of architectures and geographical areas within the United States. We can arrive at an estimate of an overall U.S. wide 2014 baseline by extrapolation, using National Cable & Telecommunications Association (NCTA) subscriber count numbers, cost increases per Figure 12 and by including an estimate for corporate facilities, which are not included in any of our audit data.

Using this technique, we arrive at a U.S. baseline power requirement of approximately 700-800MW and a cost baseline of $850 million to $950 million. This correlates well with the estimates presented by the SCTE community to date.

7. Conclusions and Recommendations

The paper reviewed the requirements for standard SCTE 212 2015 on energy baseline development and presented performance metrics established using the baseline data. A data processing procedure for implementing the standard was presented and illustrated using actual system data. Using the established sample data, we illustrated the use of associated metrics to evaluate system performance.

While some operators have chosen to contract with utility bill service organizations for electronic delivery of billing information, others may have to manually obtain and process historical billing information. The process discussed minimizes the associated effort by focusing on the largest utilities and using a sampling approach to model the access network. For operators with a broad footprint, we recommend building the overall baseline from individual data sets representing smaller subsets, either along geographic or operational boundaries.

Processing the utility bill information for the baseline entails a thorough review of billing data to ensure applicability. While the establishment of the initial baseline can be resource intensive, we believe that the associated billing review can lead to significant savings, making the baseline work potentially self financing.

While the initial baseline is being established from historical data, we recommend a review and modification of accounts payable procedures to extract energy baseline related information on an ongoing basis. This way, baseline updates can be performed regularly without additional data acquisition requirements. Using metrics as discussed in this paper, the baseline data can be integrated in a dashboard information system to be used as a review and decision making tool by technical and financial interests.

Abbreviations

SCTE	Society of Cable Telecommunications Engineers
IT	information technology
HFC	hybrid fiber-coax
GIS	geographic information system
RGU	revenue generating units
HVAC	heating, ventilation and air conditioning
ROI	return on investment
NCTA	National Cable & Telecommunications Association
V	volt
kWh	kilowatt-hour
kW	kilowatt
TB	terabyte
W	watt
Sq ft	square-feet
MW	megawatt (1,000 kW)
A	ampere
VA	volt-ampere
hp	homes passed
mi	mile
GWh	gigawatt-hour (1,000,000 kWh)
DC	direct current

Bibliography & References

Introduction to Statistical Analysis, W.J. Dixon and F.J. Massey, McGraw Hill, 1983

Average Retail Price of Electricity, U.S. Energy Information Administration, www.eia.gov, accessed June 2015

SCTE 212 2015, *Cable Operator Energy Audit Framework and Establishment of Energy Baseline 2015*

SCTE 211 2015, *Energy Metrics for Cable Operator Access Networks 2015*

SCTE 213 2015, *Edge and Core Facilities Energy Metrics 2015*

Broadband By The Numbers, National Cable & Telecommunications Association, www.ncta.com, accessed June 2015

Energy 2020 Energy Management Subcommittee Meeting, Herndon, VA, February 2015