Draining the Power Grid: Slaying Energy Vampires and Optimizing Your Cable Network's Power Consumption

A technical paper prepared for presentation at SCTE TechExpo24

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1. Introduction

The ever-increasing demand for data traffic in a cable network presents an inherent uptick in power consumption in the inside plant (ISP) and outside plant (OSP) portions of the cable network. This paper serves as a playbook to address this challenge, outlining industry-proven methods for optimizing a cable network's power consumption efficiency. We will explore traditional and cutting-edge strategies to reduce overall energy consumption, providing a framework for achieving significant savings across a cable network.

Reducing your network's energy consumption offers a two-fold benefit. Peering through an environmental lens, this focus translates to a decrease in greenhouse gas emissions, contributing to a more sustainable future and your company's and community's climate goals. Through an economic lens, it assists in reducing your cable network's overall year-over-year (YoY) operating expenses (OPEX).

Wasteful spending on energy becomes extremely costly as energy prices rise across the United States. Reducing or eliminating even a few of these ISP and OSP examples will have a compounding effect across the entire cable network. First, we will examine some common and not-so-common practices in the ISP. Second, we will discuss OSP power-saving approaches and implement a few methods we learned from the ISP techniques.

2. Identifying Low-Cost Energy Saving Opportunities in the ISP Environment

2.1. Capturing Energy Savings Through R-PDUs

When evaluating your energy-saving opportunities within a site, one of the lowest-hanging fruits to grab is turning off devices that aren't doing anything "productive."

While analyzing our sites, a concerning trend began to emerge: power strips or rack-mounted power distribution units (R-PDUs) were frequently powered on when no equipment was connected. Most of the newer, intelligent power strips have control panels that continuously draw small amounts of power. While the power consumption per unit may be negligible, the cumulative effect of numerous strips left idling can add up to be significant.

To illustrate this point, Figure 1 shows a thermal image of multiple power strips powered on but with no connected equipment. Not only is each of the strips consuming unnecessary power, but it also contributes to increased ambient temperatures in the room. The thermal image data indicates a temperature differential of 9°F (5°C) between the active 80°F (26.7°C) controller and the inactive 71°F (21.6°C) R-PDU controllers. The temperature differential further increases additional wasted energy for cooling purposes.

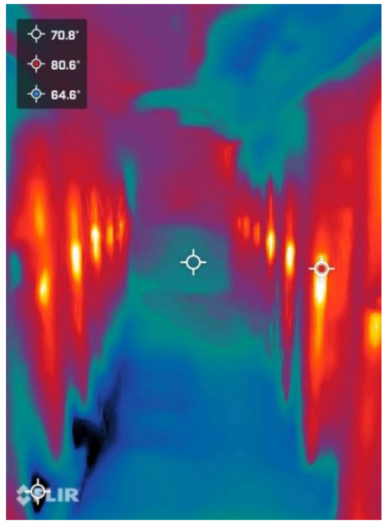

Figure 1 - Thermal photo of empty racks with energy consuming power strips

A similar example was observed at an additional site, which offered another power-saving opportunity in roughly the same quantity. The before and after photos of a single rack R-PDU with no equipment connected to it (Figure 2) show a ten-degree temperature differential between the powered-on and powered-off units.

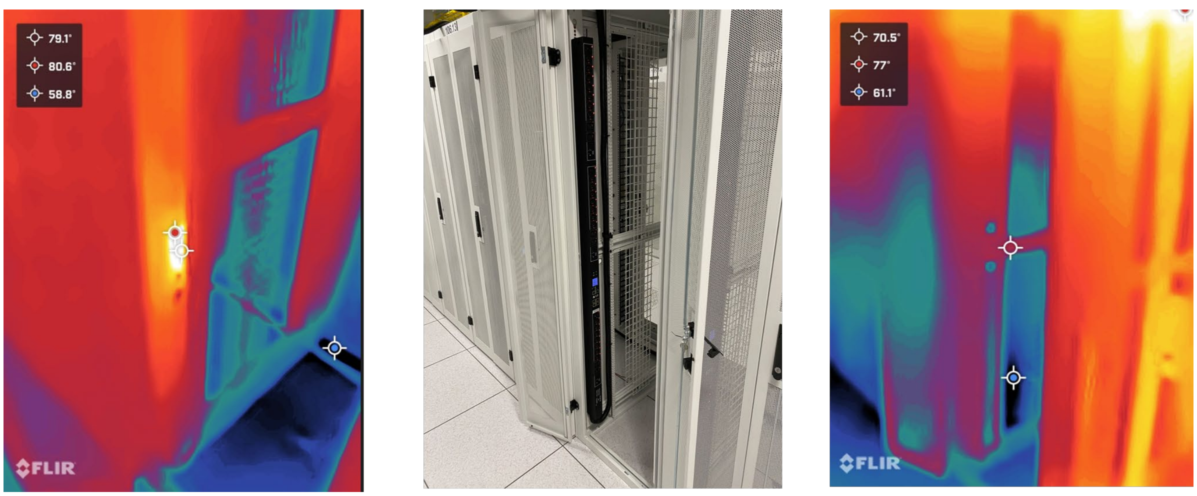

Figure 2 - From left to right, Images of the same power strip, powered-on (thermal), powered-on (live), powered-off (thermal

Ultimately, this study demonstrates that a straightforward yet often overlooked practice of powering down unused R-PDUs can yield significant energy savings. Our analysis suggests that by implementing this measure, a single site can reclaim between 0.5% and 1.5% of its total power consumption. These findings highlight the importance of continually evaluating and optimizing your site's power consumption to ensure efficient energy utilization.

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2.2. Optimizing Rectifier Capacity and Exploring Renewable Energy Integration

This section explores two strategies for optimizing energy efficiency within an ISP's power plant: rectifier capacity management and renewable energy integration.

2.2.1. Rightsizing and Managing Rectifier Capacity

Most ISP locations have direct current (DC) power plants that rely on rectifiers to convert alternating current (AC) power from the utility source to DC power for powering critical equipment. When managing rectifier counts in your DC plant, it is imperative that you at least follow the 80% rule.

> *This rule is where you take the DC plant's peak ampacity need and ensure that number is 80% of the plant's total rectifier capacity. For example, if your system runs at 800 amps DC, you'll want to ensure enough rectification to cover 1000 amps DC.*

This approach offers several benefits:

- **Increased Efficiency**: Operating rectifiers at less than peak load generally translates to higher efficiency. By ensuring sufficient headroom, the system avoids scenarios where individual rectifiers are overloaded, leading to wasted energy.
- **Redundancy and Fault Tolerance**: Redundancy provided by the 80% rule protects against potential equipment failure. If a rectifier malfunctions or needs maintenance, the remaining units can handle the additional load without compromising uptime.

Rightsizing the rectifier count ensures you have enough capacity to handle the load without wasting energy. If you have too few rectifiers, this can overload the plant, reduce efficiency, and increase power consumption. Additionally, overloading can damage equipment and create a potential fire hazard.

Too many rectifiers activated in your plant will result in wasted energy on standby power. However, it is important to maintain your minimum 80% need plus one (N+1) utilization rule, which reduces wasteful energy consumption and keeps the plant nearest to the peak of the energy efficiency curve (technical study to come later this year).

2.2.2. Exploring Renewable Energy Integration

Another energy-saving opportunity can come from trickle-charging the DC plant's batteries from a renewable source. If your site can accommodate the square footage required for solar panels, it will offer an opportunity to reduce grid dependence. Several factors must be explored to see if this option is viable.

The feasibility of implementing solar panels in a site's DC battery system depends on several factors:

- **Solar Exposure**: To validate the amount of receivable sunlight throughout the year, it is vital to thoroughly assess the site's solar potential. A secondary wind turbine option may help supplement the system.
- **Battery Bank Capacity**: The size of the site's battery bank directly influences the amount of energy required for trickle charging. Larger banks will warrant a proportionally larger solar panel array, potentially leading to higher upfront costs. Identifying the point of diminishing returns in terms of investment versus energy savings is essential.
- **Electricity Costs**: The cost-effectiveness of solar power is directly tied to the electricity rates of the utility grid. Locations with higher kWh (kilowatt-hour) costs will generally see a more significant financial benefit from solar integration.

While solar panels may not eliminate your reliance on grid electricity for trickle-charging your plant's batteries, a financial assessment can help determine their viability. By carefully evaluating your roof space and condition, sun exposure, historical power consumption patterns, and local electricity rates, you can create a financial model that estimates a solar panel system's potential cost savings and return on investment (ROI). This will help you decide if solar power is a financially sound way to offset your site's energy consumption.

2.3. Achieve Significant Energy Savings with Intelligent Lighting Systems

Are you looking for another quick and easy win? An additional opportunity to grab some low-hanging fruit will be the lighting system in your location. This section explores the potential of lighting system upgrades to achieve substantial energy savings in your facility.

2.3.1. Case Building for LED Lighting and Occupancy Sensors

Traditional lighting systems that continuously remain on through a manual on/off switch, regardless of occupancy, represent a significant source of wasted energy. This inefficiency in a manual operation, as opposed to automation, presents an easy opportunity to reduce lighting costs.

Figure 3 - Image of LED motion-activated light with attached motion detector.

In one instance, a site was identified where the lighting remained on 24/7. A strategic upgrade was implemented to address this issue. We partnered with a local lighting company to install new light-emitting diode (LED) fixtures with occupancy sensors and Bluetooth communication capabilities (Figure 3). These sensors detect motion and trigger individual or group light activation for a predetermined interval. The system's customizable features allow for fine-tuning lighting duration and brightness to optimize your energy savings. This upgrade reduced lighting utilization and costs by at least 50%, increasing energy efficiency. The transition from older fluorescent bulbs to LED fixtures further amplified the energy savings achieved.

2.3.2. Financial Incentives and Rebates

Lighting upgrades are a popular way to save energy, with LED bulbs and fixtures offering significant reductions in wattage compared to traditional options. Businesses can replace bulbs or entire fixtures for substantial savings. Simply changing a bulb or tube can reduce the wattage by more than 40%.

Most utility companies offer rebates and incentives to encourage businesses to upgrade their lighting system for lower energy-consumption alternatives. These programs are aligned with initiatives from the US Department of Energy, aimed to help businesses become more energy efficient. Additional rebate opportunities may be available upon demonstrating a kW (kilowatt) consumption reduction after completing an energy-saving project, including heating, ventilation, and air conditioning (HVAC) system upgrades. You are encouraged to investigate rebate incentives and opportunities through your local utility provider. [PSE_2022] [PEC_2024]

To secure rebates, businesses typically need to go through a trade ally or a licensed professional like a distributor or contractor. The trade ally helps with the application process, which may involve pre-installation assessments and post-installation paperwork.

Here are some preparatory steps to take advantage of these rebates:

1. Verify that your utility offers LED lighting rebates.
2. Find a licensed trade ally to handle paperwork and calculations.
3. Assess current lighting energy use and calculate potential savings from new LED systems.
4. Once installation is complete, the trade ally will secure the rebate with the utility company. Additionally, the ally will work with the local utility company to provide them with all the necessary information to secure the energy rebate.
5. During this phase, the information that will be required could include:
    - Company's W9.
    - Address of the location where the work was completed.
    - Copy of the building's utility bill.
    - Inspection to make sure lighting has been installed.
    - Full workbook completed per utility, providing a list of existing lighting and then all spec sheets for upgraded lighting.
    - Signed applications when paperwork is submitted.

Implementing occupancy sensors and transitioning to LED lighting technology represent cost-effective and impactful strategies for optimizing energy use within your facility. By capitalizing on these improvements, businesses can significantly reduce energy consumption while taking advantage of rebates and incentives offered by utility companies.

2.4. The Cost of Vampire Equipment

Equipment that is left powered on when not actively in use will continue to draw power and waste energy, negatively impacting your energy consumption in several ways:

1. **Increased Electricity Costs:** Equipment left powered on while idle or not in use continues to draw power, leading to higher electricity bills without any corresponding benefit in terms of performance.
2. **Increased Cooling Costs:** The additional heat generated by these vampire units contributes to the overall heat load in the room, driving HVAC units to work harder and use unnecessary energy.

2.4.1. Strategies for Locating Vampire Equipment

Effectively tackling vampire equipment requires an organized approach to identify and address its sources. Here are some key strategies:

1. **Outlet-Level Power Monitoring:** Implementing outlet-level power monitoring provides valuable insights into the power consumption of individual devices. This data can help pinpoint the location of equipment with high idle power draw, potentially indicating a drain on the system's power consumption.
2. **Establishing Baseline Power Consumption:** Creating a baseline for each device's idle power consumption allows for easy comparison with real-time power usage data. Significant deviations from the baseline can suggest a device is in operation, whereas underutilized or not functioning equipment will steadily remain at the baseline.
3. **Device Rationalization:** By comparing power consumption data with known active devices, it's possible to identify underutilized or non-operational equipment. In some cases, underutilized duplicate devices can be combined to perform as one to reduce the load. Discovering ways to decommission non-operational equipment can significantly enhance optimization efforts.
4. **Regular Site Audits:** Scheduling periodic site audits, complemented by the baseline power consumption data, helps maintain an ongoing understanding of equipment performance. This approach facilitates the identification of consistently underperforming devices or those no longer required, providing an opportunity to consolidate or decommission the device(s). [MUT_2021]

By implementing these strategies, organizations can effectively identify and eliminate vampire devices, significantly reducing energy consumption and operational costs.

3. Optimizing your ISP's Cooling Systems for Energy Efficiency

When it comes to larger, easier wins for your site's efficiency, look at your HVAC systems and airflow. If the HVAC units are not configured properly, well maintained, or are working harder than they should be, you are losing energy efficiency. This section explores key strategies for optimizing your ISP's cooling systems to achieve significant energy savings.

3.1. Leveraging Economization for Free Cooling

Many sites' HVAC units possess an "economization" feature that utilizes outside air for direct cooling whenever ambient conditions permit. This free cooling eliminates the need for mechanical cooling via compressors and circulators, resulting in substantial energy reductions.

In cooler climates, economization can be particularly advantageous. In one case study, we enabled economization on a previously non-utilized HVAC unit, resulting in a staggering 31% reduction in power consumption (Figure 4). It is important to note that this test was conducted during winter in the northeastern United States, where ideal outdoor temperatures offered abundant free cooling time. Additionally, the initial implementation of the economization mode exhibited "short cycling." The technician who engaged the free cooling did not optimize the settings, but rather just turned the feature on. Once the technician returned and optimized the settings properly, the short cycling ended, and the HVAC unit consistently remained in the free cooling state longer.

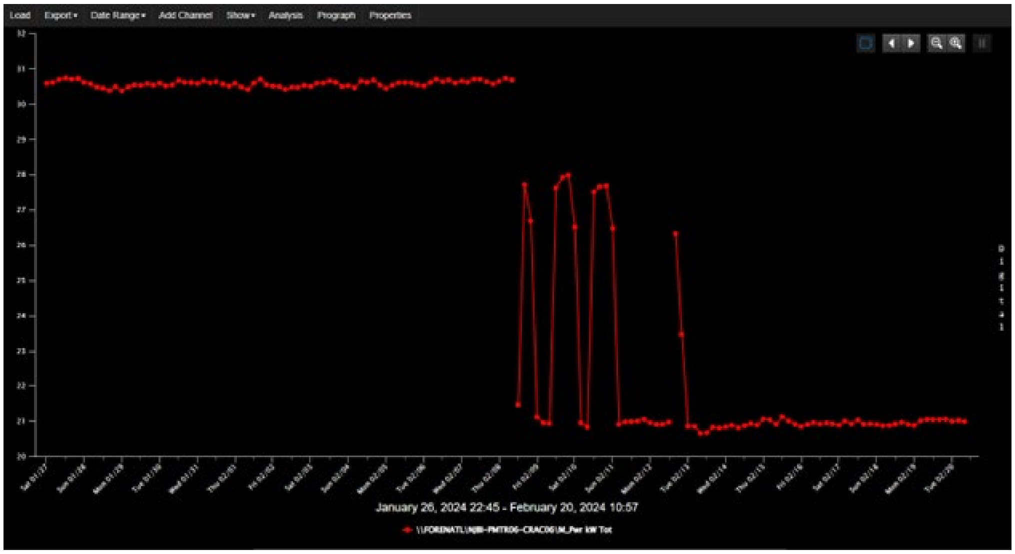

Figure 4 - Graph of an HVAC unit's power consumption before and after engaging the economization feature

3.2. Optimizing Airflow Management

Inefficient airflow management within an ISP site can create localized hot spots, often addressed through pedestal fans or portable air conditioning units. These devices can signify potential airflow issues and contribute to increased energy consumption.

An additional case study highlights this concept where the site exhibited hot spots and had additional cooling support installed throughout the room. This site has traditional downflow cooling units on a raised floor that direct the cold air to the aisles via perforated flooring tiles, server racks oriented in a hot aisle/cold aisle layout, and a shared return hot air plenum space above the drop ceiling.

Upon closer inspection, it was discovered that the facility lacked the appropriate amount of perforated ceiling tiles. This absence prevented the effective removal of hot air from the whitespace and its return to the HVAC unit for cooling. Essentially, the unit was starved of the hot air it needed to operate efficiently. Additional perforated ceiling tiles addressed this issue, enabling the unit to maintain the room temperature setpoint without excessive exertion. A 12.5% reduction in cooling energy consumption was achieved (Figure 5) solely by studying the room's airflow and finding a solution to optimize airflow management.

Afterward, additional opportunities were discovered, such as sealing up any holes in the floor with KoldLoks and optimizing the cold air perforated tile settings to deliver adequate air to the equipment.

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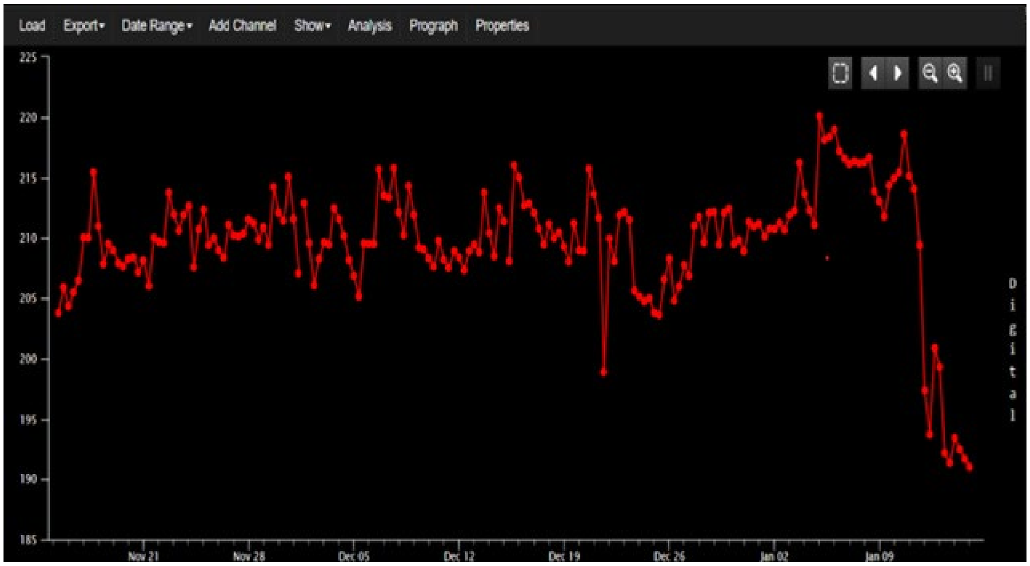

Figure 5 - Graph showing a drop in average kW based purely on airflow alignment and optimization

3.3. Evaluating Setpoint Temperature Adjustments

Another optimization strategy for ISP cooling involves cautiously increasing the setpoint temperature on HVAC units. While not universally applicable, standardizing a slightly higher setpoint can yield significant energy savings through cooling and maintenance costs by not having the equipment run harder than it should.

A test conducted in New Jersey during the winter season explored this approach. HVAC unit setpoints were raised by two degrees, from 68°F (20°C) to 70°F (21.1°C). The observed effects included:

- Increased cycling-off periods for HVAC units when satisfying the temperature setpoint.
- Extended economization mode operation.
- Reduced compressor usage. Starting at 75-100% mechanical cooling prior, to 25-50% mechanical cooling, and even operating 100% free cooling after the change.

Figure 6 depicts the graphical representation of the data collected during this month-long experiment. Despite slightly warmer ambient temperatures in the two weeks following the setpoint adjustment, a 4.4% decrease in overall energy consumption was observed. While the HVAC unit's kW consumption decreased by roughly 9%, the increased operational time of the outdoor condenser fans due to longer economization mode usage partially offset these gains.

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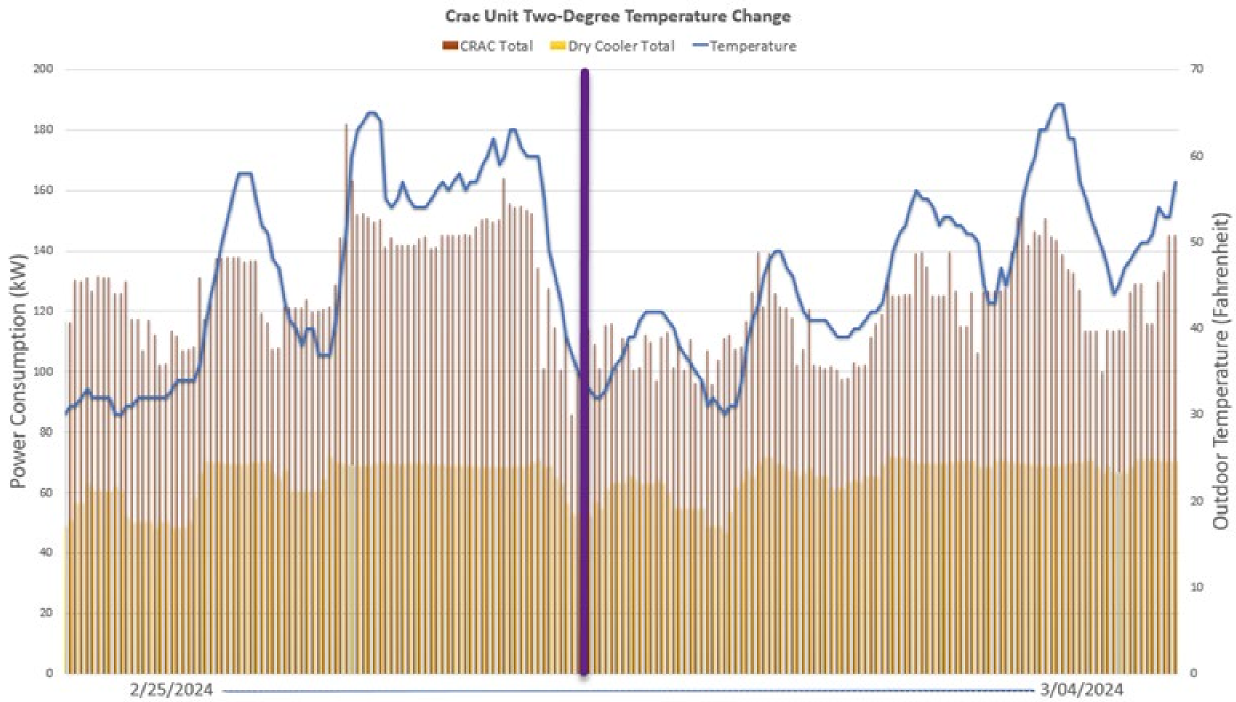

Figure 6 - Graph showing the cooling power consumption and outdoor temperature results of adjusting an HVAC temperature setting by two degrees. Before/ after indicated by the purple line.

Implementing these strategies of leveraging economization, optimizing airflow management, and cautiously adjusting setpoint temperatures (even if only by two degrees) can lead to significant year-over-year (YOY) reductions in your site's energy consumption associated with cooling systems.

4. OSP Power Optimization

Cable operators have always supplied power to amplifiers in the plant regardless of customer penetration. The same can be said for the actives; each output port runs even if the port is terminated. Looking at the SCTE Power Pyramid, most energy usage falls into the OSP section at the base. In this section, we will explore several options for saving energy within the outside plant.

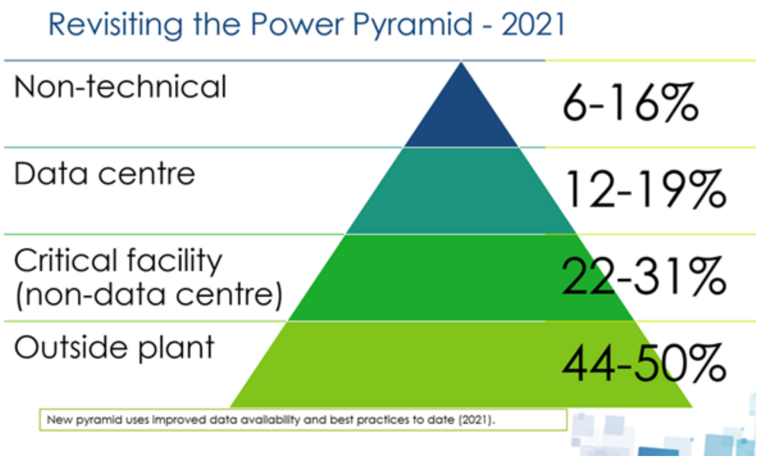

Figure 7 - SCTE Power Pyramid

4.1. Node Output

Nodes typically have four output legs, each with a radio frequency (RF) amplifier chip called a power amplifier (PA) or hybrid. The wattage of each one of these PAs can vary depending on the frequency range and gain. For this paper, we are using an average hybrid wattage of 20W per output. In a sampling of nodes, 60% of the node ports were unused equaling 120W of consumption. Across 5,000 nodes, a total of 600W in wasted energy would be from unused ports. The national average per kilowatt hour in 2022 was 12.62 cents, totaling $5,000 in potential yearly energy savings.

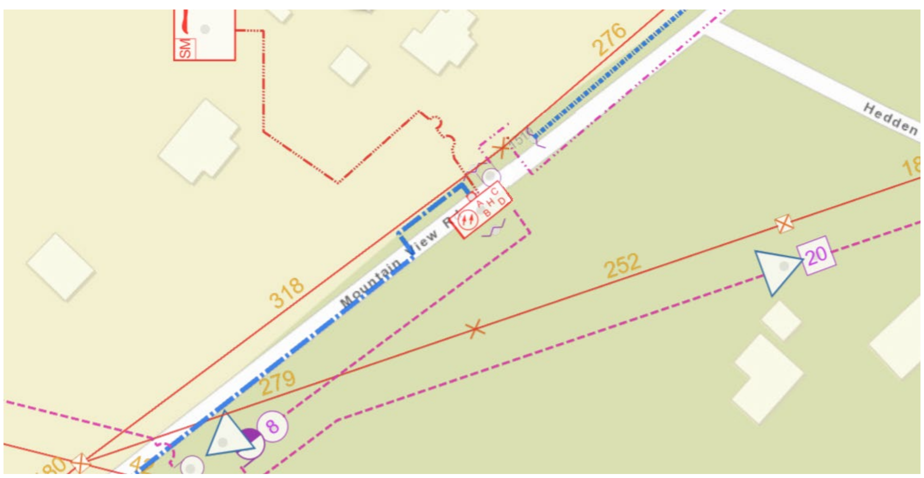

Figure 8 - Node output example

One risk associated with the decommissioning of unused node ports is verification. Analog nodes typically do not have a two-way communication system in place that allows for monitoring or control. These nodes would require a one-time physical verification before decommissioning any ports, which is a one off expensive that needs to be accounted for. To eliminate this extra cost node inspection can be completed during routine maintenance visits.

Digital nodes with a physical layer (PHY) in the field do allow for control, depending on the software being used. Automation could also be created to verify customer traffic on individual ports by increasing the attenuation of the return. Once the return has been attenuated, customer premise equipment (CPE) can be measured to determine if any device level changes were noticed. This can be done incrementally, or all at once where the return is turned off during a maintenance window. Once this verification is completed, the digital node can then power down any unused ports until they are needed in the future.

4.2. Amplifier Outputs

These same energy-saving techniques can be applied to the current 1.2GHz amplifiers, particularly actives with multiple output ports. Some manufacturers have installed a manual jumper inside the module, allowing the user to disable an unused port. Looking at the same node sampling, 8% of the total output ports were unused. Based on an industry average wattage of 15W per PA, the average potential savings per Watt hour is $267 in a year. Calculating the same average across 5,000 nodes, the total potential energy savings would be $6,000 a year.

Although there is significant opportunity to reduce the number of specific unused ports being used in the OSP, another area for savings is the decommissioning of vampire amplifiers in the field. Vampire amplifiers are defined as any amplifier that terminates at the end of a driveway, feeding non-active customers, new construction, or buildings with new architecture. Installation of new services would require a trip, and the amplifiers could be turned back on at that time. An average of the energy consumed by the current 1.2GHz amplifiers equals 30 to 45W of energy per station A sampling of nodes found only 1% of the amplifiers were vampires, with a potential for $16,000 a year in savings.

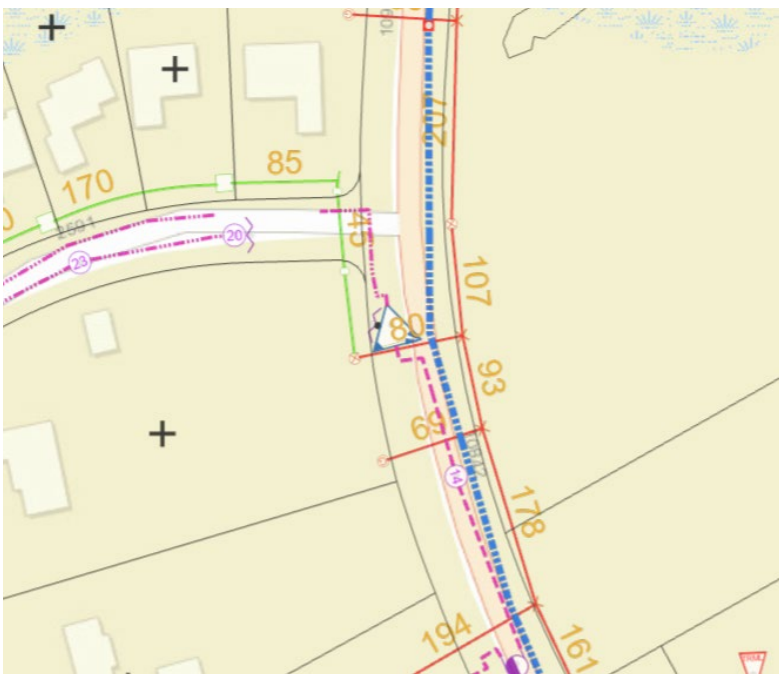

Figure 9 - Amplifier output example

The implementation of Smart amplifiers could also be used for power savings. Each amplifier will have similar telemetry to that of a Distributed Access Architecture (DAA) node, or the same two-way communication functionality. Once the topology of a node has been determined, an amplifier will know if customer CPE is communicating with the DAA virtual cable modem terminating system (vCMTS). The Smart amplifier could go through the same process of increasing the return attenuation per port to validate there is no impact on customer equipment. Furthermore, the Smart amplifier may also know if a cable is plugged into a specific port and can shut down the power to any PA once no connection is determined.

4.3. Node Power Supplies

Node power supplies offer easy energy savings if redundancy has been implemented. Power supply redundancy is when two node power supply modules are installed into a housing for either load sharing or just to provide hot standby power. Each one of these extra power supplies typically draws an average of 18W per unit. Calculating the total energy savings, 5,000 nodes would be 90kWh or $100,000 in potential savings.

5. Conclusion

This paper identified various cost-effective strategies for the ISP and OSP portions of the network to significantly reduce energy consumption. The analysis focused on readily implementable solutions with minimal upfront investment, making them attractive options to carry out immediately.

By applying these measures, service providers can optimize energy consumption across various aspects of their operations, including R-PDUs, rectifier capacity, lighting systems, cooling systems, and OSP equipment. The combined effect of these optimizations can help slay those "energy vampires" lurking in your network and can lead to substantial financial savings and reduced environmental impact.

Abbreviations

AC	alternating current
CPE	customer premise equipment
DAA	distributed access architecture
DC	direct current
HVAC	heating, ventilation, and air conditioning
ISP	inside plant
K	kelvin
kW	kilowatt
kWh	kilo-watt hour
LED	light-emitting diode
N+1	need plus one
OPEX	operating expense
OSP	outside plant
PA	powered amplifier
PHY	physical layer of the osi model
RF	radio frequency
ROI	return on investment
R-PDU	rack-mounted power distribution unit
SCTE	Society of Cable Telecommunications Engineers
vCMTS	virtual cable modem terminating system
YoY	year-over-year

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