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Society of Cable Telecommunications Engineers
International Society of Broadband Experts

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International Society of Broadband Experts™
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From the Editors

Our industry set out on a challenge to develop and expand the network to what is branded as the 10G network. This advanced network will require higher reliability and that reliability will depend on higher reliability of power to ensure the foundation of service is always available. At the same time, continued pressures on the grid grow to include how to incorporate more renewable and distributed generation power. In this important issue of the SCTE Journal of Energy Management our authors evaluate the strategy of microgrids for cable, managing incorporation of renewable power with little to no capital expense, advantages of phase change materials to combat cooling costs, access network advanced design using artificial intelligence, and airflow management to optimize cooling needs. We target a Journal release to spur further thought and share ideas to help our industry expand beyond what is the day to day norm to help plan for the challenges that lie ahead. We as editors, hope you enjoy this latest issue.

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Enhancing the Customer Experience Utilizing Modular and Scalable Power Delivery Systems

A Technical Paper prepared for SCTE•ISBE by the 2020 Microgrid Working Group – Subcommittee on Preliminary Education

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FOREWARD

To further the SCTE Energy 2020 Sub-Committee initiative to focus on the development of best practices, the Microgrids Initiative Workgroup is submitting a series of white papers on microgrid technology and its' relationship to the Cable Industry.

The SCTE Microgrid Working Group's charter is to "educate and inform the SCTE community on the applicability and use of microgrid technology in cable operator facilities." This would include: defining operational practices and standards; demonstrating the technology is deployable and manageable for service providers; facilitating communication between service providers, industry partners and other standards organizations; and creating a library of microgrid use cases showing how resiliency can be improved, operational costs reduced, and deployment times decreased through the appropriate application of microgrid technologies.

This document is an early effort from a sub-committee composed of several authors with direct knowledge of both microgrids and the cable industry. It includes observations of these subject matter experts in distributed energy resources (DER) such as solar, wind, energy storage and the importance of their direct coupling to DC loads. In addition, input was received by association members, providing insights into the deployment of microgrid technologies (MGT).

This paper will not address new cable technologies which are currently being deployed in the industry. The implementation of Remote-PHY, Fiber Deep, DOCSIS, GPON and Virtual Cable Modem Termination Systems will revolutionize the industry. How they will affect each cable operator is unique. However, while the energy impact of these new technologies is relevant, the sub-committee will not be discussing the technologies themselves. So, while the decommissioning of existing equipment may reduce power requirements, it remains critical to understand where the industry is today against standards already in place.

Executive Summary

Currently, some basic microgrid technology is deployed throughout the Cable Industry. However, for the most part, the industry has not yet taken full advantage of existing, available and relevant advanced microgrid technologies. Most existing systems are not ready to work like advanced microgrids are designed to perform. That said, cable operators can, and should, continue to leverage already deployed technologies. This paper will attempt to address how microgrid technology has continued to evolve, along with the issues facing the application of future microgrid technologies, to illustrate the benefits of adopting a proactive rather than reactive implementation strategy.

Today, traditional deployments of energy infrastructure in the cable industry includes DC and AC uninterruptable power systems, long term battery storage, transfer switches and switchgear. It also includes generator sets, renewables and other power sources that have been combined in a traditional manner to provide resiliency and sustainability when grid power is lost. And while these are many of the basic elements of a microgrid, they often lack the topology and control required for full microgrid implementation and performance. However, existing deployments can provide a foundation for transition into a more resilient and functional microgrid architecture.

The fundamental premise behind the deployment of a true microgrid architecture by a Cable Operator is the increasing opportunity to take advantage of evolving microgrid technology. This would allow new capital models and power system topology designs to reduce cost of ownership and expand or enhance the resiliency and reliability of services. The following pages include an overview and industry expert perspectives meant to provide a deeper background on issues discussed in the working group.

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1. Introduction and Background

The Cable Industry has been utilizing microgrid concepts for decades. Basic microgrids have been deployed throughout the cable industry, yet they have not taken full advantage of all their potential benefits. Cable Operators can and should begin to fully leverage more advanced and complete microgrid technologies. We address how microgrids got to where they are now and address the issues facing future microgrids. The benefits of implementing proactive and reactive changes: proactive in managing cost, generation sources and loads; reactive during utility events and other equipment failures.

The Cable Industry is not alone in its quest for better power system implementation. In considering the most effective path for collaboration with others, SCTE has begun a collaboration with The EMerge Alliance, a broad, multi-industry group that has taken on a leadership role to assist industries in enabling a more rapid adoption and development of advanced microgrid technologies. The Alliance is well-known for spearheading vanguard standards. This collaboration has been instrumental in helping the newly formed SCTE Microgrid Working Group get off to a running start.

Chaired by SCTE Standards members and EMerge VP Tim Martinson, this working group is uniquely positioned to assist our industry in rapidly capturing already recognized standards for review as it relates to the applicability and opportunity of microgrid technology beyond 2020.

The SCTE Microgrid Working Group reviewed a variety of outcomes related to the future of microgrids within the Cable Industry. A keen interest developed around combining existing technologies with newer, more efficient, energy technologies to secure increasingly reliable, resilient and sustainable sources of power. Utilizing alternative energy sources and integrating them with 380Vdc from existing microgrid technologies resonated with the committee. This approach offers its own set of unique opportunities. For example, in an article published in 2014, the *Data Center Discovery* noted that *‘users of 380vDC can benefit from the ability to integrate with renewable energy sources such as photovoltaic (solar) arrays and fuel cells.’* With this concept in mind, the authors of this White Paper looked deep into existing benefits of DC-coupling as it relates to incorporating new solar projects with existing microgrids.

Previously published articles and prior analysis have established a framework for an industry focused initiative like the Microgrids Initiative sub-group, under the coordination and guidelines as determined by the SCTE. Microgrid research published by several of the Department of Energy’s National Research Labs, including LBNL, NREL, PNNL, and Sandia is readily available at their information sites for public review. Other research has been published by both the IEEE and the IEC on this subject as well. During Cable-Tec Expo in 2014, the SCTE launched its own Energy 2020 Program specifically focused on our industry’s unique needs. Since that time, this initiative has been driven by the powerful realization that absent of an advanced electricity service capable of supporting those increasingly demanding needs could cause irreparable harm and financial burden to the Cable Industry. The working group’s initial effort has focused its research on examining energy spend across the distinctive operational elements of the industry and has ultimately resulted in the information and perspective presented in this White Paper.

Executive management of SCTE collaborated and communicated with subject matter experts (SME’s) from the organization, along with a variety of SME’s representing the vendor community. Hours were spent meeting in plenary (face-to-face) sessions and on bi-weekly webinar conferences. The group worked diligently on establishing a framework that would define standards and establish best practices that ultimately provide defined energy reduction goals. A significant step along the way was the Adaptive Power Systems Interface Specification (SCTE 216) APSIS™ standard developed for the publication of the *SCTE Engineering Committee: Energy Management Subcommittee APSIS Paper* distributed in 2015. This paper defined the future fiber and coax network elements that manage the Cable Industry’s content with the ability to manage individual energy usage resulting in the ability to have ‘Smart Loads’ in Headends and Hubs of the content delivery network. Finally, an example relevant to this topic is the SCTE 218 2015 Alternative Energy, Taxes, Incentives, and Policy Reference Document Alternative Energy document that represents a comprehensive look at navigating through the complicated regulatory environments and the potential to ascertain the financial benefits of the published government programs.

In 2019, SCTE announced the creation of a Microgrids Workgroup to focus on the specific role that microgrids could play in meeting our industries power needs going forward. The workgroup's first challenge was to characterize and quantify the use of electricity across a variety of operational elements. From there, the workgroup developed a comprehensive understanding of what these elements would suggest regarding the design and use of microgrids to meet these needs. This paper is the first of what this sub-committee anticipates as a series of industry publications.

1.1. Evolution or Revolution?

Since cable television first appeared to the greater audience in the 1940's, technologies advanced exponentially, forever altering the customer expectation and experience. Today, we embrace continual advancements and rapid enhancements: IoT technologies and high-speed connectivity and networking; the functionalities and capabilities of 5G; the impact of anti-trust laws and subsequent actions against telecommunications and the technology industry; and the reality of an ever-present IoC (Internet of Changes) unfolding before our eyes. Rapid deployment of new and improved technologies is demanded by consumers and businesses. This landscape is in constant flux, changing dramatically wherever network power is being consumed. With the growing consumption of electric energy, the challenge to manage and maintain these sources and loads escalates, creating a multi-pronged situation. For years, the Cable Industry remained relatively constant, however as service options increase, energy consumption increases and expectations escalate, so we must remain proactive to reflect these needs.

The Cable Industry is going through yet another generational technology upgrade as the means and methods of service delivery evolves. This evolution is having a direct effect on the distribution of power within the network. In addition, recent extended regional power outages and other disruptions to the power grid are driving government agencies, utilities, and policy makers to increasingly embrace and financially support the utilization of microgrid technology to enable better power surety.

Within the Cable Operator footprint, access networks and edge facilities are creating greater value, although consuming a significant and increasing percentage of an energy budget. At the same time, there is continual pressure to reduce operating costs at these same remote facilities. Microgrid technology offers opportunities to decrease stranded asset CAPEX and OPEX costs, increase resiliency, reduce grid dependency, lower energy costs, and meet sustainability objectives. Coupling incentives, cost reductions, and revenue sources previously not available changes the financial model, whether enhancing existing structures or building new critical infrastructure mission critical facilities.

Given the current environment, the Cable Industry should consider modifying current critical infrastructure topology and integrating microgrid technology into its infrastructure deployments.

The Microgrid Working Group has defined seven (7) use cases as base microgrid applications for the Cable Operator industry. These include:

- Data Centers
- National Distribution Centers
- Backbone / Colocation Sites
- Administrative Offices
- Access Network Power Supplies (outside plant)
- Edge Facilities (Hubs and Head-Ends)
- Fleet Transportation / EV Charging

These use cases align with the major industry groupings established within SCTE as part of the early Energy 2020 focus. Depicted below is the approximate percentage of energy use for each group established in a prior study done within SCTE. These use cases represent potential target areas for microgrid deployment investigation.

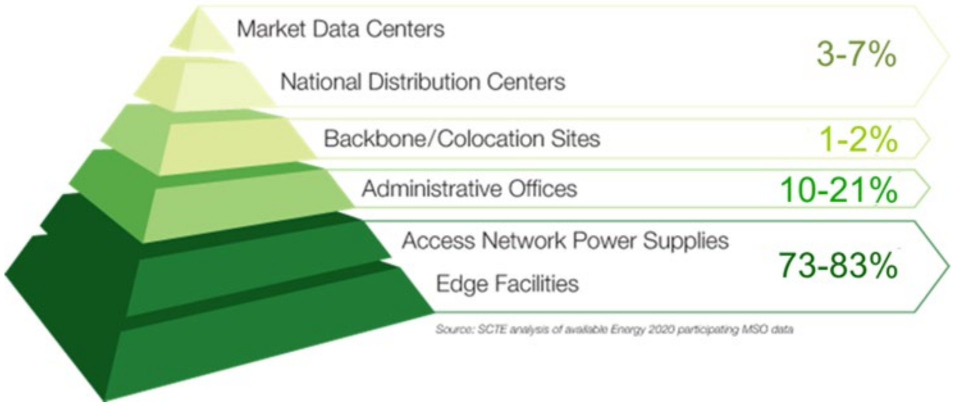


Figure 1 – Percentage of Energy Use for Each Group, published 2016

1.2. What is a Microgrid?

Microgrids in general are defined by their functional performance and can vary in size, complexity and scope. The SCTE Microgrid Working Group's (MGWG's) definition of a microgrid consists of a single behind the meter application that is generally aligned with a building location. The MGWG has adopted the following standard definition for consistency of discussion:

> A microgrid is a localized group of interconnected, integrated and managed electricity sources, loads, and storage devices that may connect with other local microgrids and/or the traditional electrical utility grid (macrogrid): properly implemented they can seamlessly and selectively supply power or use power; and/or disconnect from the main power source, functioning independently (island mode) as conditions, policies or economics dictate.

In one sense, what was old is new again. A microgrid or small grid is where the electrical industry started, ironically with the battle between AC and DC power. Electricity dissemination was first enabled by small local distributed grids with local generation. As the grid network became larger and more efficient, power generation moved away from population centers, with consumers losing the ability to operate autonomously: they developed a dependency upon centralized generation facilities connected through power distribution networks or grids.

Common operational scenarios associated with microgrid operations have been defined by the IEEE (The Institute of Electrical and Electronics Engineers). Below are six (6) common scenarios used within the IEEE documentation to classify different operational use case options. Multiple scenarios may apply to a microgrid location or a given mode of operation.

- Scenario 1 - Utility Only: No Synchronous Generation (SG) or Distributed Energy Resources (DER): This operational scenario is a conventional power system design where the utility supplies all load with no local generation or renewable energy sources.
- Scenario 2 - Utility Plus DER's: No SG: This operational scenario is a conventional microgrid with local distributed generation, like renewables, sharing power (paralleling) with the utility when there is not enough wind and/or solar generation to island.
- Scenario 3 - Utility Plus SG's and DER's: This scenario is a comprehensive microgrid operation with generation, and / or renewables generation which can export the excess power into the utility. Demand response, power factor correction, or voltage stability opportunities are represented here.
- Scenario 4 - Loss of Utility: This scenario is a system whereby it maintains local operation under the loss of utility. The system is capable of voltage / frequency regulation and power sharing.
- Scenario 5 - Load Shedding: No Utility, No DER's: This scenario represents the case that when the utility is not available and there is not enough local generation to support all loads, some non-critical loads will be shed based upon a predetermined program.
- Scenario 6 - 100% DER's: This scenario represents the case when there are enough on-site renewable generation to power the attached load, the system will operate without utility or SG support. Excess power may be available to export back into the islanding grid.

Most network critical facilities incorporate local generation, fuel storage, energy storage, and some form of an uninterruptable power system (UPS), supplying a mix of AC/DC loads. These systems are designed to operate autonomously, without the utility grid present, for reasonable periods of time. This design approach has been deployed to ensure continuity of service to end user customers. The basic components needed for a microgrid are typically available in an existing MSO site. In most cases, what is missing is the required topological arrangement, control technology, and proper application components. Converting from existing technologies to microgrid operation is best and most efficiently accomplished in conjunction with, or replacement of, existing infrastructure during periods of upgrade or expansion.

2. Microgrid Technology: an Industry and Government View

Recognizing the increased resiliency, lower energy costs and flexibility of microgrids, public utilities and governments are beginning to embrace the microgrid solution. We believe that this market expansion will further drive down costs, motivating public leaders to incentivize the marketplace as multiple fronts align to leverage these technologies.

2.1. Industry Experience Driving New, Collaborative Control Concepts for Microgrids

The electric grid in America has moved from a single entity source-controlled resource to a complex multi-user platform, with sources and loads changing without the direction of a centralized national controlling authority. This complexity has created both opportunity and difficulty for local utility providers. More advanced utilities are embracing change as they recognize dispatchable resources as an advantage to the network rather than a burden. This relationship is developing into new economic opportunities for owners and developers of microgrids. Entities in multiple areas that permit selling excess generation power back to utility companies during times of need, offering voltage and frequency stabilization, and / or power factor improvements. These advantages have increased the adoption of microgrid technology in almost all sectors; however, adoption is lagging in areas where the utility has been able to legislatively restrict adoption, or utility infrastructure deployments are not as constrained.

Changes in public policy, government goals and pressure from electricity consumers are having both a positive and negative impact on utilities and the grid. Initial efforts were focusing on renewable generation, creating unwanted stability issues on the grid. An increasing number of states are moving past 'solar only' systems and creating incentives that address the timing imbalance between peak demand and renewable energy production a.k.a. the Duck Curve, eventually changing economic opportunities for all users. Traditional regulated and non-regulated utility business models are also a problem.

The global microgrid technology market is essential to multiple initiatives that impact energy, resiliency, societal and economic growth. Software control and analytics are required for real time power understanding and control. Microgrids are a viable option for an array of distinct use cases. When there is no power available, or power is delayed by infrastructure requirements or limitations for distribution or transmission, the distributed architecture a microgrid represents is ideal. Microgrids can greatly simplify the integration of renewable generation (on-site or grid supplied) while supporting the bulk grid by locally managing critical technical issues that would otherwise burden the bulk grid provider. Most significant for the Cable Industry is the ability of a microgrid to provide reliable power in the event of a loss of the bulk grid. A well designed and implemented microgrid can 'island' itself from the grid, subsequently reconnecting itself safely and seamlessly when the grid becomes available.

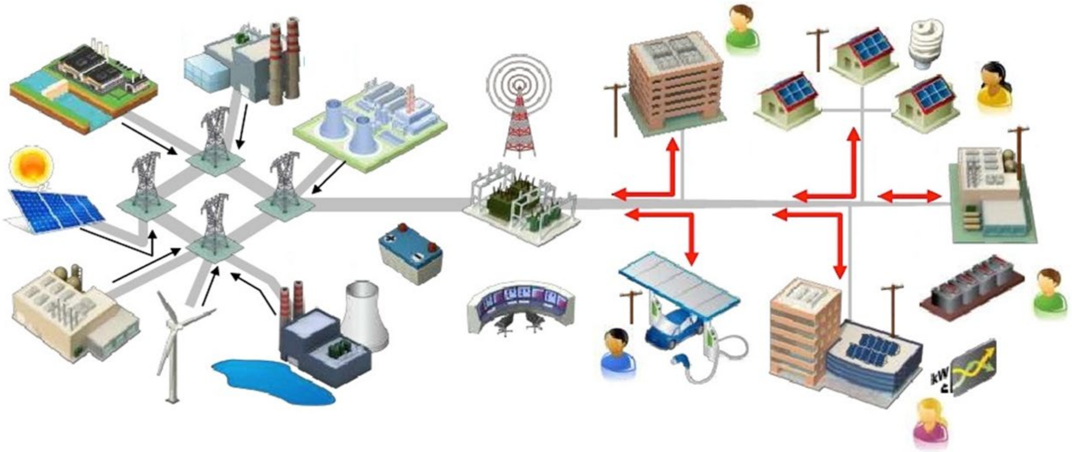
All three (3) of these high-level use cases have core economic components which include participation in energy markets and the critical element of capital cost. Virtually all microgrids (except for very small or research specific microgrids) must integrate or supplement existing infrastructure, not simply replace existing infrastructure. The ability to balance power and energy with economic value remains the potential barrier.

2.2. The Changing General Utility Perspective

Historically, traditional national utilities have resisted the creation of microgrids within their footprint, similar in manner to that of any other 3rd party uncontrolled source. Grid network stability requires constant balance between source and load. The challenge to a utility today is much different than it was several years ago, when said utility owned and controlled all generational assets. Technology and necessity are driving new communication and control methodologies, turning a microgrid into a dispatchable resource available for stabilization, load flow and control. This is creating new economic models as the market grows and matures.

Several states are leading these efforts: in particular, the Public Utility Commission of New York and the New York ISO (Independent System Operator) are prime examples of advancement. Both organizations have recognized that the future grid will have a bi-directional power flow likely with multiple microgrids.

EPRI (Electric Power Research Institute), a non-profit industry group funded by the utility industry, offers the following graphic depicting this bi-directional power flow model.



Source: EPRI

Figure 2 – Bi-Directional Power Flow Model

2.3. One Utility's Perspective

As an example, PG&E electricity customers can enroll in demand response programs offered by 3rd party Demand Response Providers (DRPs). In general, demand response programs provide customers with incentives to reduce electricity consumption during times of peak demand. Rule 24 in the state of California allows 3rd party DRPs to solicit PG&E customers to participate in their demand response programs, enabling them to 'bid into' the electricity reduction in the wholesale electricity market.

California is also experiencing rapid growth in renewables deployment. Solar produces energy that instantaneously feeds into the grid when installed without associated energy storage. Online generation must match the changing solar profile to maintain grid stability. Local battery storage installed to supplement sporadic PV energy production and / or energy use is critical to the ongoing stability of California's electrical grid. PG&E programs already exist, and new ones are being developed to provide incentives for energy storage coupled with PV systems.

In the future, the ability to store energy and deliver it as-is and when needed by the local grid utility will become a revenue stream for participating organizations. This new source of income can be used to improve the ROI of the capital dollars used to fund the stored energy technology, offset operating energy costs or applied to further enhance resiliency. Energy as a Service is a one of the new market options being offered by companies like Panasonic and Shell New Energy.

Microgrids can reduce overall utility provided energy by producing and using energy locally with sources such as on-site wind, solar and fuel cells. The economic advantage for microgrid owners comes from the ability to control and manage their own power sources and loads to peak shave usage behind the meter, better manage power factors, adjust for time of day usage, and control other rate and / or tariff events.

2.4. A Perspective from the NREL and CableLabs

The DOE and other government agencies have been spearheading the definition of microgrids while documenting their value. The intersection of two (2) predominant industry organizations, NREL (National Renewable Energy Laboratory) and CableLabs should send a clear message that it is time for the Cable Industry to grab the lead and create microgrid standards specifically designed for Cable Operators.

Microgrids are very important to the Cable Industry for several reasons:

1. They provide additional resiliency and reliability in times of unplanned power outages when managing on-site DER and non-critical loads. During severe weather, microgrids can provide the ability to continue providing power to critical facilities.
2. With competitively priced on-site self-generation from renewable and other energy sources, microgrids can provide a hedge to increasing costs of energy for Cable Operations.
3. In the presence of time of use electricity pricing, microgrids can allow Cable Operators to buy low and sell high for their operational energy needs, as well as the energy needs of their customers.
4. Existing, stranded asset, emergency power systems can be integrated within microgrid systems as a transition foundation to build from.

The idea of purchasing energy at low rates and selling high over a 24-hour period will become increasingly important. Time of use rates become pervasive to effectively manage the supply and demand balance of the grid in the presence of increasing on-site / utility grade renewable energy resources. This is evidenced by the increasing number of cities, states and countries that have made 100% renewable generation commitments, most notably, the states of California, Hawaii and several others by 2045.

While these economic drivers are valid, other areas of the country with lower electrical costs are justifying microgrids by combining other value propositions with time of use gains. Such value propositions include added resiliency, demand shaving, and the utilization to the benefits of higher voltage direct current in a DC-Coupled microgrid.

Editorial Note: The command and control to drive utility policy in collaboration with the Cable Industry is needed sooner rather than later.

2.5. EMP’s (Electro Magnetic Pulse), Man Made and Natural

While the threat of an EMP is both unlikely to happen and expensive to deal with, the reality of such an event is gaining serious attention at the Federal and Utility level. The impact of a major outage at one (1) or more interconnects is truly overwhelming. Whether it be a massive solar flare, a natural weather disaster, or a man-made / terrorist disaster, the issue to address it is how to best prepare for a sustained outage of the grid.

Solar storms and extreme space weather are fascinating phenomena that motivate scientific investigation with substantial real-world consequences for the power grid. In 1989, a relatively minor solar event interrupted power in Canada for more than nine (9) hours. In 1859, the so-called Carrington Event struck North America with a walloping solar storm and induced a geomagnetic disturbance (GMD), damaging telegraph lines and stations. Across the continent, the sun randomly produces coronal mass injections (CMEs) that are capable of physically destroying much of the power grid the nation depends upon. The only defense thus far is that the Earth was not in a direct path that the directional CMEs could cause much damage.

On July 23, 2012, the Earth narrowly missed a major coronal mass injection from the sun by about nine (9) days.[i] Described as a Carrington-Level storm, according to estimates by Lloyds of London, it could create a power outage lasting as long as 18 months from NYC to DC.”[ii][iii][iv]

On March 26, 2019 President Trump created Executive Order 13865. The review and the corresponding hardening of critical infrastructures is defined as follows:

“Critical infrastructure means systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.”

The Cable Industry is seen as an essential service and needs to evaluate how this Executive Order applies to them. Will EMP protected critical infrastructure become a factor in choosing which service provider is selected to provide telecommunications services? Will it eventually be mandated by law? Should the Cable Industry take the lead now to leverage its technology? Moving forward should all Cable Industry upgrades / improvements to the fiber/coax network and associated Hubs, Headend and Data Centers include devices or specifications that would neutralize or minimize the impacts of an EMP event?

3. Microgrids Support the Enhancement of the Customer Experience

As stated earlier, microgrid technologies are currently deployed within the Cable Industry, but they are not positioned to best leverage the new microgrid technologies. The opportunity exists for the industry to take a review of what is changing in their networks, followed by an exploration of how the industry should or can leverage new technologies. As the industry strives to enhance the customer experience, there needs to be a conscious review of how energy use has evolved. As new cable technologies are deployed in the access networks, infrastructure costs to accommodate these changes could end up being fiscally prohibitive in meeting business goals without proper consideration of modular microgrid technology deployments.

3.1. Current State: Cable Headend Example

The Cable Industry started in the 1950’s and has been dramatically evolving ever since.

In the early days of cable television, the industry did not have to conform to telecommunication standards for four (4) to eight (8) hours of battery backup power established by the FTC. As cable technology evolved and included telephony and life-safety services, the industry responded with concepts defined by Telcordia standards. These tended to drive large quantities of energy storage be directly connected to the load. Each Cable Operator had their own guidelines as to how much energy storage a specific site required. The concepts were quite simple.

Based on specifics like local utility integrity, trust in back up generation, transfer switch technology and the proximity of technicians to respond to a grid outage, an industry decision would be made. The energy storage was based on value and the need to provide enough energy to offset potential failure of the backup generator and transfer switch system. Redundant generators became common at high value sites.

Climate control systems were backed up solely by generators. As new technologies driving the enhancement of the customer experience are being deployed, the power density is growing from one kW per rack to as high as forty kW per rack. With the kW / hour requirements established at each site, massive amounts of energy storage were deployed. Once again, the only purpose of this energy storage was to assure that the critical load was protected in the event of a generator system failure. Meanwhile, generator systems and new energy storage technologies in microgrid solutions have advanced greatly.

In addition to these changes, implementation of solar only solutions is being deployed based primarily on a desire to meet environmental sustainability goals of utility cost reduction. The next two (2) sections will suggest a few options for the Cable Industry to take under advisement.

3.2. Resiliency Microgrids for Backup Power

At a recent closed-door meeting, a highly respected Cable Operator Vice President stated that the priorities as it relates to microgrid implementations are to: meet business objectives (fast deployment of enhancing the customer experience); assure that the customer experience was not interrupted (reliability and resiliency); and to see an increase in energy savings (reduce cost and waste). Similar projects running on a national scale are being driven by a similar component of resiliency.

Several years back, an in-depth study of a Time Warner multi-use facility was conducted by NREL.[v]

The study claimed that "…the United States has seen an increase in the number of high-impact, high-cost natural disasters: seven of the ten (10) costliest storms in U.S. history have occurred in the last ten (10) years." The chart below visually depicts these statistics.

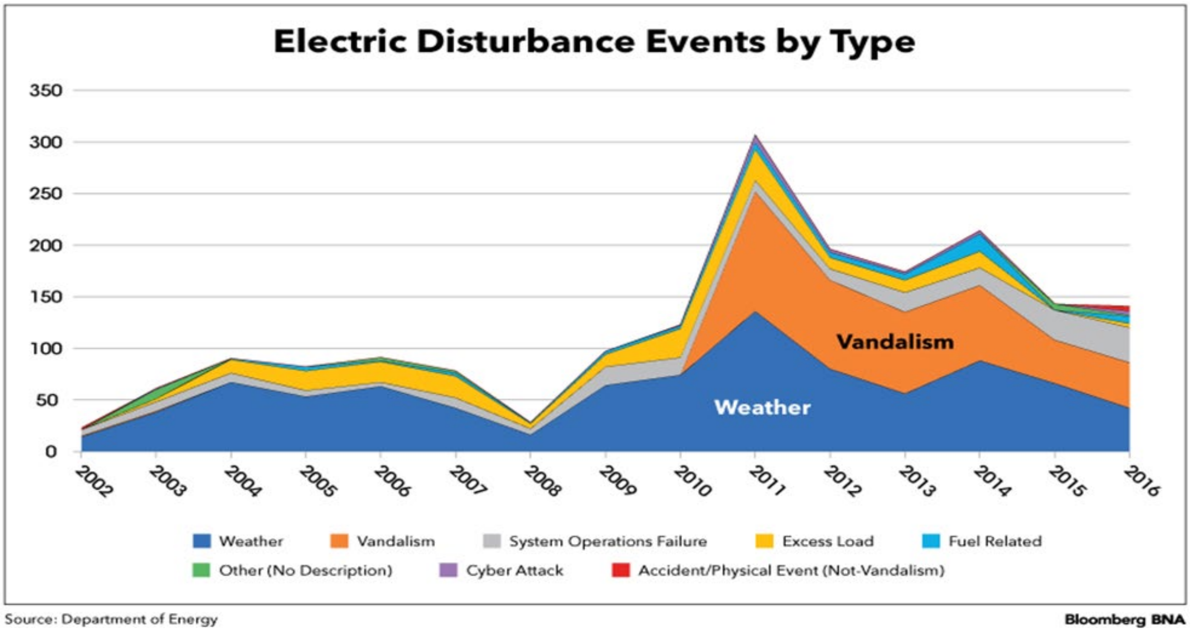


Figure 3 – Electric Disturbance Events by Type

The study points out that diesel fuel supplies typically last only one (1) to two (2) days, partially due to regulatory requirements that limit on-site fuel storage. During a disaster, fuel supplies may be diverted to higher priority needs or delivery trucks may not be able to maneuver through disaster area streets to make deliveries. Even natural gas is subject to supply issues, as we experienced during Hurricane Sandy where in some areas the natural gas infrastructure was destroyed. For safety reasons, the incoming natural gas supply had to be shut down. Additionally, we have seen that the advancements in solar and energy storage have had a combined effect of driving utility prices down to all-time lows and we expect to see continued declines (an abundance of natural gas is creating low energy prices).

The study claims that "…RE / storage / diesel hybrid microgrids provide resiliency + energy savings + cost savings." The facility studied had an average load of 150kW, ranging from 120 to 250kW, with a critical load of about 155kW. Backup generation was 300kW and the annual electric bill in this Southern California facility was $250,000.

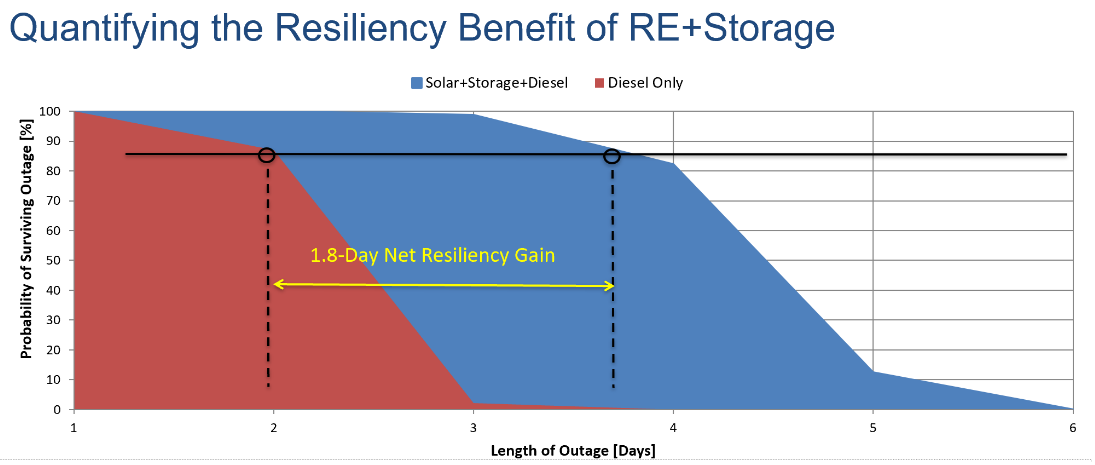


Figure 4 – Quantifying the Resiliency Benefit of RE + Storage

In this case, the sizing of the solar and energy storage was based on the ability to integrate the utility grid-connected system and save $519,000 over the project lifecycle, yet it provided no added resiliency.

Quantifying the Economic Benefit of Solar PV+Battery

Solar PV Size	845 kW
Battery Size	155 kW, 172 kWh
Developer Cost[a]	$2,450,000
Annual O&M	$16,900 /yr
% Renewable Energy	91%
Year 1 Savings	$42,000
Net Present Value	$519,000
Lifecycle Savings	18%

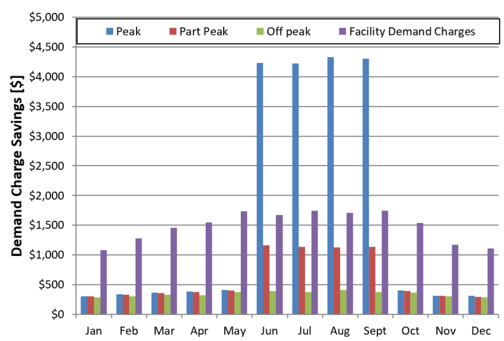


Figure 5 – Quantifying the Economic Benefit of Solar PV+ Battery

The Results:

- Solar PV allows a generator to turn off during daytime hours, extending diesel fuel supply
- Battery provides backup during transition from diesel to solar and during cloudy times
- After diesel fuel is exhausted, PV + battery can support daytime loads indefinitely
- The microgrid system saves only $104,000 over the project life ($415,000 less) but provides an extra 1.8 days resilience plus indefinite daytime power. Is an extra 1.8 days plus indefinite daytime power resiliency worth $415,000?

3.3. Headends and Hubs Focus

When it comes to discussing headends and hubs in the Cable Industry, the sub-committee referenced key points from a published press release in February of 2015 by SCTE entitled *Edge Facilities and HFC Network Represent Greatest Opportunity for Energy Cost Avoidance by Cable System Operators*. It focused on opportunities within the vendor community, highlighting a need for collaboration and innovation to drive efficiency in the marketplace.

As quoted in the article, "…the greatest opportunity for energy 'cost avoidance' in cable system networks is in the HFC plant from the headend or hub to the home. Between 73% and 83% of cable's overall energy consumption is by hubs and headends, as well as the access network power supplies powering the active equipment on the HFC network, according to detailed SCTE analysis of energy usage of a cross section of major operators."

From the Tier One Cable Operator perspective, we are interested in the microgrid concept and its various configuration possibilities. We have not done a microgrid project yet, but we are in the process of evaluating an energy storage project that could lead to a microgrid. We have done fuel cells and solar at a few sites (typically not critical facilities, but Admin or at least a hybrid of Critical / Admin).[vi]

4. Direct Current in Microgrids

The Microgrid Working Group examined how combining microgrid and direct current technologies can address several objectives. Aside from high cost electric markets, microgrids and DC coupled microgrids are being deployed in industries who share similar goals with the Cable Operators. Direct current is increasingly being used to provide direct coupling to DERs (Distributed Energy Resources) such as solar, wind, energy storage and DC loads.

4.1. The EMerge-SCTE Relationship

As part of the Energy 2020 Initiative, the newly created SCTE Microgrid Working Group, is supported by the Emerge Alliance and chaired by EMerge VP Tim Martinson. This working group is uniquely positioned to quickly assist the Cable Industry in creating applicable industry standards. The collaboration between the EMerge Alliance and SCTE has already created an active forum for advanced discussions regarding microgrids. This committee, along with other adjacent industry trade and standards organizations, will bring a broad range of information to the Cable Industry on the expanded usage of DC power systems and microgrids.

4.2. EMerge History and Background

Nearly ten (10) years ago a small group of technologists and entrepreneurs joined forces to explore best practices to incorporate direct current electricity into large power systems. Early exploration focused on the increasing use of native direct current sources, loads and storage in residential, commercial and technical applications. Started as an informal collaboration between Armstrong World Industries, Philips, Osram, Johnson Controls and Nextek Power Systems, the group formalized its work and created a non-profit (501c) open industry association called the EMerge Alliance in 2008. As the group evolved, it attracted additional member organizations including data centers, central office telephony companies and some highly recognized Cable Industry stakeholders like Eltek and Vertiv. Membership has expanded to more than 100+ academic, government, industry, and non-profit organizations including the DoE, DoD and GSA. Several national laboratories joined, including Lawrence Berkeley, Pacific Northwest, NREL and Oakridge. Its formal trade organization and SDO liaisons include IEEE, IEC, IET, EPRI, NFPA, UL, SEPA, PHIUS, NEMA, SEIA, CABA, ZigBee, EnOcean, USB, PSMA, CVTA, CLASP, BACnet, ASE, and others. All its participants share the simple goal of catalyzing further development and practical use of DC and hybrid AC / DC power systems.

Since its establishment, the EMerge Alliance has taken a leadership role in advocating for greater use of direct current in microgrids and other, largely hybrid AC / DC power systems. With the increasing use of DC in sourcing, storing and utilization of electricity, direct current is becoming recognized as a game changer, capable of enabling a more rapid adoption and the overall development of microgrid technology in general.

But rapidly evolving power system technologies and topologies have left gaps in industry standards' portfolios. EMerge's lean, largely 'virtual' organization structure leaves it nimble to quickly create and facilitate the use or adoption (in whole or in part) of advanced standards that serve to fill those gaps. The Alliance is well known for spearheading these vanguard standards related to direct current. It follows this up by simply helping other standards organizations (SDOs) develop their own standards, bringing together early technology developers and adopters to share new information and accumulated expertise with more veteran standards stakeholders. Two (2) of the standards often referred to when using direct current in power systems are EMerge's Occupied Space Standard version 2.0, which defines low voltage DC power distribution system requirements for use in commercial building interiors and their Data / Telecom Standard version 1.02, which defines low voltage DC power distribution system requirements in data centers and telecom central offices. The Alliance claims little proprietorship over the development of such standards: it sees its role as more of a catalyst, regardless of who creates, promulgates or uses them.

Early EMerge work had primarily focused on power standards for systems on the enterprise / premises side or 'behind' the utility meter. As such, they have addressed the integration of power sources, wiring infrastructures, controls and a wide variety of loads (such as lighting, HVAC, appliances, IT gear and the connected Internet of [smart] Things) in platforms that add flexibility, surety, resiliency, economy, safety and sustainability in building and campus power system architectures. But more recently, with a focus on the integration of these renewable and distributed site-based energy sources, the Alliance is helping prepare a new generation of electricity consumers and service providers to use these distributed, site based energy platforms (sometimes called nanogrids) in conjunction with a second tier of neighborhood and community microgrids. The end game for EMerge is to see this approach become a part of an evolving new electricity network, a grid of grids, or as some are calling it the 'Enernet.'

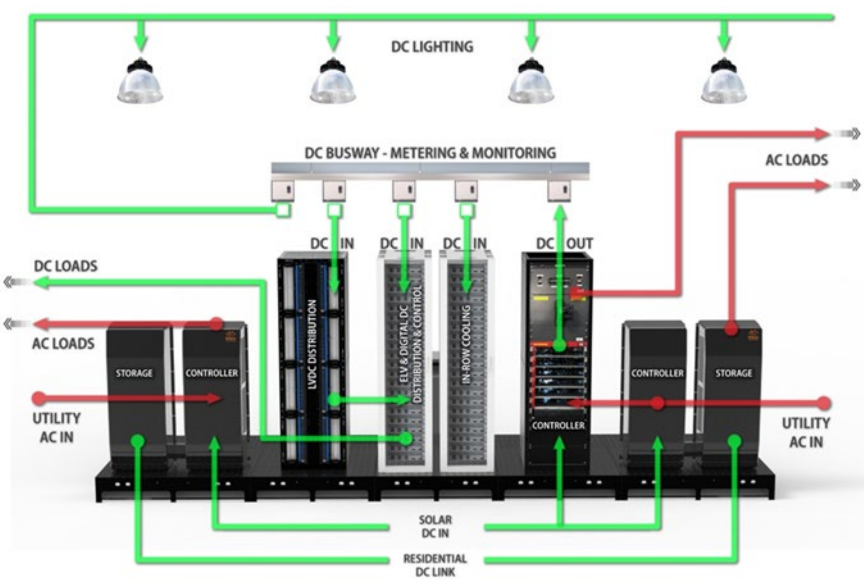


Figure 6 – Microgrids Example

But Emerge goes beyond simple standards development, playing a role in the promotion and industry education relevant to the technologies it supports and addresses. With the microgrid and distributed energy market taking off, there is great interest in an increased utilization of direct current electricity, alone or in combination with AC electricity. Leading by example, at the recent National Smart Energy Week Exposition in September 2018, hosted by the Smart Electric Power Alliance and the Solar Energy Industry Association, its 'live' on-site generic demonstration microgrid powered over 100 exhibitor booths in an islandable configuration that also fed back excess power it generated on-site (using onsite solar arrays and storage) to the convention center itself. It has stood up similar demonstration microgrids at other major tradeshows including the Greenbuild International and various Consumer Electronics shows. As shown by the 'live' microgrids demonstrated by EMerge, hybrid AC / DC microgrid technology is a 'here and now' thing and not just a PowerPoint presentation fantasy or academic science project. *This EMerge demonstration microgrid linked three (3) first tier converter / controllers and two (2) battery banks.*

Thanks to advanced power electronics, the integration of site-based energy resources can help in meeting economic, surety, resiliency, and power system growth goals. After seeing one (1) of the demonstrations, the question most frequently asked is "…who do I talk with to find out more about the products, services and companies that can help with my next energy infrastructure project?"

4.3. The Benefits of Collaboration

Working in collaboration with EMerge will enhance SCTE's access to equipment and service organization representatives, and a broad cross-section of general industry experts, academia, and government thought leaders focused in the field of evolving AC / DC power systems and microgrids. It will help working group members stay current with trends, activities, new legislation, revised codes and interpretations that affect the use of DC and hybrid AC / DC power systems. Personal and professional growth is a significant benefit of being involved in such trailblazing initiatives. And finally, it gives participating organizations a unique voice in making certain their products and services are properly considered in industry standards requirements.

5. Conclusion

The Cable Industry looks to further standardize on strategic energy concepts like that of microgrids, as discussed opportunities continue to development. This environment warrants the need to continue to trial, pilot and ultimately move to commercial deployment of microgrid technologies. It has been demonstrated and documented that microgrids are being deployed globally. While economics and the rising cost of electricity may drive the widescale deployment of solar, wind and other distributed energy resources, there is a realization that energy storage must be addressed to fully realize the benefits of multi-source smart power grid scenarios adhering to cable specific use cases mentioned in the early pages of this paper. Finally, the consensus body represented in the SCTE Microgrid Working Group will pave the way to help accelerate the deployment of robust microgrid solutions that lay the foundation of new network for the implementation of ideas as represented by the announcement of 10G early in 2019.

6. Abbreviations and Definitions

6.3. Abbreviations

10G	10 gigabit fixed broadband technology
5G	5th generation cellular network technology
ASE	Alliance to Save Energy
BACnet	A data communication protocol for building automation and control networks
CABA	Continental Automated Buildings Association
CCAP	Converged Cable Access Platform
CESAR	Converged Edge Services Access Router
CLASP	A national, nonpartisan, anti-poverty non-profit advancing policy solutions for low-income people
CMAP	Converged Multiservice Access Platform
CMTS	Cable Modem Termination System

CORD	Central Office Rearchitected as a Data Center Project
CVTA	Connected Vehicle Trade Association
DER	Distributed Energy Resources
DOCSIS®	Data Over Cable Systems Interface Standard
DoD	US Department of Defense
DoE	US Department of Energy
EMerge Alliance	Open Standards NGO advancing vanguard standards and promoting greater use of DC and hybrid AC / DC power systems
EPON	Ethernet Passive Optical Networks
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
GPON	Gigabit Passive Optical Networks
GSA	US General Services Administration
HFC	Hybrid Fiber Coax
HVAC	Heating, Ventilation, Air Conditioning
IEC	International Electrotechnical Commission
IEEE-SA	Institute of Electrical & Electronic Engineers Standards Association
IET	Institution of Engineering & Technology
ISO	Independent System Operator
MDU	Multi Dwelling Unit
MetroE	Metro Ethernet
Cable operator	Multiple Cable System Operator
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NREL	US National Renewable Energy Laboratory
PHIUS	Passive House Institute of the United States
PSMA	Power Supply Manufacturers Association
PUC	Public Utility Commission
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
R-Phy	Remote Phy
RTO	Regional Transmission Organization
SDO	Standards Development Organizations
SEIA	Solar Energy Industries Association
SEPA	Smart Electric Power Alliance
TSO	Electric Power Transmission System Operator
UL	Underwriters Laboratories
USB-IF	Universal Serial Bus Implementers Forum
ZigBee	ZigBee Wireless IoT Association

6.4. Definitions

Distributed Energy Resource	A distributed energy resource (DER) is a unit of power generation that operates locally and is connected to a larger power grid at the distribution level, generally via a local microgrid
Grid of Grids or Enernet	The self-organizing tiered interconnection of nanogrids and microgrids with a macrogrid which enables transactively managed and balanced bi-direction flow of electricity between its tiers: information flowing from the user to the hub

Macrogrid	A network of transmission lines, substations, transformers and more, that deliver electricity from power plants to consumers: in the continental US, the electric grid consists of three (3) systems: Eastern, Western Interconnect, and Texas Interconnects
Micro grid	Localized group of interconnected, integrated and managed electricity sources, loads, and storage devices that may connect with other local microgrids and / or the traditional electrical utility grid (macrogrid): properly implemented they can seamlessly and selectively supply power or use power; and / or disconnect from the main power source, functioning independently (island mode) as conditions, policies or economics dictate (analogous to a local or metro area network in computing)
NanoGrid	A single domain of power for voltage, capacity, reliability, administration, and price: they are indifferent to whether a utility grid is present (always, never, or intermittently): analogous to a personal or device area network in computing. Information flowing from the hub to the user
Non-Synchronous Electricity	A term generally applied to direct current electricity since its characteristic flat wave form does not require multiple lines of equal voltage to be synchronized when interconnected
Resiliency (Infrastucture)	Infrastructure resilience is the ability to reduce the magnitude and / or duration of disruptive events: the effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and / or rapidly recover from a potentially disruptive event
Tier 1 Grid	Refers to nanogrids and microgrids that operate in or on a single owner's property and control: power flows within this tier may or may not be bi-directional
Tier 2 Grid	Refers to microgrids comprised of an interconnected group of nanogrids and / or other microgrids that have a single connection to a macrogrid that is managed transactively: power flows within this tier are bi-directional
Tier 3 Grid	A macrogrid that includes bi-directional interconnections and central power services for microgrids and uni-directional connection and services for non-microgrid power consumers

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Optimizing Node+0 Outside Plant Design for Cost and Energy Efficiency Using Artificial Intelligence

Findings from a Proof-of-Concept Effort

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1. Introduction

A proof-of-concept (POC) effort was undertaken in late 2017 and early 2018 to determine the efficacy of applying expert system artificial intelligence technology to the production of preliminary designs for Node+0 outside plant which are optimized for cost, and to substantially reducing the time and cost of producing such designs. The POC was undertaken with the cooperation of a major North American cable operator that is considering N+0 architecture for deployment in, at least, portions of its current footprint.

Success of the pilot was defined as the production of preliminary designs which are:

- about 70% to 80% complete with respect to construction drawings, where the remaining 30% to 20% of the design work (to produce construction drawings) can only be done by engineers in the field;
- visually comparable to what would be produced manually by an experienced outside plant (OSP) planner/engineer;
- technically compliant with all of the operator’s relevant network design standards;
- reliable for use in the planning, costing and capital approval process;
- essentially buildable as presented, and;
- the least costly to build.

The efficient use of N+0 nodes in any given preliminary design was fundamental to the optimization for lowest capital cost. An immediate corollary effect is the reduction of energy consumption in N+0 outside plant, which is fundamental to reaching the industry’s Energy 2020 objectives.

The POC was successful. The subsequent sections of this paper describe the general methodology employed, significant findings, design deliverables, and the results in terms of cost and energy savings potential.

2. Methodology

The POC was conducted using as-built OSP designs as extracted from the operator’s network engineering/geospatial information system (GIS) platform as basis for executing a N+0 preliminary design exercise. A total of 45 existing traditionally configured HFC nodes were ultimately processed by the automated design tool to produce N+0 preliminary designs.

Fundamental to the execution of the POC was a very close and collegial working relationship between the operator’s senior OSP planning personnel and the POC team. Given that the POC was a significant step into uncharted territory and could lead to very powerful benefits for the operator, it was critical that everyone involved in the POC be completely comfortable in sharing critical information and objectively assessing the results produced.

The automated design tool was configured to use the operator’s RF design standards, approved OSP equipment list, and standard network construction cost estimation figures.

Rules for the placement of new N+0 nodes within the OSP infrastructure were articulated and formalized so that the automated design tool would tend to place the N+0 nodes much as would an experienced OSP planner in order to minimize the likelihood that any selected location would be proven unfeasible in the field engineering process.

Decisions were made regarding the use of existing cable, placement of new cable, and placement of new infrastructure

The resulting preliminary designs were compared to manually produced preliminary designs for the same 45 nodes, thus providing a basis for direct comparison of the relative qualities of the two sets of preliminary designs on a node-by-node basis. The POC team did not have access to the manually produced preliminary designs until after the first production run of the automated design tool.

An interesting and rather impactful finding made during the POC was that, whereas the automated design tool strictly followed the operator’s written RF design standards and other rules without exception, the OSP planners often exceeded certain of the RF engineering specifications - to an extent they knew from experience to be practically acceptable - in order to optimize their respective designs. Indeed, the first production run resulted in preliminary designs that tended to be substantially unacceptable when compared to the manually produced designs.

This finding resulted in a second round of working discussions with the cable operator’s OSP planners to identify and explicitly state where the automated design tool could similarly exceed those same RF engineering specifications, the intent being to allow the automated design tool to operate most consistently with how the OSP planners actually produced their preliminary designs. (See section 3. Design Rules below for further details in this regard.)

During the second round of working discussions, it was decided that the automated design tool was to optimize solely for capital cost while, of course, respecting the design rules, whereas in the first production run, the optimizer considered both capital cost and a number of network characteristics that ultimately proved irrelevant to producing optimal preliminary designs.

The figure below provides a simple overview of the automated design tool in terms of inputs, basic processes, and outputs.

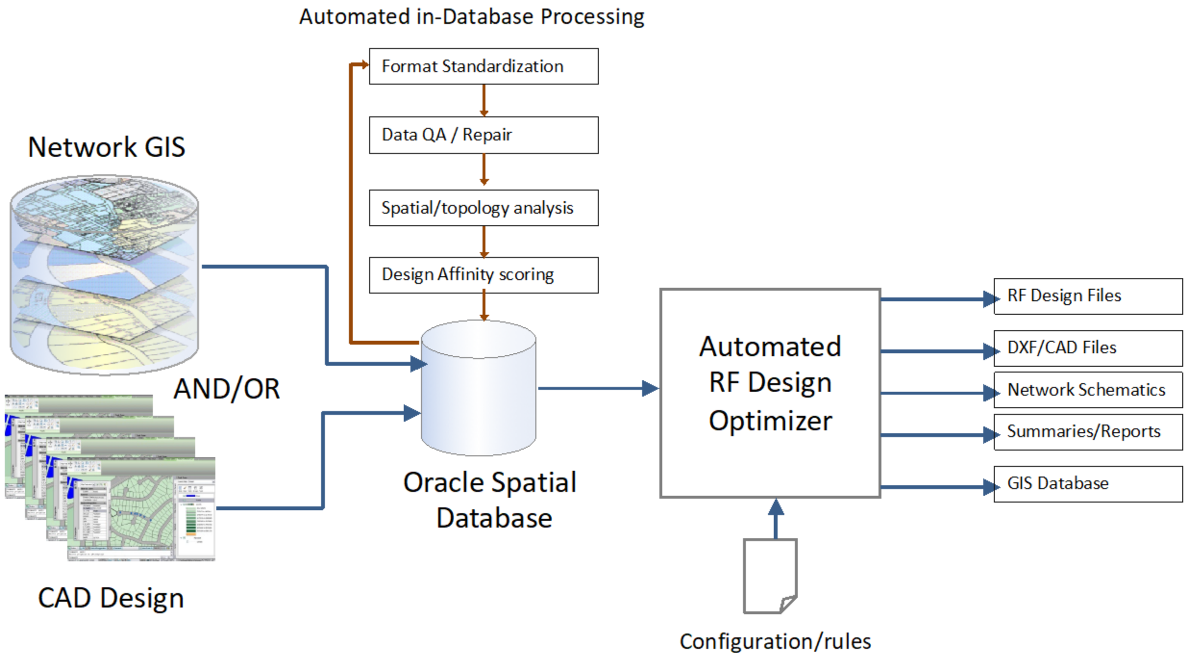


Figure 1 - Overview of Automated Design Process

3. Design Rules

Significant effort was expended in the articulation and documentation of the design rules under which the automated design was to operate. This was due to the relative complexity and inter-relatedness of the rules themselves, as well as the fact that the OSP planners often exceeded certain RF engineering specifications when producing N+0 preliminary designs.

As noted in section 2. Methodology above, the ways in which the operator's OSP planners exceeded certain RF engineering specifications were ultimately identified and documented, at least to the extent required for the purposes of the POC. The specific variations to the design rules identified were as follows:

- The hard limits on homes passed per node (128), homes passed per segment (64), and homes passed per bus (32) were removed, thus allowing the design tool to fully utilize the available RF signal;
- The upper frequency and lower frequency tap spigot minimum threshold levels could be relaxed by up to 0.5 dB where doing so would avoid the placement of an otherwise required additional node;
- Coaxial cable could be added where doing so would avoid the placement of an otherwise required node AND where the cost of adding such cable would result in a lower total cost than adding a node, and;
- Cost minimization is to be taken into consideration in the optimization of the designs.

Notwithstanding the variations noted above, it was agreed by the cable operator and the POC team that the design rules applied to the second round would not necessarily result in designs being produced by the automated design tool that could be compared on an "apples-to-apples" basis with the designs previously produced by the operator's OSP planners, given:

- the recognition that the OSP planners may have used their knowledge of "customary design tolerances" to make node placement decisions that would slightly further transgress RF threshold values whereas the automated tool would not do so absent human intervention;
- the expectation that both the OSP planners and the automated design tool may place N+0 nodes in locations that prove, in the field engineering process, to be not feasible.

3.1. RF Engineering Specifications

The table below identifies the relevant RF values and equipment types applied by the automated design tool in the production of N+0 preliminary designs.

Table 1 - RF Engineering Specifications

1	Upper/Lower Forward Design Frequency	F1/F8(50/860 MHz)
2	Return Design Frequency	R2 (42MHz)
3	Upper/Lower Tap Spigot Minimum Threshold	7.4/18.5db
3 - Stretched	Upper/Lower Tap Spigot Minimum Threshold	6.9/18.0db
4	Return Minimum Threshold Level at Node	8.0dB
5	CPE return launch level	40.0dB
6	New FTTC Node Type	NC4000HD-3
7	Assumed Tap Series	MGT2
8	Assumed 2-way splitter model	LHS-102
9	Assumed 3-way splitter model	LHS-103
10	Cable type for new distribution cable	P3-625
11	Cable type for new express cable	P3-750
12	RF ports per FTTC Node	4
13	Max homes passed per FTTC Node RF port	RF levels to govern
14	Ideal homes passed per FTTC Node RF port	RF levels to govern

The following additional rules were defined and utilized by the automated design tool:

1. Design to and within vertical multiple-dwelling units (MDU) is not in scope;
2. Existing RF cabling as specified in network engineering/GIS platform as-built data must be utilized as-is, i.e. the automated design tool cannot replace existing cable with better performing cable;
3. The RF design cannot extend beyond the original HFC node serving area boundaries;
4. The RF design must include all single-family and low-rise MDU residential addresses currently served by RF plant, as shown in network engineering/GIS platform as-built data (via a non-zero house count on an associated structure).

3.2. N+0 Node Placement Rules

Significant effort was expended to define rules for the placement of new N+0 nodes by the automated design tool such that it would place new nodes in locations most likely to be consistent with where an experienced OSP planner would do so, or would be deemed acceptable by the OSP planner even if said location might not have been one selected thereby.

In general, the cable operator required that N+0 nodes be distributed generally evenly throughout the original HFC node serving area rather than be concentrated in a small area within the node serving area. This requirement was intended to result in asimilar placement of fiber-optic cable and splice cases throughout the serving area, which would be supportive of a future deployment of a fiber-to-the-home network architecture.

After reviewing several early revisions with MSO engineers, it became apparent that the decision making process for placing nodes was inherently fuzzy, and required finding a balance between a number of competing goals. The fuzzy logic engine utilized a scoring system which was developed by assigning a “relative preference” score from 0 to 10 for each structure where a node may potentially be placed, as indicated in Table 2 below.

Table 2 - Node Placement Location Scoring

Structure/Location	Point Score
Existing node contained in existing structure (note that the 1st N+0 node will be placed at the location of the existing HFC node)	10
Power supply contained in existing structure	10
Trunk amp or bridger amp contained in existing structure	3
Line amp contained in existing structure	2
Existing Structure is on side-lot location	1
Structure is not side-lot located and has no active equipment attached	1

The following rules were also defined and utilized by the automated design tool:

1. N+0 nodes will, with the sole exception being noted in 2. below, be placed in an underground environment. This pertains even if the existing network to which the new node must connect is aerial, whereby a new at-grade cabinet and a short amount of underground route will be placed and connected to an appropriate pole, to which a riser will be added, if a riser does not

already exist. The riser length will be included when calculating the length of cable added to the node.

2. If an HFC node already exists on a pole, an N+0 node may be attached to that pole in place of the existing HFC node.

3. The scoring protocol noted in the chart above is to be applied to the selection of a location for each new node. However, the scoring protocol is to be overridden if it produces a design with a higher construction cost than one with more favorable node locations.

4. In cases where more than one location condition is true, only the highest-scoring condition will be considered, and the location/structure will be assigned the point-score of the highest scoring location condition.

5. If no locations with non-zero points are available for placement of a required node, a new side-lot cabinet will be created at the midpoint between the front and rear property lines of the adjacent lot, along with underground route sufficient to connect the new location to the existing network, and the N+0 node will be placed in the new cabinet.

6. If no locations with a non-zero score are available for placement of a required node, and no side-lot locations exist within the area reachable by the Node+0 plant, then a new cabinet may be placed at a location with a zero-points score;

7. No N+0 nodes can be placed on back-lots (defined by distance of support structure from road centerlines), and;

8. Only one N+0 node may be placed at any given location.

3.3. Cable Placement and Usage

The following rules were defined and utilized by the automated design tool:

1. To minimize cost, existing cable is to be re-used where possible and practical. However, new trunk and distribution cable may be added as necessary for efficient design. (The addition of new cable was governed more by the cost minimization requirements rather than engineering constraints.)

2. In situations where the in-place cable does not have the performance characteristics to carry 1GHz signals, no action will be taken in the POC and the design will be assumed to be valid even though the cable does not meet the operator's performance specifications.

3.4. Drop Count Determination

The following rules were defined and utilized by the automated design tool:

1. Residential, commercial, multiple dwelling unit (MDU) and other types of drop count will be determined by using the network engineering/GIS data associated with each structure, not any on-screen CAD annotation.

2. No distinction will be made between the various drop types. Taps will be configured to support the total number of required drops, regardless of the type of structure being connected to the network.

3.5. Costing Rules

The following costing rules, as derived from the cable operator's standard cost estimation tables, were applied to both the preliminary designs produced manually and those produced by the automated design tool:

1. The cost of each new node shall be $40,000, regardless of location. For greater clarity, the cost of the first new N+0 node shall be considered as $40,000, even though it will always be placed at the location of the existing HFC node.

2. The cost of new coaxial cable shall be based on route-metres, not cable-metres. For greater clarity, this means that the cost of placing a single cable in a new underground structure shall be calculated at $135/metre AND the cost of placing a second, third, fourth and fifth cable in the same underground structure shall be calculated at $0/metre (zero dollars per metre).

4. Design Output Products

The automated design tool produced the following output products for each preliminary design:

1. A DXF format network map showing all relevant structure, nodes, cable and taps to describe the design of the RF network downstream of each N+0 node;

2. A CSV "Design File" listing each network element and its sequence in the signal flow, its upstream connection, its configuration characteristics as relevant to the device type, and the support structure(s) to which the network element is physically attached;

3. A CSV file summarizing the cost estimate and bill-of-material;

4. A set of schematic drawings showing how network segments are assigned to node RF outputs.

The formatting and graphical appearance of the network maps, while essentially consistent with any map produced by the operator's network engineering/GIS platform, was tailored specifically to allow the operator's OSP personnel to more easily evaluate the designs produced by the automated design tool.

5. Analysis Of Results

The design products of the automated design tool were analyzed both visually (qualitatively) and using database queries (quantitatively) to characterize them in a consistent and meaningful manner. The manually produced designs (in the form of AutoCAD) drawings were similarly analyzed and characterized.

Qualitatively, the following was observed:

1. The manually produced preliminary designs and those produced by the automated design tool were visually comparable to one another;

2. Certain differences in N+0 node placement were understandable given that the automated design tool did not take into consideration the deliberate distribution of fiber cable across the original HFC node boundary, which was a factor in the manual preliminary design production process, and which would tend to shift N+0 node locations accordingly;

3. As well, other differences in N+0 node placement were explained by the requirement that the automated design tool N+0 node placement rules are weighted to avoid placing new infrastructure and N+0 nodes at any location other than a side lot, whereas such weighting did not apply to the manual production process.

In terms of a quantitative analysis, the chart below provides an overall summary of the preliminary designs produced by the automated design tool and presents same in comparison to the manually produced preliminary designs. As can be seen in the chart, the automated design tool placed fewer N+0 nodes, employed more additional coaxial cable, and indicated a lower overall capital cost relative to the manually produced preliminary designs.

Table 3 - Summary of Quantitative Analysis

Design Characteristic	Produced Manually	Produced by Automated Design Tool
Total # of Existing HFC Nodes	45	45
Total # of N+0 Nodes	263	198
Total Metres of New Coax Route	15,910	22,164
Total Cost of N+0 Nodes + Coax	$12,300,000	$10,450,000
Lower Cost to Upgrade to N+0 Architecture	17 of 45 existing HFC nodes	28 of 45 existing HFC nodes
Avg. Cost to Upgrade Exist HFC Node to N+0 Architecture	$275,000	$235,000

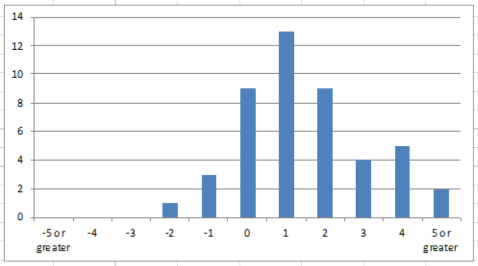
Table 4 below tabulates and graphs the differences in N+0 node quantities across all 45 original nodes between the manually produced preliminary designs and the respective preliminary designs produced by the automated design tool.

Specifically, the table and graph show how many manually produced preliminary designs contain how many more, or less, N+0 nodes as compared to the respective preliminary design produced by the automated design tool

As can be seen, on the whole, the number of N+0 nodes placed in a given manually produced design tends to be more than the number placed in the corresponding design produced by the automated design tool. It is worth noting that the distribution of the N+0 node count differences is Gaussian, indicating that the comparison between the two sets of designs is statistically valid and that the two sets of designs are, in fact, comparable.

Table 4 - Difference in N+0 Node Quantity Between Manual and Automated Design

	-5 or greater	-4	-3	-2	-1	0	1	2	3	4	5 or greater	Average	Std. Dev.	Skew
#Nodes	0	0	0	1	3	9	13	9	4	5	2	1.5	1.7	0.93



6. Conclusions

The proof-of-concept effort described in this paper demonstrated that the application of machine learning AI to the production of preliminary designs of N+0 outside plant network is effective by virtue of satisfying the criteria for success as listed in section 1. Introduction above.

In particular, it was demonstrated that the automated design tool produced preliminary designs that are optimized for capital cost (i.e. lowest possible) which tend to cost less and to use fewer N+0 nodes than would be specified in a manually produced design. The potential for capital cost savings relative to manually produced designs is significant and is expected to prove very attractive to an operator considering the deployment of N+0 outside plant.

Given that the automated design tool tended to produce designs using fewer N+0 nodes than did manually produced designs, potential energy savings comparable to the potential capital cost savings are indicated. It is noted that the potential energy savings indicated herein are in addition to the very significant energy savings offered by N+0 outside plant relative to existing HFC outside plant undergoing business-as-usual node splitting. *(*see [ULM2_2016]: *Giving HFC a Green Thumb: A Case Study on Access Network and Headend Energy & Space Considerations for Today & Future Architectures;* John Ulm, Zoran Maricevic; 2016 SCTE Cable-Tec Expo*)* Such energy savings are understood to be critical in the context of meeting the industry's Energy 2020 objectives and mitigating the adverse financial impact of rising energy costs upon the operator.

Furthermore, the reduction of energy demand through optimal design of the outside plant network supports the deployment of Remote-PHY nodes, Remote MAC-PHY nodes, and other devices such as 5G cellular radios, all of which will place further demand on the network power infrastructure. Clearly, every operator will seek to avoid the extensive time and significant cost involved in adding power supplies to the network power infrastructure, preferring instead to upgrade existing power supplies and reconfigure the power distribution network within the coaxial portion of the outside plant.

Future considerations for the application of automated design technology include:

- production of optimized N+x outside plant preliminary designs, where x=1, 2, or 3, thus allowing operators to evaluate fiber-deep architectures other than N+0 when planning an outside plant network upgrade;
- optimization of network designs across multiple existing node boundaries, which is anticipated to provide for further capital and energy cost reductions, and;
- optimization of the network power infrastructure to best utilize the existing powering assets while properly supporting all the current and future active devices in the outside plant.

In general, it is expected that operators, which are now required to consider, evaluate, build and operate multiple architectures in the outside plant, will require the kind of cost and time savings offered by automated design technology in order to make effective and timely management decisions, maximize the capital intensity of all capital expenditures, and minimize energy consumption and cost.

7. Abbreviations

CSV	comma separated value
DXF	drawing exchange format
GIS	geospatial information system
HFC	hybrid fiber-coax
MAC	media access controller
MDU	multiple dwelling unit
OSP	outside plant
PHY	physical layer
POC	proof-of-concept
ISBE	International Society of Broadband Experts
SCTE	Society of Cable Telecommunications Engineers

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Powering the Future 10G Access Networks

A Technical Paper prepared for SCTE•ISBE by

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1. Abstract

Demand growth and competitive pressures are changing the access networks at a rapid pace. To keep up with these changes, the network operators are looking at several technology options to expand capacity from current sub-1Gig up to 10Gig in the near future. In addition, there are other demands arising on the network from new businesses as well as mobile backhaul services (such as, small cell, macro cell and 5G evolution).

While a lot of work has gone into exploring the transmission technologies to support these growing demands, this is only the necessary first step. Most network upgrade actions will have a major impact on the network powering requirements. The network operators need to plan and prepare for such changes.

In this paper, we discuss some of the expected powering impacts of the upcoming network upgrades including node-splits, fiber-deep, mid-split, high-split, extended-spectrum DOCSIS and full-duplex DOCSIS on the outside plant network. We will also evaluate some of the powering requirements coming from the new opportunities.

Finally, network operators are facing a daunting challenge of continuously evolution the access network. There are many upgrade paths operators can take over the next few years. Although, this paper is not focused on evaluating the upgrade options, we will discuss how such rapid access network changes impact long-term powering solutions. We provide different financial, operational and life-time (or obsolescence) metrics for the operators in evaluating different powering solutions.

2. Powering challenges will grow exponentially

Cable operators are going through major transformational changes. As shown in the Figure 1, these are driven by the customer's never-ending appetite for bandwidth, hyper competitive environment to gain customer share, and the need to increase the revenue through newer service offerings. These three are making the access architectures a challenge to say the least. Every aspect of the access network evolution (starting from the strategy, to planning, to permitting, and to the execution) in these challenging times are very complex. In this paper we focus on one aspect of the architecture, the powering needs, due to the access transformational activities.

2.1. Drivers behind the challenges

Demand Growth: As shown in Figure 1, the year-over-year bandwidth demand is still growing exponentially. Typically, operators are observing 40 – 50% downstream and 20 – 30% upstream demand CAGR. These are driven by the traditional application such as streaming video (including 4K content), newer delay sensitive gaming applications, and of course the general increase in the demand consumption. For cable operators traditionally met this demand growth through adding additional carriers to the CMTS DOCSIS 3.0 service group (which increases the effective downstream capacity for the subs on the given node) or by splitting the node. Adding carriers to the service group increases power consumption at the CMTS level and node splitting (which adds additional actives in the field) requires re-assessing the outside plant (OSP) power architecture

.

Competition: In addition to the growing needs of existing subscribers, operators are facing growing challenges from other competitors who are continuing to offer higher capacity capability like Gigabit service offerings. In order to stay competitive, network operators must match with the access capacity plan of their own services. These bandwidth wars are on-going in the Telecom industry right now. Cable Labs recently upped the game by announcing the 10G capable networks by 2020 [1]. Such network capabilities in addition to transforming the access network, will also fuel new breed of next generation applications [2]. These next generation of fiber or coax (or a mix of both) access networks are creating newer active elements. These transformations will fuel the rethinking of the power architectures both in the facility and in the OSP.

Figure 1 - Drivers behind the access network transformation

New service opportunities: To keep up the pressure on the topline and to stay competitive, network operators have to offer a range of new services and features. On the residential side many operators have started offering new smart-home eco-systems [3]. On the business subscriber side there is a huge demand coming from the growing adoption of cloud computing technologies. On the mobile front, the increasing demand is driving proliferation of small-cells requiring ever increasing backhaul needs. These are expected to explode with the coming 5G evolution [4]. These new opportunities are driving operators to rethink their access network architectures and hence their powering needs.

2.2. So-what to the power architecture

The powering architects in the cable industry are facing many challenges due to the access transformations. To summarize, they are faced with -

- How to design for the future organic growth (Node splits etc.)?
- How to support newer architectures (Fiber deep, FTTH etc.)?
- How to cope with the unknown changes (business services, back haul services etc.)?
- The goals being
  - Reducing faster powering refresh that leads to obsolescence, and increased OpEx

- o Reducing the overall power consumption or going green
- o Upgrading power solutions when needed – not early or not late, and
- o Open to future newer technologies

Some of the contradicting goals in such an environment include – reusability, grow as you need modular architectures, higher life time of the solutions to reduce obsolescence costs, and of course reduce the power consumption (while increasing the supported services).

2.3. Scope of this paper

Although the access network transformation impacts facility, OSP and in-home powering needs, in this paper we focus only on the OSP powering architectures. We intend to extend this framework and the analysis to the end to end needs in a later paper.

This paper specifically focuses on -

- Defining the scope of the powering problem in the current and future OSP access networks
- The desired outcome of the powering solutions
- Different metrics to measure the usefulness of a solution

This is not anyway close to be a primer on powering, a solution manual or validation of different powering technical solutions. Our approach in this paper is to -

- Create a framework for the evaluation of different powering options
- Identify the current and future cable access powering needs, and
- Provide preliminary guidance on the OSP powering solutions

3. How to measure a power architecture success?

Being a strategy consulting team (although we do have engineering degrees), all the time our customers ask us how to compare multiple solutions. In this paper before dwelling into some of the technical challenges the operators are facing, we would like to define a framework for the analysis of the future solutions. In our analysis, in addition to architectural needs, we would like to consider some of the strategic issues the access power architects are facing. These can be classified into architectural, financial and operational measures. Other metrics related to the greenness of the solution can be included in these three dimensions. In the following framework, we provide our thoughts on the drivers (refer to Figure 2 for summary) behind these three dimensions and their importance in the overall evaluation of an access powering solution. Keep in mind these metrics are not for the solutions at a point in time but for an access evolution path that your leadership has chosen.

What drives the cost of a powering solution?

Upgrades: In simple terms shelf life of a solution drives the upgrades and hence the cost. We need to consider how these solutions are upgraded in the context of the access transformation.

SLAs: We are carrying traffic with different SLAs. Need to keep them up and running. Hence, power solution reliability is one of the essential drivers.

Basic operating costs: End to end life time (5 or 10 yr.) operating cost of a solution in many times keeps us, the architects, at check in picking the solution.

Figure 2 - Drivers behind the Metrics

3.1. Architectural measures

These measures evaluate a powering solution in the context of supporting the current access architecture and the future planned upgrades.

- **Feasibility**: How feasible is this upgrade in their current network?
- **Ease of upgrade**: How easy is it to extend to future needs?
- **Life time of the solution**: How often one needs to upgrade?

3.2. Operational measures

The operating metrics determine how a powering solution meets, at a minimum, the committed SLAs and offer a simpler maintainable solution.

- **Reliability**: What level of reliability needs to be considered to meet the SLAs?
- **Complexity**: What are the maintenance complexities?
- **Failure recovery**: How long does it take to recover from failure?

3.3. Financial measures

The financial measures provide the investment overlay (total and time-adjusted) views of the solution over a long-term transformation.

- **5 Yr. CapEx**: What is the 5 Yr. capital expenditure of the solution?
- **5 Yr. OpEx**: What is the 5 Yr. operating expense of the solution?
    - o Including the obsolescence and disposal costs
- **TCO NPV**: What is the net present value (NPV) costs over 5 yrs.?

4. Current and future cable access powering needs

With the high-level view on the metrics, in the following sections we briefly touch the network evolution options and their impact on the powering solution in turn motivating the proposed metrics.

4.1. Current outside plant powering needs

The current cable HFC outside plant deploys numerous active devices throughout the network that need to be powered. Starting with the optical node that converts the signal from optical to electrical for transmission over the coax network. That is followed by a series of RF amplifiers that ensure the signal level is maintained before reaching the subscriber. These amplifiers are spread throughout the cable plant. HFC networks are classified as N+X, where x is the maximum number of amplifiers the signal has to pass through between the node and the subscriber. Typical nodes in most operator's current network range between N+2 and N+7. Some operators also support land-line telephony services using a Network Interface Device (NID) mounted outside a subscriber's home that also has to be powered. Use of these devices has mostly been phased out in favor of new voice-over-IP (VoIP) services.

Operators use a variety of powering arrangements to support the above active devices in the outside plant [5]. Power is typically supplied from outside plant power supply units that are either centrally located or distributed across the network. These power supply units use a metered connection to the electrical power grid and convert it to a 60V or 90V AC quasi-square-wave signal to be transmitted over the coax network. Due to the high resistive loss in a large network, operators either deploy distributed power supplies or use special heavy gauge powering coax cable (Express cable) to distribute the power over longer distances. The outside plant power supplies typically also include a battery backup to provide power in times of electric grid power loss.

Until now, the operators are defending their product and growth needs though node splits or carrier additions. Many of them have upgraded their current network to DOCSIS 3.1. In such a simplistic evolution the operator has less challenges to face.

4.2. Future outside plant powering needs

As discussed above, network operators must constantly upgrade their networks to keep up with the demand [6]. Several technology and network architecture options are available that can extend the life of the HFC plant many years into the future [7]. They are constantly faced with many upgrade scenarios based on their current status and the future needs. In the following sections we assume an operator is evolving into an eventual 10G symmetrical speed offering capable network. Although we do not elaborate more on non-powering related concerns in this paper, we recommend you refer to the impact of 10G evolution from financial, operational etc. points of view in [8]. Let's look at the powering impacts of these upgrade options.

The fundamental building blocks that are available for the operators on the HFC networks to reach 10G capable access networks are:

- *Continual node splitting*: Continue with the node splits which reduces the service group size
- *Spectrum upgrades*: Increase the spectrum to 1.2GHz, 1.8 GHz or 3GHz with the mid-split or high-split in the upstream direction, and full duplex (symmetrical spectrum) capabilities
- *Fiber deep upgrade*: Split the current node to N+0 configuration in one upgrade action

Node split powering: As described above, a node split upgrade requires adding a new node near the existing congested node. The new node must be powered – typically this is a simple exercise of adding the new node to the existing power supply by extending a power feeder cable. In cases where the power supply capacity is not enough, the power supply can be upgraded as well.

Spectrum upgrade powering: In case of spectrum upgrades, the powering impact is mostly limited. For mid-split, high-split, and spectrum reuse upgrades there is little or no change in powering. However, for extended spectrum or full-duplex DOCSIS upgrades there can be significant impact. Extended spectrum support will require new active devices that need to transmit additional high frequency spectrum. This also needs to be transmitted at higher transmit power in order to compensate for the higher transmission loss at higher frequency. This means increased power needs for the node as well as all the amplifiers. If the existing power supplies cannot deliver additional power they will need to be upgraded. In addition, a design evaluation of the coax plant will have to be done to identify and rectify any power transmission issues.

Fiber-deep upgrade powering: Of all the upgrade options, a fiber-deep upgrade has the most significant impact on the outside plant network powering. Fiber-deep upgrades require locating nodes much deeper in the network such that there is no need for any coax amplifiers. This requires pulling fiber much deeper in the network. Nodes in a fiber-deep configuration typically serve only between 40 to 50 homes each. This is a big reduction from the typical 500 – 1000 homes passed node configurations of today. While this results in removal of all amplifiers in the network, the amplifiers are replaced by many new high-power nodes. A typical 500 homes passed per node can get split into 10 to 12 fiber-deep nodes. The new high-power nodes more than make up for the power savings from the removed amplifiers – and in most cases the power requirement goes up significantly. Furthermore, the power needs are also at different points in the network. This requires re-design and re-build of the power feeding coax plant in addition to any power supply upgrades.

4.2.1. New services powering needs

10G capable network will be used for different next generation service offerings. Some of these services will add additional powering requirements to the network.

Significant new requirements will come from supporting the small-cell backhaul needs of mobile networks. The number of small-cells is growing rapidly in many areas and they are likely to grow even faster with the upcoming evolution to 5G. Quite often, the existing cable HFC network is used to backhaul the traffic. Each small-cell node also needs to be powered. These can be powered either using a dedicated metered connection or by using the existing HFC plant power.

There are also some business applications requiring active network devices, such as switches and routers, to be installed in the outside plant. These devices will also need to be powered.

4.2.2. Estimating the powering impact

As described above, each network upgrade option has a powering impact. In order to get a better view of how much impact there is for various upgrade actions, we compiled a simple model of all active devices in 500 homes passed N+x node. Then we estimated the power impact based on device changes required for each upgrade scenario. Figure 3 shows the results for our sample scenario. While these results are based on simple assumptions which cannot be generalized, they illustrate the significant impact network upgrades can have during the life time on their powering needs.

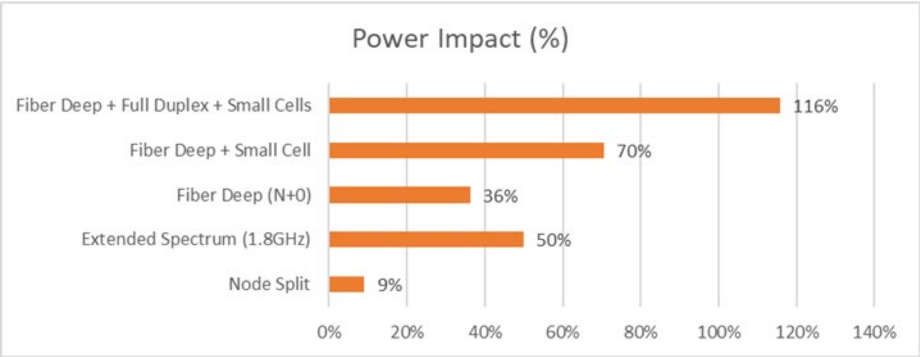

Figure 3 - Estimated upgrade impact on a node

4.2.3. Planning for future powering needs

Outside plant network upgrades come at a significant cost. It is therefore critical to plan these well. As stated earlier, network upgrades are not one-time events. Operators will need to evolve their network over many years. It is therefore essential to take a long-term view on planning [6]. Quite often what may appear to be an optimal solution in the near term may end up being a highly regrettable investment in the long-term.

As such, operators will have to make a best-effort forecast into their network needs in the long term. They will then need to determine the optimum network upgrade strategy which will deliver the necessary capability at the right time. This is not a simple exercise given the broad range of upgrade options to choose from. What makes it even more complex is the multi-stage upgrades that will be done over the long-term. What will be the consequences of doing upgrade-A followed by upgrade-B and C? In Figure 4, we have highlighted two upgrade paths an operator can take to reach 10 G capabilities.

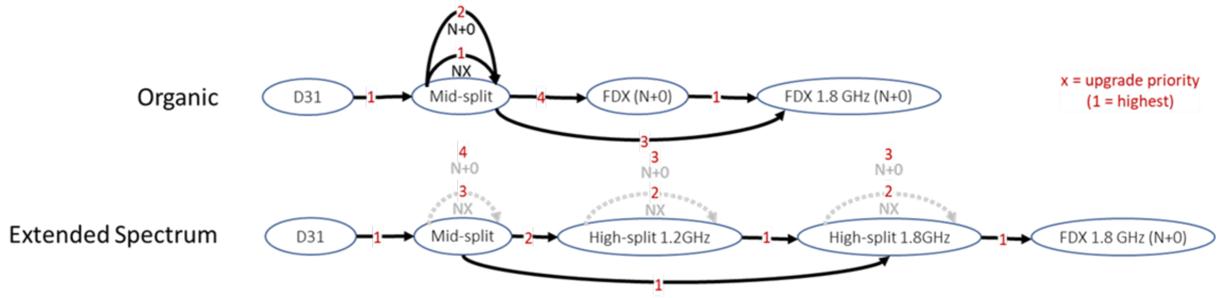

Figure 4 - Example of the network upgrade options to reach 10G capability

We use these two upgrade paths to evaluate the quarterly powering needs of a 50K homes passed facility. Preliminary results are presented in Figure 5. Note that this consumption needs, is only one aspect of the analysis. There will be other metrics, as highlighted before in evaluating a powering solution. That said, having a clear macro and micro goals (in the dimensions of the metrics provided before) along with a clear understanding of the drivers behind the consumption as highlighted in the graphs are crucial for a proper selection of the powering solution. Note that selection heavily depends on the current status of the operator’s network.

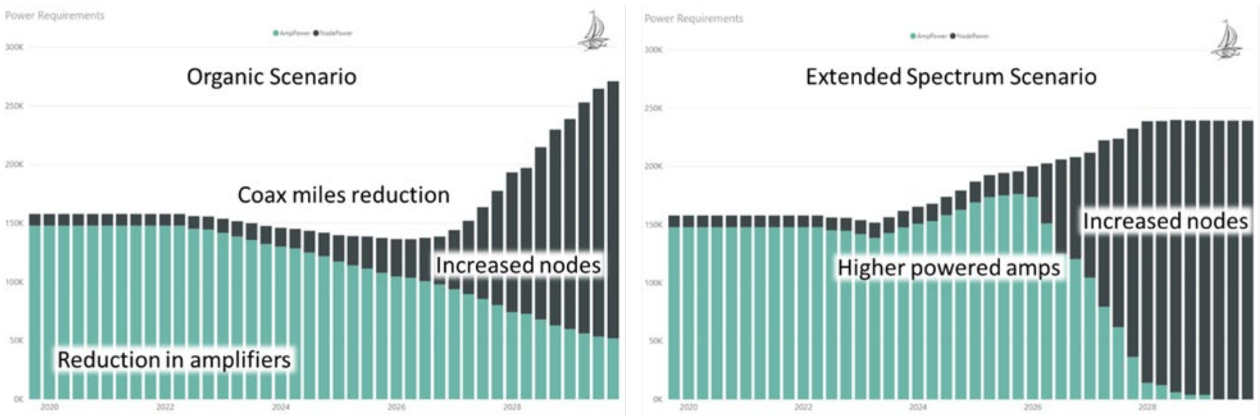

Figure 5 - Quarterly projected power needs for an organic and extended spectrum upgrade paths

5. What is next for the power architects?

World energy consumption has been growing at an unsustainable rate over past many years. This has been leading to serious concerns about future energy availability and environmental impact. The cable industry is a significant energy user. Having recognized the challenge, the cable industry launched the SCTE Energy 2020 program [9] to address the end-to-end energy usage. The Energy 2020 initiative has done a lot of work to address optimization of energy usage in the cable industry. A few key developments that can minimize the powering impact of the upcoming network upgrade include:

- Adaptive Power System Interface Specification (APSIS) standard [10]: This standard enables active network devices to monitor, report, and control device power usage based on network utilization. Thus, during times of low network usage, devices can scale back their operations and reduce their power consumption. Use of this capability can lead to significant energy savings.
- Micro grids [11]: In this case alternate energy sources such as wind or solar are used to power network devices locally instead of using the electric power grid. This can significantly reduce the electric grid power usage while providing a power backup capability.

5.1. Next steps and recommendations

We recommend the following steps be taken by the operators and the standards forums –

- *Align with your company’s access strategy*: As explained in this paper, a powering solution cannot be an afterthought or a point solution. It needs to align with the transformation strategy being developed by the operator’s access team.
- *Consumption is not the only metric you need to optimize*: Albeit, consumption reduction is one of the main goals of the next generation energy strategy, the powering solutions need to be evaluated in the context of the architectural, operational and financial metrics as mentioned.

- *Plan long-term powering solutions before making the short-term next steps*: Gaining a clear vision on the long-term powering needs and their impact on the metrics is essential to make the short-term decisions.

As a next step, we are working on the next iteration of this analysis with the facility powering considerations along with the OSP needs in the forth-coming paper.

6. Acknowledgements

We acknowledge that powering is a very complex issue that the telecom industry is facing. As the access networks are going through major transformations, so are the powering solutions. Finding the right solutions needs to be a collaborative effort amongst the operators, the vendors and the strategists. In this effort, Duke Tech Solutions is actively working with Jessie McMurtry and Mike Glaser of Cox Communications, and AP-Jibe access planning product from First Principles Innovations to model different access scenarios. We thank them for their support.

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Phase Change Materials as an Energy Conservation Measure

A Technical Paper prepared for SCTE•ISBE by

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1. Introduction

Communication providers are faced with the challenge of managing energy costs while supplying increased network capacity that supports faster speed, bandwidth, and storage. The communication industry continues to engage in measures to help improve building efficiencies as part of their environmental stewardship and in response to the growing cultural pressure to address environmental concerns, such as CO_2 emission, carbon footprint, and global warming. HVAC energy consumption represents the largest adjustable cost variable in a communication shelter's technical space. Many providers are actively replacing HVAC systems, retrofitting HVACs with economizer kits, and optimizing controllers; however, these mechanical investments represent a significant capital commitment per square foot, and owners are now exploring additional Energy Conservation Measures (ECMs) that can consistently provide incremental savings.

Phase Change Materials (PCMs) are materials which undergo a change of phase, at a useful temperature, for a specific purpose. The term 'phase change' typically refers to two primary thermodynamic modes:

1. Freezing (liquid to solid)
2. Melting (solid to liquid)

Engineered PCMs absorb and release heat energy when the surrounding temperature rises above or falls below its predetermined transition range. When applied at the proper temperature PCMs fundamentally change the thermal behavior of a shelter by stabilizing the temperature, reducing the number of HVAC cycles, and consequently reducing the total amount of HVAC runtime as compared to an identical Shelter without PCMs.

"The efficiency "electricity mileage" (kbtu/kWh) improves when the air conditioner stays on longer. The total energy consumption drops because there are also longer pauses between cycles when the air conditioner does not run."

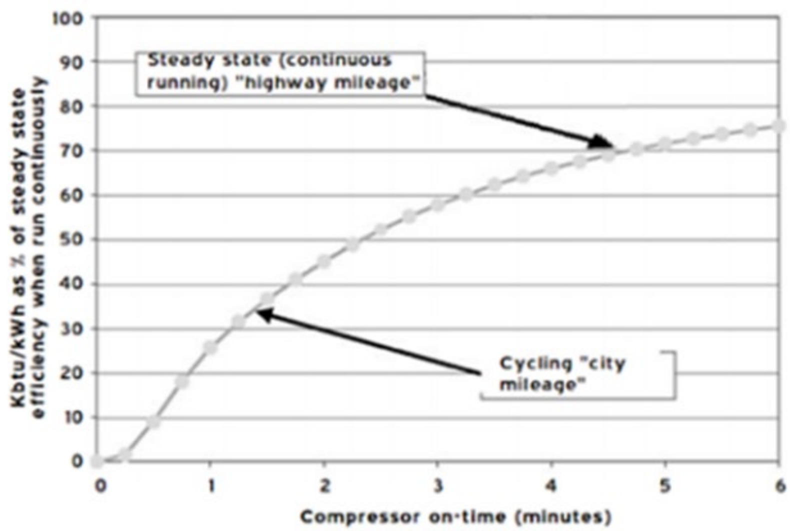

Figure 1 - Air conditional efficiency "mileage", taken on August 2019, www.bijlibachao.com

Short Cycling renders an HVAC system inefficient as each compressor start requires an excess of energy during the first few minutes of a cycle (See figure 1 for an A/C Efficiency to Mileage comparison). By stabilizing the temperature profile inside the shelter there are fewer HVAC cycles; moreover, each cycle is extended. The cumulative effect is fewer cycles resulting in less wear on the mechanical system. The compound effect lower maintenance costs and End of Life cost avoidance.

The Communication Shelter is an emerging application for engineered phase change materials. The retrofit application of PCMs, on internal walls/ceilings of a communication shelter, have proven to deliver a measurable impact on HVAC load and thus utility cost. When applied correctly, PCMs can help mitigate the temperature spikes frequently found in a constant heat load environment. The PCM acts as a buffer to rapid temperature rise. By slowing the rise in the room's temperature, the HVAC rest period is extended. Ultimately, this effect results in longer rest periods between HVAC cycles and thus fewer HVAC cycles each hour, day, month, and year.

Figure 2 - PCM mounted to interior walls & ceiling of shelter

2. Executive Summary

This paper is intended to help readers understand the impact of introducing phase change materials (PCM) on the energy performance of a communication shelter. Phase change materials (PCM) were applied, as a retrofit solution, to the interior of shelters. Pre and post energy data were collected and measured to demonstrate the following:

- Energy avoidance due to the introduction of PCMs
- Economic benefits of PCMs in the communication shelter
- Cost of a PCM retrofit solution
- Return on Investment of PCMs in the communication shelter

Analysis methodologies used in this paper are recommended by Overlay Consulting of Denver, CO; an independent third-party energy management group that specializes in providing energy efficiency and sustainability services to the private sector, utilities, and government agencies. This study was performed to develop a pure energy savings model and is focused only on cooling costs.

Study was constructed and executed in partnership with one of the world's leading Communication companies. Study is based on over 4,600 shelters where PCM has been introduced as an energy conservation measure. This initiative offers the industry an opportunity to study PCM's real world impact on HVAC type/tonnage, control strategy, and climate zone.

2.1. Key Performance Metrics

The following represent the greater goals of the telecom pilot:

- Reduce total building utility costs by 4% - 9%
- Deliver a simple ROI of 3 years or less
- Shift peak electricity demand to off-peak hours
- Introduce a sustainable, resilient, and long-term solution

2.2. Building Description

Shelter characteristics for this study include:

- 350 ft^2, Single-story, one room concrete structure
- (2) 5-ton DX packaged HVAC units
- 7-day lead/lag interval
- 24/7 operation
- 78°F targeted indoor set point
- Un-manned facility
- 7.5 KW site demand (3-yr average)

3. Measurement and Verification Plan

3.1. Proof of Concept M&V Plan

The International Performance Measurement and Verification Protocol (IPM&V) document was used to provide a framework for the M&V plan. IPM&V Option B, Retrofit Isolation, was selected to evaluate the performance for the proof of concept study. Option B, in conjunction with regression methods, deliver a reliable performance evaluation of ECMs such as phase change materials. When combined with regression methodologies, Option B is valid for both short term and continuous post-retrofit studies.

Option B requires data acquisition via field instrumentation. In the case of this proof of concept study the following instrumentation was deployed at two telecom shelters possessing similar construction, location, size, and HVAC capacity. HVAC energy consumption was the target for isolation.

- HOBO T-WNB-3D-480 kWh Transducer
- HOBO H22-001 Energy Data Logger
- HOBO T-MAG-0400-75 Split-Core Current Transducer (CT)
- HOBO UX100-003 temperature/RH% data logger

Instrumentation was deployed (4) weeks prior to the introduction of PCM. "Pre-install" data was collected to define the baseline for each site's HVAC system(s). Instrumentation remained in place (4) weeks after the introduction of PCM and was used to define the "Post-install" energy profile of the HVAC system(s).

Multiple variable regression analysis was used to quantify annual energy savings. The multi-variable regression method measures the impact of three independent variables on a single dependent variable. This procedure delivers a reliable prediction of energy savings across a 12-month time frame. The following represents a regression diagram of a dependent variable correlated with independent variables:

- Electricity usage (kWh) >>>>>>>>>> Dependent Variable
- Ambient (dry bulb) temperature
- Dew point temperature
- Relative humidity

} Independent Variables

Data loggers were set to collect at single minute intervals throughout study. Data collected during the "Pre-install" period was compared to data collect during the "post-install" period using the above multiple variable regression methodology.

Weather data, spanning the (8) week study, was collected from the nearest NOAA weather station. This weather data was then synced with the consumption data and used to correlate consumption behavior under specific weather conditions.

TMY3 data retrieved from the National Solar Radiation Database was used to define normal weather conditions/patterns at site. TMY3 weather profile was used to normalize consumption throughout study and predict annual consumption with and without ENRG Panel.

3.2. Single Site M&V Plan (Davis, California)

The International Performance Measurement and Verification Protocol (IPM&V) document was used to provide a framework for the M&V plan. IPM&V Option C, Whole Building Energy Evaluation, was selected as the approach for the Davis, California project. Option C, in conjunction with regression methods, deliver an entire building evaluation in cases where no other ECM has been introduced. In the case of this review no other ECM was introduced during the studied time period.

15-minute interval data was retrieved from the utility provider and used as the consumption source. Just as in the proof of concept study, multi-variable regression methods were applied to deliver a weather normalized prediction of energy savings with and without PCM.

3.3. Full Deployment M&V Plan (Sample Review)

Again, the International Performance Measurement and Verification Protocol (IPM&V) document was used as a framework for the full deployment analysis. Option C, whole Building Energy Evaluation, was used as the approach for analyzing the 2016, 2017, and 2018 deployment. Option C methods deliver an entire building evaluation in cases where no other ECM has been introduced. As with both the single site and proof of concept reviews, the 1,347 sites included in this sampling review had no other ECM introduced during the studied time period.

A full 24 months of utility data was collected from each energy provider and used to evaluate pre/post PCM performance.

Month-over-month whole building kWh review combined with a weather normalizing process that weights HVAC load based on Cooling Degree Days. A Cooling Degree Day is defined by each days' median temperature minus 65°F, example: if the median temperature is 75°F for each day in June then the total cooling degree days for June is 300 = (75-65)*30. This methodology accounts for the difference in weather seen year over year or even month over month.

4. Analysis of Results

4.1. Proof of Concept Results

The following results were derived using the International Measurement and Verification Protocol, Option B. In conjunction with a multiple variable regression analysis these results reflect a normalized view of performance, as compared to a site without PCM, over a 12-month period. These results do not consider the avoidance of peak demand charges.

Table 1 - Proof of Concept via HVAC instrumentation

International M&V Protocol, Option B – Retrofit Isolation (Instrumented)					
Location	**% HVAC Load**	**Total kWh Offset**	**% HVAC Savings**	**% Whole Building Savings**	**Annual $$ Saved**
Shelter A	40.5%	5,144	15.2%	6.2%	$818
Shelter B	36.3%	3,169	13.4%	4.9%	$504
Weighted Average	**36.6%**	**4,393**	**14.5%**	**5.7%**	**$699**

4.2. Single Site Results (Davis, California)

Based on the regression analysis, using option C of the IPM&V Protocol, the owner saved 20% of the base HVAC electrical energy costs and 8% total utility costs during the months studied. These results do not consider the avoidance of peak demand charges.

Table 2 - Telecom shelter in Davis, California

International M&V Protocol, Option C – Sub-Metered Data	
Building ft²	350

June/July Total Offset (kWh)	1,516
% HVAC Savings (kWh only)	20%
% Total Building Savings	8.1%
June/July Electric Savings	$224 (2.23 months)
Electric Savings Extrapolated across 12 Months	$1,205

4.3. Full Deployment Results (Sampling Review)

The following is the utility analysis of 1,347 sites spanning the West, Southeast, and Northeast regions of the US (whole building kWh data). Results represent 30% of the Tier I deployment year to date. All sites were confirmed by customer to have no other Energy Conservation Measures (ECM) introduced during the baseline or post PCM installation periods.

Table 3 - 24-Month utility bill review (*Assumes an average 35% HVAC load per POC study

International M&V Protocol, Option C – Utility Bill Analysis	
Average Building ft²	350
Total Offset per Site (kWh)	4,813*
% Total Building Savings	6.7%
Annual Electric Savings per site	$716

4.4. Economic Review

Table 4 extrapolates results across the entire Telecom deployment (4,608 shelters). The median % Total Building Savings of 6.7%, derived from utility analysis (table 3), was used in this economic calculation.

Table 4 - Utility bill analysis extrapolated across full deployment

Economic View - Extrapolated	
Site Count	4,608

Total Investment	$6M
Annual Savings	$3.3M
Simple Payback	< 2 years
5-yr NPV	$3M
Maintenance Cost	$0

5. Challenges/Solutions

Operational anomalies are often discovered through the evaluation of a site's baseload profile. Operational baseload shifts can be indicative of a mechanical failure, T-stat adjustment, or another building changes. Operational baseload anomalies should be removed from the data analysis procedure. The following reflects anomalies found in each of the studies categories.

5.1. Proof of Concept Anomalies

No operational anomalies were observed during the pre and post installation periods. PCM was introduced in both sites on April 4th, 2016.

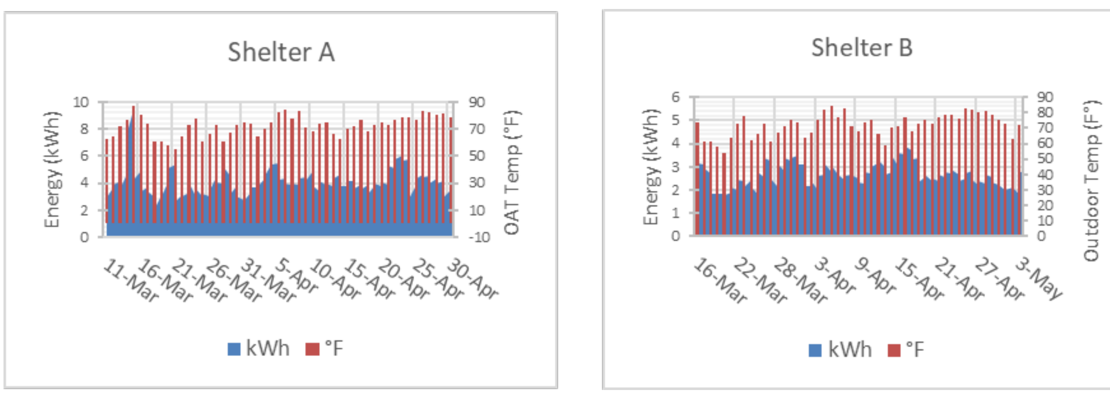

Figure 3 - Energy consumption vs outdoor temperature shift over time

5.2. Single Site (Davis, California) Anomalies

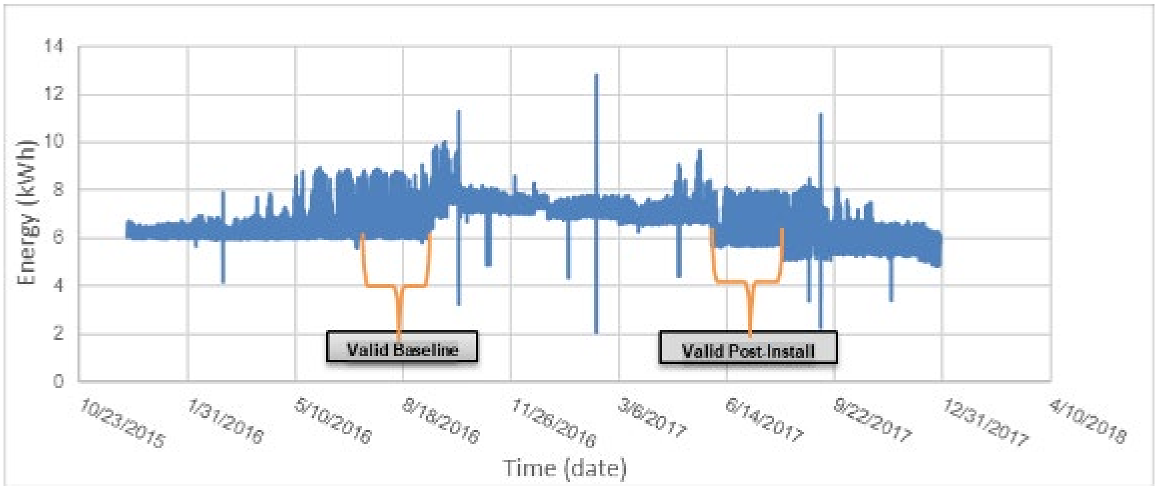

Figure 4 - Operational base load shift

Data analysis showed operational anomalies that eliminated all but 2.23 months of data. Where appropriate, anomalies were removed to ensure data integrity. The below energy profile highlights the valid data used for the single site review.

6. Conclusions

The methodologies used in this paper to evaluate energy performance are recommended by industry leaders such as ASHRAE, ENREL, and the DOE. Using these methods this paper demonstrates the effectiveness of PCMs as an energy conservation measure in the communication industry. Furthermore, this paper highlights the economic advantages of low cost PCM solutions versus the high cost mechanical intervention when dealing with 24/7 constant heat load sites.

In the telecom shelter, PCMs effectively reduce energy consumed by the HVAC system by up to 30%. HVAC load percentage varies across the country and should be considered when forecasting financial benefits.

Further studies are ongoing to determine best fit for PCMs including localized “hot office syndrome” and/or comfort related issues. Climate, HVAC condition, maintenance, and operational controls all play an important role in how effective PCMs can be as a passive ECM solution.

Given the performance longevity of organic PCMs, without significant performance degradation, PCMs will play an important role in reducing energy consumption in technical spaces throughout the communication and IT industries.

7. Abbreviations and Definitions

7.1. Abbreviations

PCM	phase change material
ECM	energy conservation measure

HVAC	heating, ventilation, and air conditioning
DOE	Department of Energy
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
NREL	National Renewable Energy Laboratory
ISBE	International Society of Broadband Experts
SCTE	Society of Cable Telecommunications Engineers

7.2. Definitions

Organic PCM	Bio-Based or carbohydrate and lipid derived

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Letter to the Editor: HVAC Rightsizing and Airflow Optimization Impact to Headend sites

Letter to the Editor prepared for SCTE•ISBE by

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To the Editor:

In any discussions related to the "rightsizing" of air conditioners for cable hubs and headend sites, the impact of airflow volume and distribution from the air conditioners in these facilities must be considered and addressed to make the best use of limited capital dollars. Matching cooling capacity to IT kW load (and specifically, the energy used to power routers, servers and switches) is an easy calculation on paper. But in the widely varying spaces of hubs and headends, it is not so simple. There is a common mindset that "more is better," leading entire industries into what could be likened to a "CRAC addiction." This social metaphor -- that CRACs (computer room air conditioners) are a problem -- is meant to suggest that the careful consideration of space, airflow paths and obstacles typically receives insufficient upfront examination, relative to the purchase of additional CRAC units. As a result, purchasing new equipment is often acted upon as the easiest and seemingly preferred method to address change.

This letter to the SCTE's Journal of Energy Management readership is meant to question this practice, on the supposition that valued capital is being spent on trying to overwhelm a condition, rather than optimize it.

The theoretical sizing of an air conditioner, whether in units of cooling tons, BTUs or kilowatts, can be a simple math exercise that is well supported by science, formulas and the laws of physics for thermodynamic heat exchange. This is not to diminish the multiple factors that must also be addressed (humidity, altitude, control strategy, enthalpy, sensible/latent heat etc.) to satisfactorily size a system to meet a prescribed heat load. Rather, the HVAC industry has done a remarkable job of providing multiple products that can deliver the rated cooling capacity at a defined set point (more on this later) with a variety of technologies and heat exchange mediums. The less commonly known aspect of an air conditioner is that it is primarily designed to *reject* heat, and airflow anomalies directly affect how much heat is rejected. The hotter the return air temperature, going back into the CRAC, the more efficient the unit will be.

Significant challenges face the operating efficiencies of CRAC units, including their location and installation, space configuration, rack locations and other variables and obstacles in our headends. A focus on these variables and airflow obstacles can identify optimization opportunities that improve the long-term efficiency of the space -- and can cost significantly less than new CRAC units.

The point of this assertion (that airflow matters a lot) is that in the cable industry, we have a lot of small, irregular, and inconsistent hubs and headends that were not necessarily "purpose built." Our headends have morphed over time, as mergers and acquisitions have occurred, resulting in many inefficiently operating sites. It is common to state that these inefficiencies are a result of "overcooling the room" and as these spaces grow and contract, the managing engineer must contend with making educated decisions to properly address change. Specific to this discussion is HVAC (air conditioner) sizing. With inconsistent layout and CRAC configurations we see **3 primary airflow issues** that contribute to inefficiencies:

1. Mixing -- cold air mixes with warm return air, diluting return temperatures
2. Bypass – conditioned air leaves the CRAC but never cools any server and returns directly to the CRAC again
3. Recirculating/wraparound -- warm air leaves a server and is pulled back in again due to poor airflow separation

Cable headends predominantly use air to cool the space (and remove the heat), regardless of how that air is cooled (DX, chilled water, glycol, pumped refrigerant etc.) The volume of air delivered to the servers, switches and routers must be adequately supplied from the CRAC units to match or exceed what is required by the electronics. Any failure to deliver the minimum CFM (cubic feet per minute) of required conditioned air will result in hot spots, somewhere in the space.

Conversely, for the CRAC or any other HVAC device (roof top, wall mount, split or packaged units) to operate correctly, it must be capable of rejecting the heat generated from the IT equipment. Any failure to adequately reject the IT load heat will also lead to thermal anomalies and hot spots, which can reduce IT equipment performance or lead to unplanned shutdowns.

For that reason, heat rejection should be the prime consideration when redesigning hubs and headends.

The industry standard and generally accepted practice is to keep IT equipment below 80.6° F. With that in mind, and in a perfect world, we could set our HVAC thermostats to 80 degrees and happily walk away to let the machine do its job. The “set points” are similar to your home thermostat, where you set the temperature that you want to maintain. If you set it low, the AC unit runs a lot; set it high and the run time is reduced (as is your electric bill.) In the real world, we find many return temperature set points, in the mid to upper 60s range, keeping the room unnecessarily cold (over cooling) and wasting huge amounts of electricity/dollars. In addition, we find many CRAC units running with little or no cooling produced, yet the fan blows 24 hours a day. The velocity from the fan energy is generally needed to deliver cooling to parts of the room, so conditioned air can get to the corners or hot spots. This is where “rightsizing meets airflow optimization,” which is trying to use the least amount of cooling energy to reject the IT load heat, and keep the IT equipment in a safe operating range.

Let us acknowledge some general principles and formulas:

1 Refrigeration Ton (RT) = 12,000 BTUs

1 kiloWatt (kW) = 3,412 BTUs

3.5 KW = 1 RT

General rule of thumb at the rack:

150 CFM cools 1 kW (CFM required to cool 1 kW server at 75 deg F at the rack inlet)

General rule of thumb at the CRAC:

400 CFM required per 1 RT of cooling

20-25 degree Delta T is considered 100% cooling

As stated earlier, many spaces are overcooled, because excessive cooling tons (capacity) are available -- in some cases far more tons than IT kWs in the space. The heat exchange process occurs in BTUs and the total BTU load in a space is generally pretty consistent from the IT equipment (excluding the miscellaneous lights and solar load acquired during hot days). With that consistent BTU load, the air conditioner will only remove the heat generated. If there is 100 kW of IT load, then only 29 tons of cooling is needed (theoretically, 100/3.5 =29), so no matter how many tons of cooling is available, only 29 will be needed or used. As a result, the room will always be sufficiently cooled and overcooling does not occur (again, broadly speaking, and to demonstrate a point). What does occur, though, is low set points creating an "unnecessarily cold" space.

We are seeing many spaces that have more than enough cooling capacity and additional CRACs running to move air. In these cases, if a hot spot occurs, we do not need additional HVAC units, but rather better distribution of conditioned air. It is common to see up-flow CRAC units blowing conditioned air into a common duct plenum, with branch lines run out into the cold aisles. This makes for good supply delivery, but the return air is now seriously cooled as it is drawn back to the bottom return of a CRAC (rising warm air mixes with cold). This configuration is a good case for rear return CRACs that have a ducted chimney, up to near ceiling height, to capture the hot air and maintain high Delta Ts (difference between supply and return air temperatures) at the CRAC.

If we use the formula for CFM at the rack (150 CFM per kW), we can calculate a good approximation of airflow needed vs supplied. Take the 100 kW IT load example from earlier:

100 kW x 150 CFM = 15,000 CFM required.

Knowing this rule of thumb allows us to see the discrepancy between supplied vs. required air volume, and allows us to look for the cause of oversupply, such as 1 & 2 stated above (bypass and mixing air). Separating the Supply air from the Return air is an effort worth pursuing. "Low hanging fruit" solutions for these airflow anomalies include blanking panels at the racks, gap fillers between racks, containment doors or curtains at the ends of aisles, and duct registers with dampers. Raising the Set Points is also an efficiency play that can save energy immediately, when done in a controlled and measured approach.

Because we have so many CRAC airflow configurations, rack layouts and mixed equipment orientations, we see inefficient airflow mixing occurring all the time, and no amount of new air conditioners can correct this deficiency. We must be looking at airflow optimization options first, whenever new HVAC units are being considered, to provide efficiency gains and to maximize the overall performance of the AC system in a space.

Use of Financing for Solar PV in Telecom

Accomplishing Your Organization's Renewable Energy Goals with Minimal Use of Capital

A Technical Paper prepared for SCTE•ISBE by

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1. Introduction

Adopting a plan for renewable energy sourcing has proven to have a positive relationship with companies' bottom lines. With few avenues remaining in mature industries to improve net profit margins, integrating renewable energy into overall sustainability and operating plans can help a business outperform its competitors. (The Climate group and CDP, 2018). The top four wireless telecommunications service providers in the United States have issued statements committing to sustainability goals and have adopted the use of renewable energy as a part of these goals. While these telecommunications companies and others have added renewable energy goals to their performance metrics, they often lack the capital funds to achieve these goals or the Return on Investment of these technologies do not meet traditional MSO hurdles or lack the tax appetite to take advantage of the Federal Investment Tax Credit (ITC) and accelerated depreciation. Many sustainability managers are challenged with delivering ambitious goals only with existing, budgeted operating expenses and no additional capital. Further, achieving these goals can be challenging when energy asset ownership is not a core business function and displacing capital funds intended for your core business is impractical.

Renewable energy financing is an effective and growing means of achieving corporate renewable energy goals for telecommunications companies. Organizations gain near- and long-term benefits by using financing options, with benefits including price stability, utility bill savings, no impact on the balance sheet, and zero out-of-pocket costs. Additionally, many solar financing partners work most effectively programmatically. By deploying renewable energy projects over many sites with a range of geographies and configurations, an organization can shift the burden and risk of project evaluation to the program solution provider and optimize their portfolio for greater cost efficiencies, lower financing costs, and deeper savings.

2. Financing Solutions for Renewable Energy Programs in Telecom

Once a business identifies its renewable energy goals – possibly as part of a larger corporate sustainability plan – it must develop a program to execute the plan and achieve those goals. Programs may include a range of technologies, such as wind and solar generation. Further, programs may deploy a mix of on-site or off-site solutions, such as utility-scale, off-site generation or smaller behind-the-meter[1] on-site solar generation. Constructing a renewable energy program depends on complex factors, and organizations can be constrained by the availability of financial resources and a lack of technical wherewithal. The element of time adds an additional constraint with the introduction of factors such as time-oriented, publicly announced renewable energy commitments, sunset provisions on enabling legislation, and state-wide pilot programs with limited project acceptance periods. Mapping these constraints – funding, know-how and time, and identifying the associated risks are key to successfully planning an executable renewable energy program.

Once a company decides to include solar as part of its renewable energy portfolio, they must then determine how to finance the project. A range of project financing options exists that enables procurement without the burden to develop and construct, and potentially, without the need to own, operate, and manage an energy asset. An understanding of the financing options is helpful in deciding which choice to make. Knowing the key features of financing a project – such as an organization's Return on Investment requirement, appetite for tax credits and depreciation, utility cost savings, or on-balance sheet treatment –

[1] 'Behind-the-meter' refers to a generator that produces power to offset the metered consumption and not produced on the side of the utility grid.

may drive a company's preference. Companies are advised to check with an accountant for current and proper accounting and tax treatment of all options. Operating lease options, for example, if not meeting the minimum Internal Revenue Service requirements, may have an unintended negative impact on long-term debt.

Financed projects are often developed by a third party in collaboration with the host company, and the host company begins payments for power generated only when the project is complete and operational. This contractual arrangement creates a mutual interest in the success of the project – the host company seeking to procure the renewable power from the project and the financier seeking to generate sales so it may recover its investment in the asset over the term of the contract. Often, all of the following procurement alternatives will include multi-year operations and management of the asset to ensure optimal performance and adherence to the terms of the warranties of the equipment in the long run or for the warranty period.

Descriptions of some of the possible financing solutions for solar, including a cash sale for comparison purposes, are as follows.

- Cash Purchase (not considered a financed transaction): A Developer will design and build a renewable energy system for a host company[2] usually behind-the-meter. The system is directly purchased by the company, who will also receive tax credits and environmental attributes.
- Power Purchase Agreement (PPA) Financing, Onsite: A provider will design and build an onsite renewable energy system that will owned, operated and maintained by the financier. The host company purchases electricity produced by the system over a typical term of 25 years at a contracted fixed price. The PPA contract may be structured such that the contract will transfer to a new property owner if the property is sold, or the system can be purchased at fair market value. Tax credits and environmental attributes are typically retained by the financier, but this is negotiable. An annual fixed escalator may also be identified at the onset of the contract and applied to the annual PPA rate. The magnitude of the escalator is typically negotiable and often reflects anticipated market changes, such as projected utility price increases.
- PPA Financing, Offsite: Similar to an onsite PPA, but the renewable energy project is located at an offsite location in the same state or service territory as the customer purchasing the power. This is only available only in certain states and utility territories with enabling regulations, such as remote net metering or community solar programs.
- Operating Lease: A developer will design and build an onsite renewable asset that will be owned by a third party. The company will pay fixed monthly lease payments over a typical term of 7-10 years, with a fair market value buyout option at the end of the term. The contract may transfer to a new owner with a sale of the property. The tax credits and environmental attributes are typically retained by the lease holder.
- PACE (Property Assessed Clean Energy): A long term clean energy financing option available in many states. Qualified projects may have a term of up to 30 years. A provider will design and build a renewable system that will be owned by the company. Property owners take out a loan that is repaid via a special assessment on their annual property tax bill. The payment obligation can automatically transfer to a new owner with the sale of the property. The tax credits and environmental attributes are typically retained by the property owner.
- PACE PPA: A combination of PACE and PPA financing, where a provider designs and builds a renewable energy system, but the customer makes payments for electricity produced by the

[2] The host company refers to the company seeking to build or buy renewable energy on its own hosted location.

system through a special assessment on their property tax bill. The tax credits and environmental attributes are retained by the financier, which lowers the annual payment when compared standard PACE financing. In the event of a sale of the property, the PACE PPA transfers to the new owner.

- Lease of Unused Solar Resource: Monthly lease payments to customer for unused rooftop or other available real estate to use as a host site for a solar project. The power generated by the renewable asset is sold to another party. The tax credits and environmental attributes are typically retained by the financier.

A key feature of procuring solar is the operational expense savings on utility electricity costs as compared to the baseline utility tariff rates. Regardless of whether the system is procured through a cash sale or a PPA, determination of the savings can be accomplished with a two-step calculation. Compute the Levelized Cost of Electricity (LCOE), which is equal to the lifecycle cost of the solar project divided by the lifetime energy production of the solar project. LCOE can then be compared to the net present value of the expected cost of purchasing electricity from the utility for the lifecycle of the solar project. Identifying escalation factors are an important consideration on both the LCOE and utility rates, as savings in the first year of operating a solar project will be different than in year two, and so forth. A PPA contract with a high escalation factor, where the same escalation is not applied to the utility tariff rates, will often show greater savings in the first year and diminish over the yearly period of the analysis. The U.S. Department of Energy provides both a lifecycle cost calculator and an energy escalation rate calculator.[3]

Deploying solar across the United States can be a complicated, but worthy, endeavor. The enabling legislation, rules, and regulations for installing solar all vary greatly from one state to the next. Take Maryland, for example. The Public Service Commission allows third party ownership; has instituted programs for behind-the-meter net metering, remote net metering, and community solar; maintains compatible interconnection standards; and offers an avenue for monetizing for renewable energy credits. The same is not true if you cross the southern border of Maryland into Virginia, where the ease of installing renewable distributed generation is nearly the opposite – limited third party ownership, no value for renewable energy credits, and utility rate structures that discourage solar implementation. Knowing these enabling rules is necessary for project success, and the right program manager will mitigate these risks by navigating through the regulations and project permitting. An example of this may be the know-how to secure a conditional land use permit in a local Maryland jurisdiction or evaluating the available unused pilot PPA program capacity in Virginia. A third-party program manager will typically provide these early diligence considerations during an at-risk development period, prior to the an executed PPA or lease, effectively shifting these development tasks away from your company.

Public perception of a company’s sustainability efforts can also be driver of deploying or purchasing power from solar and wind renewable energy systems

3. Conclusions

Telecom companies, who may have a range of facilities such as administrative sites (i.e. office buildings), data centers, and telecom towers, can take a portfolio approach to renewable energy management to result in an effective implementation strategy for several reasons. First, leveraging larger volumes of equipment procurement across many sites puts downward pressure on suppliers when there is predictable and steady

[3] https://www.energy.gov/eere/femp/building-life-cycle-cost-programs

demand. Second, by combining a range of characteristics in sites, the portfolio has more optionality around solar technology solutions, financing, and complementary technologies such as battery storage. In other words, the renewable energy solution for a single site may be different than the optimal solution for a combination of sites. Lastly, a portfolio of projects will result in a lower cost basis for a variety of reasons including engineering, operations and maintenance for standardized equipment, and efficiencies in labor costs.

Renewable financing is a robust marketplace with reliable and secure market participants and price transparency. For companies seeking to procure renewable energy, using available financing is a powerful tool to meet their objectives. Understanding that financing is typically tied to a fixed price power purchase contract, companies can mitigate long term price fluctuations, lower costs near- and long-term and avoid capital expenses. Renewable energy markets are made complicated by widely varying enabling rules. These risks can be mitigated by engaging a third-party program manager whose core business is renewable market participation. By combining projects to create a portfolio, companies create a new lever – purchasing power – for deeper savings.

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