Impacts of Legacy and Next Generation Cooling Technologies on Power Demands and Environmental, Social and Governance Strategies

A Technical Paper prepared for SCTE by

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1. Introduction

Environmental, Social and Governance (ESG) is a framework within the umbrella of sustainability. It is used to describe and measure an entity's behavior with respect to environmental issues, which includes greenhouse gas emissions and impact on natural resources, its engagement with and impact on society – both local and global, and the strength of its governance and the ethics behind its decision and policy making.

Companies around the world are being pressed to provide more transparency around their ESG risks and meaningful progress toward the mitigation of those risks.

ESG matters for a number of reasons, not least because the criteria are a set of standards that potential investors use to screen and evaluate companies. When a company's ESG "score" (a measure of a company's exposure to long-term environmental, social, and governance risks) goes up, its capital costs are reduced, and the company valuation improves. It is like a sustainability credit rating.

A good sustainability program drives business growth and enhances the brand, while cutting costs and reducing risk.

The most important reasons for focusing on ESG, however, are the long-term impacts on society and the planet.

Energy use is a key component of the Environmental element of ESG. For Cable Operators energy use for critical facilities operation represents one of, if not the largest operating expense. Heating, Ventilation and Air Conditioning (HVAC) systems typically account for 35% to 45% of the cable facility energy use. The Information Technology Equipment (ITE) heat loads represent approximately 45% to 50% and miscellaneous lighting is +/- 5%. By achieving reductions in energy use, related Greenhouse Gas (GHG) emissions can be reduced resulting in an improved ESG score.

The Environmental part of ESG is categorized in three scopes.

- -Scope 1 - direct GHG emissions occurring from sources that are controlled by an organization - eg emissions associated with furnaces or vehicles
- -Scope 2 – indirect GHG emissions are due to the organizations use of electricity
- -Scope 3 – are indirect emissions occurring in the supply chain.

This paper will explore how legacy sites with older cooling systems can achieve significant energy and carbon footprint reduction and will also step into new technologies that will lead to further energy efficiency improvements.

Scope 2 emissions will be the primary focus of this paper and more specifically emissions related to cooling in legacy facilities. Reducing GHG is best done within a management lifecycle process and must include a focus on all three emissions scopes. Meaningful measurement needs to be performed, where baselines and targets are set, and progress is tracked.

Due to variations between operators' approach to preventive maintenance (ie. internal or external business partners) and operators not having readily available emissions data for purchased goods, Scopes 1 & 3 impacts are not considered in this paper. See also Note 1.[1]

[1] Note 1: This paper represents the opinions of the authors and is the product of professional research. It is not meant to represent the position or opinions of Rogers Communications, and Rogers Communications does not accept any responsibility or liability for the accuracy, content, completeness, legality, or reliability of the information contained in this paper. The information contained in this paper is not intended to be relied upon for any specific application without independent verification and assessment of suitability.

2. Cooling Technology and GHG

Guidance in collecting and managing data to determine GHG and carbon footprint is found in SCTE 208 2021 – Cable Operator Greenhouse Gas Emissions Data Collection Recommended Practices.

As can be seen from Figure 1- Footprint of a Typical Cable Operator (from SCTE 208 2021) Cooling Technology consists of *Scope 1 (Direct Emissions)*, Refrigerants, 4.2%, and *Scope 2 (Indirect Electricity Emissions)*, Cable Critical Facilities Electricity of 22.2%.

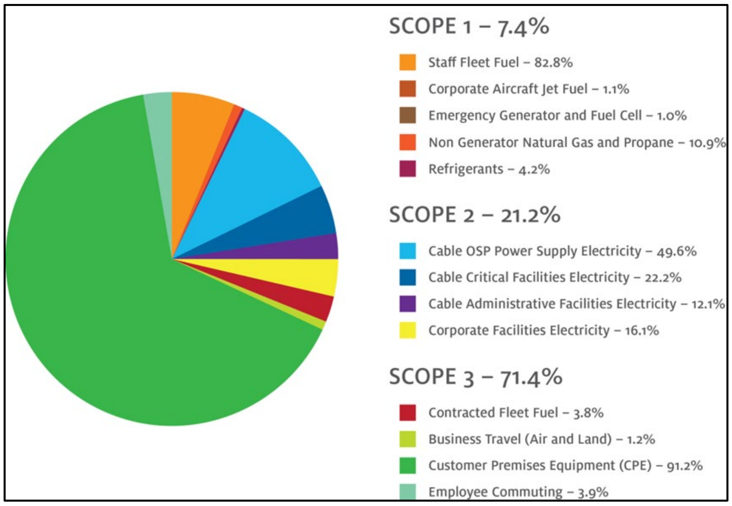

Figure 1- Footprint of a Typical Cable Operator (from SCTE 208 2021)

2.1. Refrigerants

For Refrigerants, *Scope 1 (Direct Emissions),* the Environmental Protection Agency (EPA) provides a method to estimate emissions from: Installation, Operation and Disposal to determine total emissions in this category. This is covered in detail by the EPA in: *Greenhouse Gas Inventory Guidance: Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases.*

Refrigerants used in HVAC systems affects their efficiency and therefore can have an effect on *Scope 2 (Indirect Electricity Emissions)*.

2.2. Cable Critical Facilities Electricity – Cooling Systems

Cable Operators Critical sites commonly consist of a combination of older and newer cooling systems.

Cooling systems that are over 10 years old are generally considered “Legacy” Cooling Systems with higher electrical consumption hence higher emissions.

Legacy Cooling Systems have a number of limitations which result in contributing significantly to the Scope 2 reported emissions of 22.2%.

2.3. Legacy Cooling Systems

Legacy HVAC systems operate at a fixed capacity, or at best in a rudimentary step function to provide some variable capacity, and therefore have a high mechanical Power Usage Effectiveness (PUE) for a given heat load. Energy saving features such as: Free Air Cooling; Pumped Refrigerant, were not available.

If more than one unit is used to cool a given heat load, quite often they operate independently which means they may not share the heat load causing one unit to operate at a much higher cooling level than another. In some cases, networking, sequencing and 'teamworking' the units to operate together, if applied properly, can improve their combined efficiency.

The fans in the evaporator and condenser are fixed speed and so have a fixed energy consumption, regardless of heat load.

Monitoring capability is rudimentary and does not provide any significant data on "real time" energy consumption to enable effective energy management.

Air cooled HVAC installed in Critical Facilities prior to 2010 used the refrigerant R-22. Although the GHG (Measured by Global Warming Potential (GWP)) of R-22 was similar to refrigerants used today, for example R-407C or R410A, they are not chlorinated substances which are classified as an Ozone Depleting Substance (ODP). That makes R-22, a chlorinated refrigerant, a much less desirable refrigerant. New R-22 refrigerant is no longer available which means cooling systems using R-22 are reliant on recycled refrigerant if top ups are required. The supply of R-22 will diminish over the next few years resulting in higher costs and will eventually not be available.

2.4. Cooling Systems Today

HVAC systems in use today have variable cooling capacity, using scroll type compressors or the equivalent to gain over 2000 points to adjust the evaporator. Evaporators have a higher capacity and Electronically Commutated (EC) capability enable variable speed fans to be used on evaporators and condenser. Pumped Refrigerant, or direct free air cooling are also available to reduce energy consumption. This has allowed a significant energy reduction for a given heat load.

Controls and monitoring are much more sophisticated but represent a training challenge for operations teams. There is room for significant improvement both in the operation of units and in right sizing for a given heat load.

Air Cooled units now use more environmentally friendly refrigerants such as R407C or R410A which have zero ODP and a reasonable GHG/GWP.

3. Improvements to Reduce Energy Consumption in Legacy/Existing Facilities and Cooling Systems

Older critical facilities suffer from poor cooling efficiency due to older cooling systems being used and because the sites were not designed for the heat load levels being experienced today. As a result, the racks and cooling designs were not well laid out for effective heat removal. This resulted in poor air flow management requiring excess cooling and air flow to meet the growing heat load demands.

The SCTE Facilities Cooling Technology Optimization Working Group has addressed methods to improve and optimize cooling in legacy facilities in the papers highlighted below.

- Improving air flow management – resulting in less air flow required and higher return air temps – SCTE Journal SCTE-EM-V5N1 – Rightsizing Network Cooling – Getting Ready for 10G
- Increase in set points – SCTE 253 2019 Cable Technical Facility Climate Optimization Operational Practice: Understanding Set Point Values, Part 1
- Air containment – SCTE 274 2021 Cable Operator Critical Facility Air Containment Operational Practice
- Control Systems and Networking cooling units Reference SCTE 184 SCTE Energy Management Design, Construction and Operational Practices for Cable Facilities
- Operational Practice to improve air flow and climate conditions in Critical Facilities – SCTE 219 2021 – Technical Facility Climate Optimization Methodology

Pilots and research trials by multiple Cable Operators have measured and verified the possible energy savings potential of the listed Energy Conservation Measures (ECMs) as shown in Figure 2 - ECM Estimated Savings. The scalability and magnitude of these measures will be unique to the site and providers as they identify, through assessments, where their baselines are, and what would have the most impact to their sites.

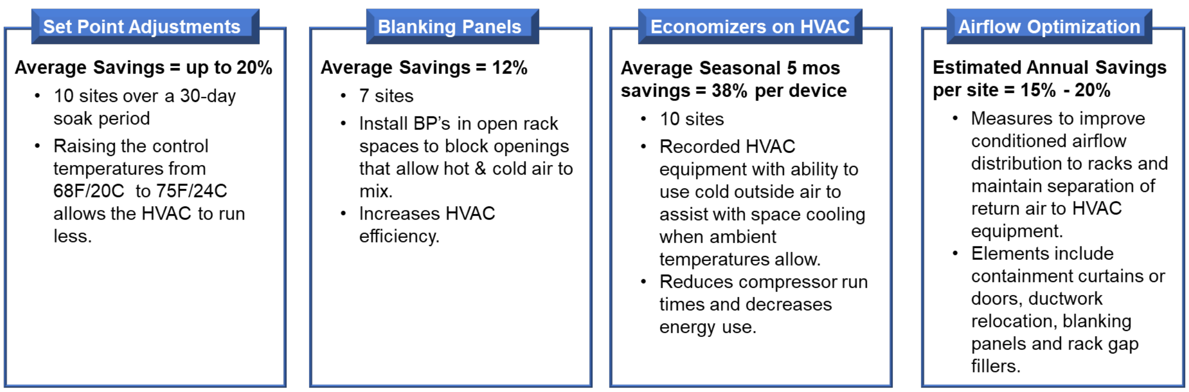

Figure 2 - ECM Estimated Savings

As the savings above indicate, several low-cost implementations can result in measurable energy reductions. Additionally, the replacement of existing aged HVAC units can result in immediate efficiency gains resulting in improvement of Scope 2 by 20% to 30%.

3.1. Floating Head CRAC Retrofit

Floating head retrofit is applicable to Computer Room Air Conditioning (CRAC) units that are Direct Expansion (DX) based and that are 5 years or older. This retrofit will improve energy efficiency and reduce carbon footprint. The mechanical expansion valves in these older units are replaced with electronic expansion valves, enabling the unit to adapt to ambient temperatures and regulate condensing temperatures accordingly.

Traditional fixed head pressure systems run at a condensing temperature of 40°C (105°F). The energy savings for retrofitted low condensing systems begins to accrue whenever the ambient temperature is below 24°C (75°F). Figure 3 below shows the percentage of time the respective area is below 24°C (75°F) geographically.

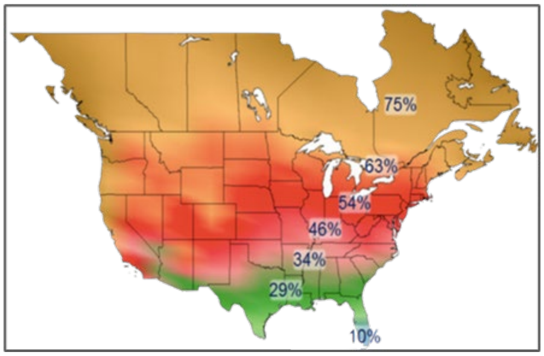

Figure 3 – Map of Temperatures for selecting Floating Head as an ECM

(SCTE Journal of Energy Management 2016 V1N1, New A/C System Architecture Promises Significant ROI in Data Centers, Floating Head Pressure Technology Reduces Energy Costs and Consumption)

Temperatures below 10°C (50°F) ambient represents the level at which the maximum energy savings from low condensing operation can be achieved as the compressor wattage decreases. A small increase in cooling capacity also occurs.

Energy consumption can be reduced by up to 45%, and the life expectancy of the unit will be extended as there is less wear on the main components.

A floating head retrofit won't make the legacy unit as energy efficient as the newest economizer models. However, comparing the cost and short payback, typically 2 years or less, of this retrofit, with the capital cost and operational disruption caused by replacing a cooling unit with an economizer system this option is very attractive. The retrofits do qualify for energy incentives if available.

In addition to energy savings two other benefits are captured with the retrofit. If the unit is using R22 refrigerant, that is units produced before 2010, this can be replaced and upgraded to R407C. The second significant benefit is less refrigerant is required for the retrofitted unit. Approximately 35% of the refrigerant is removed. The amount of refrigerant removed is dependent on the cooling capacity of the unit and the physical layout, distance from condenser.

The table below shows a case of retrofitting two Liebert DH-290's and one Liebert DS105. In this example the R22 refrigerant in the DH-290's was removed and appropriately disposed and replaced with R-407C. CO_2 equivalence was calculated using the EPA Greenhouse Gas Equivalencies Calculator.

Table 1 - Floating Head CO_2 Reduction

Floating Head Retrofit - example			
Cooling Units	2 - Liebert DH290; 1 - Liebert DS105		
	Pre-Retrofit	Post-Retrofit	Reduction
Cooling Power kW	67	34	33
Cooling Energy (kWh)	585,416	299,201	286215
Energy Cost ($0.12/kWh)			$34,346
CO2 Equvialence			
Refrigerant Removal (kg)			211.47
Refrigerant Removal (lbs)			466.2
C02 Equivalence Reduction			Metric Tons
	Due to kWh avoided		203
	Due to refrigerant removal		383
	Total		586

3.2. Room or Perimeter Cooling

Room scale cooling is where interior perimeter CRAC or Computer Room Air Handlers (CRAH) are used to remove heat from the space and provide conditioned air into the room. These systems are spaced around the exterior and in larger rooms near the center. This system typically provides bulk conditioned air into the room via raised floors, direct air discharge from the unit or through overhead duct work on a slab floor. Because of this bulk delivery approach several inefficiencies are evident due to hot and cold air mixing, by-pass airflow, high volume over provisioned air, and older fixed fan speed and staged compressor speeds. ECMs can be applied to improve efficiency.

3.3. In-Row Cooling

As rack heat loads increase a more efficient cooling method must be implemented to manage high density heat zones. In-row cooling is the deployment of multiple smaller units selectively placed between the cabinets within the rows of server racks. With the assistance of containment doors, curtains and sometimes row caps, a more controlled environment can be created. Having available space for the added in-row devices can be an obstacle for a retrofit application in legacy sites. As the density within the server racks increase so too will the added requirement for redundancy.

Figure 4 - Example of in-row cooling where air conditioning units fit inside rack rows. Courtesy: PRWeb

3.4. In-Rack or Close Coupled Cooling

In-rack or close coupled cooling places the cooling much closer to the source of heat . The extremely short distance between the server exhaust and rear door coils is measured in inches vs feet for the room and row applications thus eliminating the opportunity for mixing and other efficiency losses. .

The rejection of heat is accomplished with pumped refrigerant or chilled water running through coils at the rear doors, to an in-room heat exchanger using outside condensers. The exterior components have either economizer or mechanical cooling to complete the cooling cycle. The refrigerant pump within the main heat exchange chassis can also be DC powered. The rear door heat exchangers, as shown below, can handle 10 kilowatt (kW) per fan pair and have redundancy when all 3 pairs are installed.

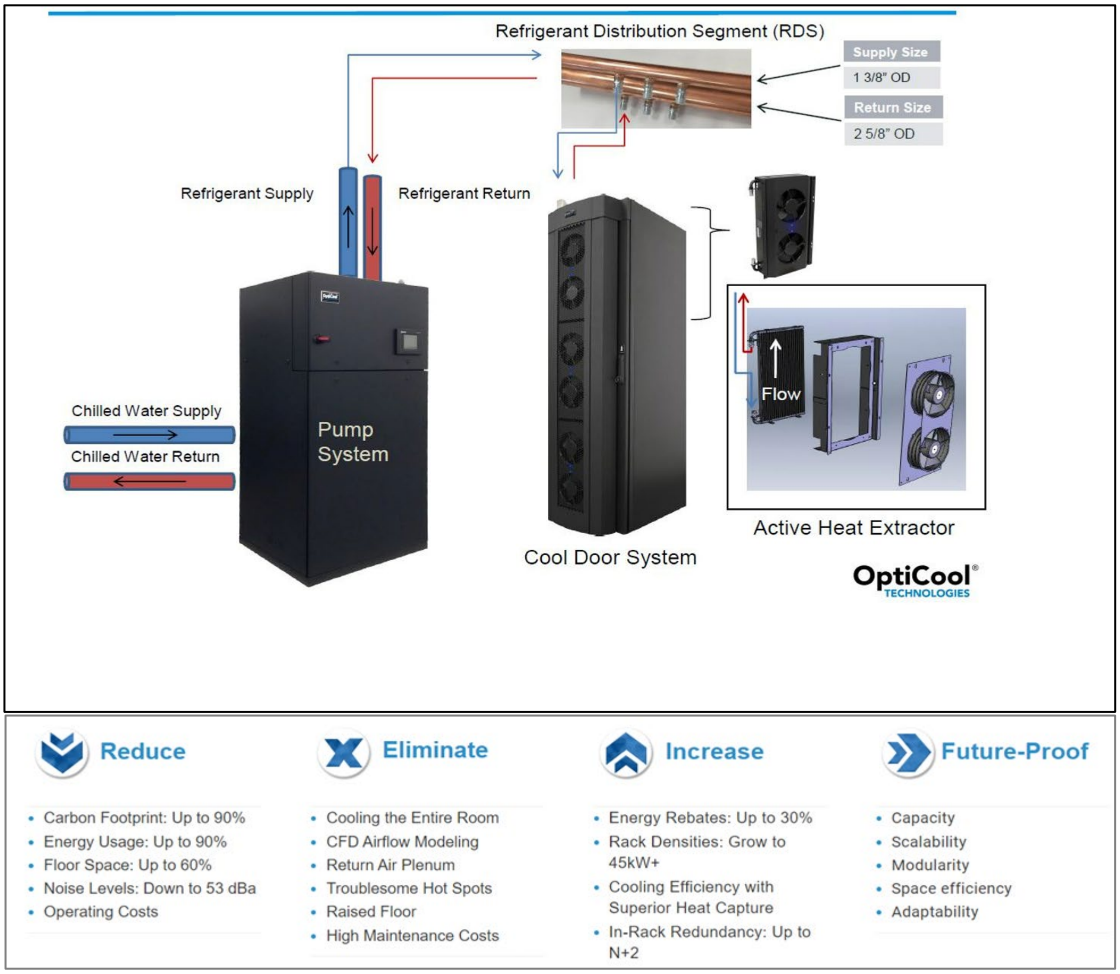

Figure 5 - Rear Door Cooling (Diagram credit: OptiCool)

Additionally, these systems require a minimal load working best on a high kW density (typically 10 kW to 30 kW per rack) applications. Overhead space is required for manifold piping and each rack depth is extended approximately 12-14 inches for the rear doors.

3.5. Investigating bulk rack exhaust fans vs server muffin fans for rack containment

Another innovative In-Rack cooling approach being developed is to utilize an existing raised floor environment or overhead ducted supply system to bring the cooling more efficiently where it is needed. This approach uses a clear solid door on the racks with a separate supply and return ducting with dual in-line fans reducing the need and cost of the server fans. Additional in-rack airflow manifolds have been developed to direct airflow for equipment intake variations. As shown, the doors would be solid and individual servers would be fed and exhausted via side discharge.

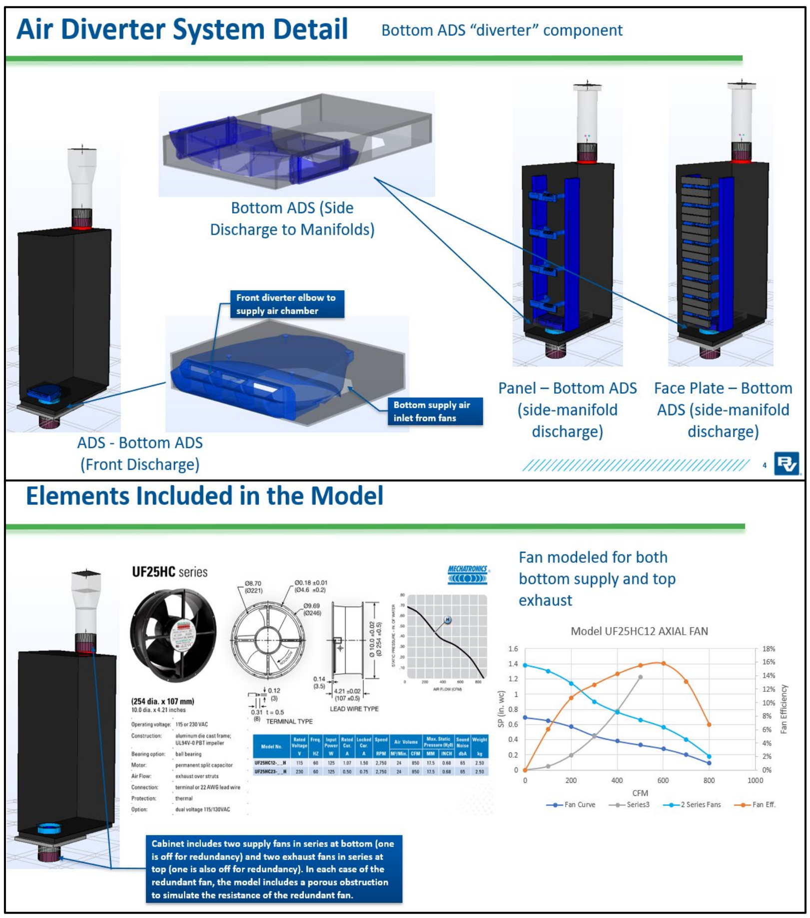

Figure 6 - Air Diverter System (Courtesy of Chillirack)

3.6. Why not Switch To CO_2 (R744) Refrigerant Based Cooling Units?

High pressure Carbon Dioxide, CO_2 or R744 systems were developed at the end of the 19^{th} century. It has an GWP of 1 so it would seem to be the ideal refrigerant. There are real advantages to using R744 but also some drawbacks holding it back from general adoption in the industry.

The following table summarizes some of the advantages and disadvantages of R744.

Table 2 - R744 Advantages and Disadvantages

Advantages	Disadvantages
Refrigeration capacity is high, approximately 5 times that of R404A (smaller compressor displacement but the same motor size)	Operating and standing pressures are high with resulting higher leak potential. Components specific to R744 required
Pressure drops in pipes allowing longer lines	Compressors are R744 specific, steel, or stainless-steel welded fittings required
Evaporators and condensers have high heat transfer	System complexity resulting in higher costs
System pressure drops, compression ratios all result in higher system efficiency	Complexity can result in poor performance and reliability because commissioning and operation need to be done correctly
Thermosyphoning of the refrigerant is possible reducing compressor run time.	Not suitable for high ambient temperature areas
R744 is inexpensive to manufacture, has low toxicity so release, often just by venting, or leakage is not an issue as there are no disposal restrictions	Listed as an asphyxiant so leak detection is required in small, enclosed spaces and release needs to be in well ventilated areas.

As can be seen from Table 2 - R744 Advantages and Disadvantages although there are significant advantages to R744, the disadvantages, particularly the complexity that operational staff will need to deal with, and the specialized materials, have resulted in a low adoption rate of these systems.

3.7. Monitoring and Control Systems

3.7.1. Background

Mechanical thermostat controls are the most traditional form of control for HVAC systems that can still be found today in headend and hub locations performing basic on/off control of the HVAC systems. Unfortunately, these types of controls do not lend themselves to modern facilities and certainly do not provide the necessary data needed to monitor and control HVAC systems to ensure optimum performance. Fortunately, there are options available today to quickly and reliably upgrade existing HVAC to smart thermostats that network into a cohesive system.

The Building Management System (BMS) have been a powerful tool to help critical facility managers monitor and control key facility infrastructure support systems. These typically include main facility electrical and mechanical systems such as: electrical power distribution systems, central air conditioning and ventilation, fire protection and lighting.

BMS systems will tend to be a localized system consisting of a software and hardware. Older BMS systems however typically do not offer a more granular control for specific critical support equipment necessary for today's demands from critical processing servers.

3.7.2. Current Monitoring and Control Technologies

Critical facility management relating to energy consumption, costs, downtime as well as its carbon footprint contribution can be challenging to most organizations without the proper tools. For this reason, monitoring and control systems play a crucial role in assisting facility management. Although current systems such as BMS, have been a valuable tool for facility management, these systems are becoming dated and lack sophistication for optimizing energy consumption management. These existing systems, albeit provide critical information to the operator, and primarily serve as a historical data archive and alarming system. These systems serve a limited capability with respect to data collection and usage as well as critical metrics and features for control optimization. As the industry looks towards updated systems offering enhanced tools and features, current systems employed are pushed to their limits of operation and obsolescence.

Systems are becoming more intelligent, providing access to significant amounts of data from their sensors regarding the performance of the equipment.

3.7.3. Data Aggregation

Most control and monitoring systems today have some form of a local user interface to view trend data such as room temperature and the ability to make adjustments. While this is necessary at a site level, it is important when managing multiple sites to have a central server-based monitoring software that can gather trending and alarm data from all of your facilities. Modern monitoring and control systems offer comprehensive monitoring and data acquisition and data storage capabilities. Many of these systems are now capable of integrating services and solutions across multi-vendor platforms for data centers and other complex mission critical facilities.
These systems have the capability to aggregate data from separate and disparate systems to provide a useful database for system comparisons, interactive intelligence and enhanced control decisions for energy savings, optimization, and efficiency. Incorporating data from ITE Assets and existing BMS systems into a single cohesive platform will provide the most comprehensive intelligence for monitoring critical facilities.
This provides the ability to identify outlier/trouble sites and prioritize maintenance resources.

3.7.4. Data Analytics

Central monitoring software is being used to provide operators with information that can predict operation of equipment and serve early warnings to impending failures which improves network reliability. These tools provide true real time situational awareness and insight to present operators with critical information to address system availability across a single facility or facilities throughout the enterprise. This approach integrates advanced energy analytics, asset management and facility monitoring tools with advanced analytics to increase visibility, improve overall efficiency, reduce costs, and mitigate risk.
This ability to create actionable data can be used to further optimize operation to reduce energy consumption of equipment and provide verification of carbon reduction. For example, the software can analyze excessive runtime with HVAC equipment at all sites. It can include frequency of ON / OFF occurrence and shortest duration between ON / OFF (To indicate unhealthy short cycling). The report can show historical performance, live data overlays, suggested targets, and remediation. Another example, the central monitoring software can poll the local control systems to gather the current cooling operation and then generate a report indicating zones where temperature setpoint is not maintained when cooling is on. Time between triggered cooling event and time to satisfy zone temperature are tracked to indicate degradation in cooling effectiveness.

3.7.5. Next Gen Controller Technologies

Control systems can use machine learning for adaptive control strategies. This is leading to control systems that can automatically adjust their settings to changes in the facility and better matching of the heat load. An example of this is the ability to adjust the economizer control setpoints based on successful cooling using outside air. Traditionally the economizer settings are fixed thresholds for when outside air can be used. Intelligent control systems can learn what outside air temperatures will provide necessary cooling and then adjust the settings to allow for more opportunity to use outside air for cooling. Conversely if there is an increase in heat load in the facility or changes in the HVAC equipment then the settings can automatically be lowered. Figure 7 below is a graph showing the economizer setpoint of the HVAC system adapting over a 30-day period.

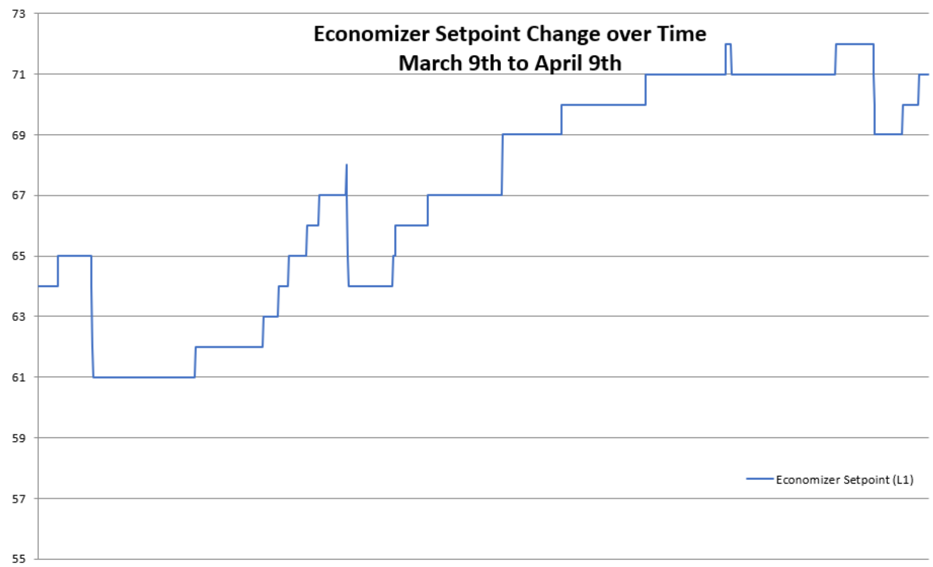

Figure 7 - Economizer Setpoint Change over Time

For example: A site in Denver, CO with the ability to float up the economizer setting to 55 ºF (13ºC) compared to a fixed economizer setting of 50 ºF (10ºC) and would see a 35% increase in the available opportunity to use economization. [2]

Facility control systems will need to continue to evolve to support the increasing use of intelligent equipment. This will require a focus on communication protocols and networking to communicate with "smart equipment". HVAC systems as well as other systems (generators, power meters, etc.) are being equipped with Programmable Logic Controller (PLC) which provide complex control sequences for the device they are monitoring and controlling. Control systems must also provide a solution for existing HVAC equipment that use traditional mechanical control devices. By providing smart networked T-stats (see Figure 8) for example, would allow existing equipment to obtain some of the benefits of newer units with built in PLCs. The challenge is to integrate these smart systems into a cohesive monitoring and control solution for the facility. The ability to share data and to coordinate control of dissimilar stand-alone equipment will improve overall operation and allow the stake holders to know precisely what is occurring in their facilities. This will provide further optimization by understanding how the entire facility is operating vs. individual components.

[2] Based on degree day calculations for a year using https://www.degreedays.net/. Calculations used weather stations ID KDEN

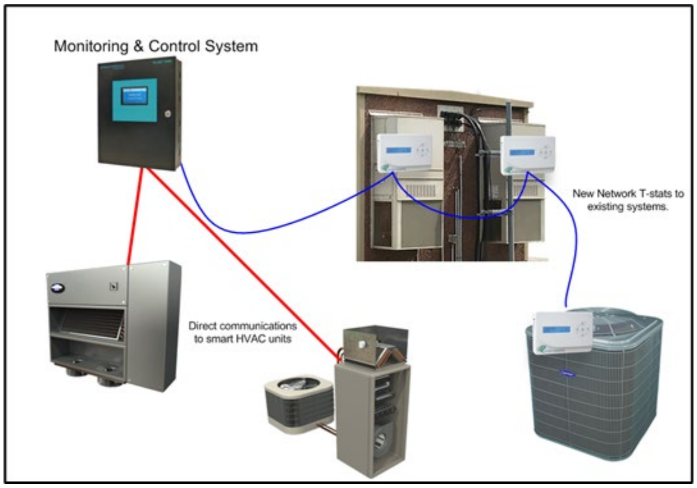

Figure 8 - Control System Communicates to Smart Equipment and Smart T-Stats Connected to Legacy Equipment

3.7.6. Tie to Carbon

With the advancements of control and monitoring systems, organizations are able to realize significant reductions in direct energy usage and carbon footprint. Monitoring and control systems for today's facilities are at their best when they can take dissimilar or standalone intelligent systems and coordinate their control to ensure the facility is sufficiently cooled for their intended use. Intelligent controls are able to take advantage of alternate cooling methods such as outdoor economization to further reduces compressor run time. Charter Communications, Inc. reported in 2021 that "evaporative free-cooling avoided over 5,700 megawatt-hours of electricity usage"[3]. This translates to a CO_2 reduction of approximately 4,039 Metric Tons[4]. Another MSO has recently completed a free air economization proof of viability at a Northeast facility where a reduction in compressor run time provided a savings of approximately 19,162 kilowatt-hours (kWh) during a five-month period available for economization use. This will yield a CO_2 reduction of 13.6 metric tons.

The ability to remotely monitor the performance of a portfolio of facilities and make necessary changes prevents unnecessary travel to sites which reduces carbon emissions and saves on fuel expense. Through the advancements of the Internet of Things (IoT), additional sensing is economically being deployed to remote facilities. The ability to gather information and turn it into actionable data will further increase an operator's ability to document, categorize and manage their carbon footprint.

4. Next Generation

4.1. Next Generation Refrigerants

Refrigerants available are being updated to reduce their GWP. One of the drivers for this is the Kigali Amendment to the Montreal Protocol. This primarily affects R22 for Cable Operators at this time. Refrigerant properties are available in ASHRAE Standard 34 Designation and Safety Classification of

[3] Charter-2021-ESG-Report.pdf, https://corporate.charter.com/esg-report
[4] Carbon reduction calculated using the EPA calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Refrigerants which provides refrigerant numbering, toxicity, and flammability ratings. The pursuit of other refrigerants may take place over time and depends on low pressure, medium pressure, or high-pressure systems. The best choice today may change tomorrow. Although complex, the key decision for selecting a new refrigerant needs to be made on efficiency.

Nonetheless for GWP the HVAC system has a direct effect from the chemical refrigerant, and indirect effect from the energy use adding up to the total climate performance.

The biggest factor that can be controlled by the Cable Operator is then the indirect effect from energy use and the associated GWP of that energy source.

4.2. Next Generation Cooling Technologies

4.2.1. Phase Change Material (PCM)

The effectiveness of cooling systems that use outside air (free air-cooling systems), can be improved considerably with the use of (PCM). This can cool the incoming air reducing compressor run time, extending the free air-cooling time, and be recharged at night when the temperature is lower.

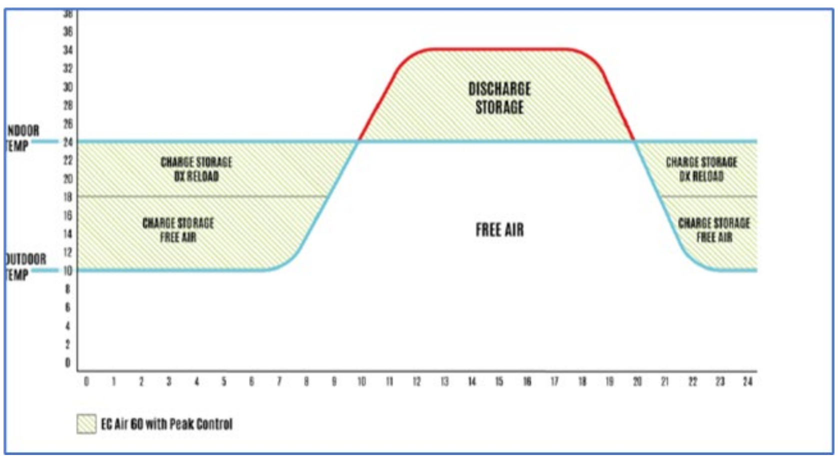

Figure 9 - Phase Change Material and Free Air Cooling (Diagram Courtesy of Energy Cool®)

4.2.2. Liquid Cooling

As ITE heat loads increase, the effectiveness of air-cooling systems will reach a limit with reduced efficiency. In order to cool the higher heat loads and drive PUE down below 1.1, closer coupling of heat removal is required using some form of liquid cooling. This paper will not go into detail of the technologies that are available, but they are:

- Liquid cooling - A cabinet or plate to remove heat directly from the surface of the chips used by the ITE heat load.
- Immersion cooling - Removes all fans and submerges the ITE heat load directly in a dielectric cooling liquid.

Currently both are used for higher density computing above 50 kW per cabinet.

4.2.3. *Internal Server Cooling*

Internal server cooling may improve using hybrid two phase cooling using passive low height thermosyphons to dissipate the heat generated in high power components of servers. This augments traditional cooling of other server components.

5. Conclusion

Through the careful use of ECMs, and selection of cooling technologies that are appropriate, Critical Facility energy use for cooling can be significantly reduced as the ITE heat load increases. This in turn will help to reduce Scope 2 emissions and overall GHG impact.
Additionally the use of more environmentally friendly refrigerants can help to reduce GHG's. Refrigerants are being updated to reduce their GWP but must be selected carefully as this can in turn affect the HVAC performance.
It can be seen in Figure 10 - GWP Life Cycle Climate Performance, that the major climate impact of HVAC is the electrical power used, and how it is generated, over the equipment lifetime. The key factor in refrigerant selection then is its effect on the efficiency in the HVAC system. A refrigerant that results in overall lower HVAC cooling effectiveness per kW of heat load will result in a higher Scope 2 emission for the system as it will consume more electrical power.
With the source of the electrical power being a key factor in the critical facility life cycle, climate performance consideration must be given to reduce that impact through use of microgrids, Demand Energy Response (DER) and other solutions for greener energy sources.

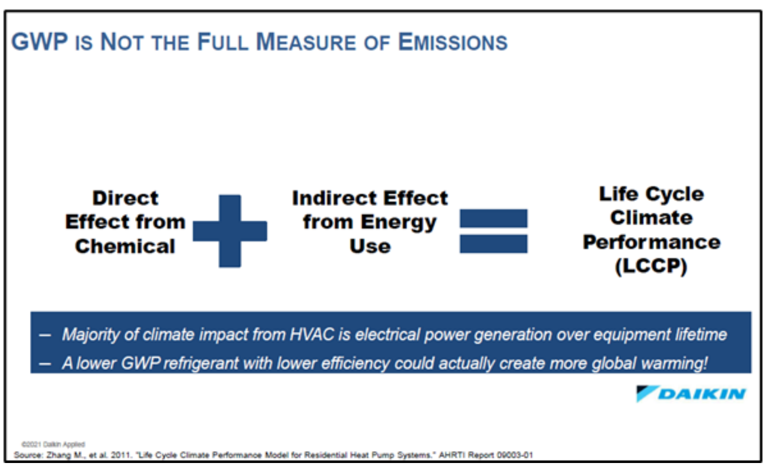

Figure 10 - GWP Life Cycle Climate Performance

Abbreviations

BMS	Building Management System
CRAC	Computer Room Air Conditioner
CRAH	Computer Room Air Handler
DER	Demand Energy Response
DX	Direct Expansion
EC	Electronically Commutated

ECM	Energy Conservation Method
EPA	Environmental Protection Agency
ESG	Environmental, Social and Governance
GHG	Green House Gas
GWP	Global Warming Potential
HVAC	Heating, Ventilation and Air Conditioning
ITE	Information Technology Equipment
ODP	Ozone Depleting Potential
kW	kilowatt
kWh	kilowatt-hours
PCM	Phase Change Material
PLC	Programmable Logic Controller
PUE	Power Usage Effectiveness

Bibliography & References

ASHRAE Standard 34 Designation and Safety Classification of Refrigerants, available at: https://www.ashrae.org/technical-resources/bookstore/ashrae-refrigeration-resources

EPA Greenhouse Gas Equivalencies Calculator - https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Greenhouse Gas Inventory Guidance: Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases - https://www.epa.gov/sites/default/files/2015-07/documents/fugitiveemissions.pdf

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