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How Modernizing Aging Data Center Infrastructure Improves Sustainability

White Paper 45

Version 1

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Executive summary

Data center operators today are tasked with helping achieve corporate sustainability goals, including net-zero emissions commitments. Aging physical infrastructure is a significant obstacle to this effort. In addition to posing downtime risks or added maintenance costs, this infrastructure can negatively impact efficiency and environmental sustainability. But operators may struggle to understand how modernizing their power and cooling systems will help them meet their sustainability goals. In this paper, we describe the challenges that aging infrastructure pose to your environmental sustainability goals and present three approaches to modernizing data center infrastructure systems. We then provide specific examples of how each approach leads to improved sustainability and discuss seven key factors that help assess which approach(es) to take given the breadth and complexity of systems in a typical data center.

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Introduction

IT equipment in a data center is replaced, on average, every 4 years.[1] But the physical infrastructure systems that support the IT equipment is generally expected to last much longer. Data center environments are complex, with multiple interconnected subsystems, including switchgear, switchboards, generators, uninterruptible power supplies (UPSs), power distribution units (PDUs), computer room air conditioners (CRACs), heat rejection systems, and so on.

As this physical infrastructure ages, it can pose a significant risk to data center operations. Facility operators often think about modernizing their equipment when:

1. spare parts become difficult and expensive to obtain
2. maintenance and repair frequency and costs are rising
3. components are visibly deteriorating
4. failure and downtime risks are increasing or have already happened

Aging infrastructure also comes with efficiency and environmental sustainability implications. Many data center owners and operators today have established sustainability targets such as net-zero carbon emissions commitments and/or find themselves in the value chain of major firms who have done the same. But they often don't consider how their aging power and cooling systems hinder the achievement of these goals, and often struggle to make a quantified connection with how modernization of these systems helps reach environmental sustainability goals faster.

In this paper, we describe the challenges that aging infrastructure pose in reaching your environmental sustainability goals, and present three key approaches to modernizing this data center infrastructure (illustrated in Figure 1). We then walk through three specific use cases to demonstrate how each approach leads to improved sustainability. Lastly, we discuss seven key factors that help assess which approach to take given the complexity in the data center. With this information, data center operators will be better prepared to make the business case for modernizing their infrastructure.

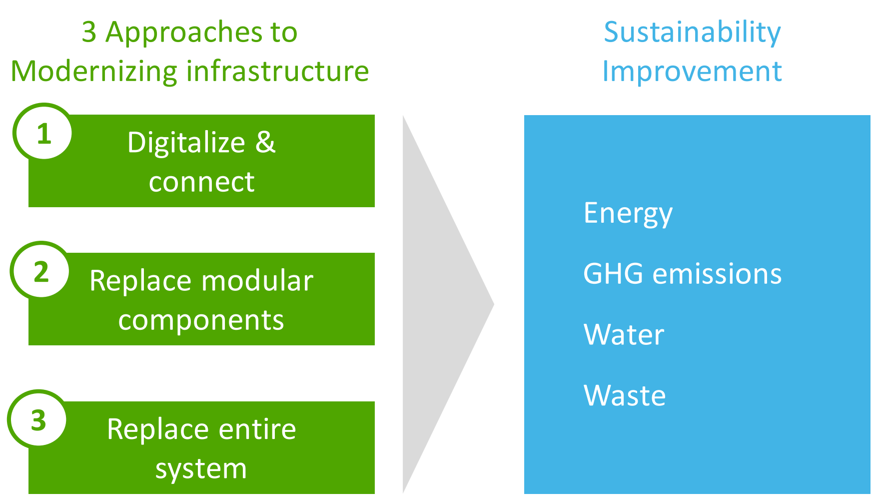


Figure 1

Sustainability metrics are improved through modernizing aging physical infrastructure

[1] https://horizontechnology.com/news/data-center-hardware-refresh-cycles/

Sustainability impacts of aging infrastructure

The environmental sustainability impact of aging data center infrastructure is broad and varied. In **Figure 1**, we illustrate four main categories of sustainability improvement: energy, Greenhouse gas (GHG) emissions, water, and waste. The metrics to measure these improvements, are discussed in greater detail in White Paper 67, *Guide to Environmental Sustainability Metrics for Data Centers*. Below we describe how aging infrastructure negatively impacts sustainability in each of these categories.

Energy

Data centers consume significant energy, on the order of 1-2% of global energy use. This makes optimizing energy use a high priority. Inefficient data centers often consume as much or more energy for their physical infrastructure systems as they do for the IT equipment they are designed to support. A power usage effectiveness (PUE) of 2.0 means for every watt of IT equipment, another watt is consumed by the power and cooling infrastructure. Modern data centers are capable of achieving PUEs much lower than that (<1.5). One way to improve energy consumption is to improve the efficiency of the systems in the data center. The three main drivers to inefficiency that result in increased losses and energy expense with aging infrastructure are:

- **Inefficient systems** - Older equipment generally operates less efficiently than newer equipment, because of technology advancements.
- **Oversized infrastructure** – Systems operating at light load run less efficiently than right-sized systems.
- **Lack of visibility** – When older systems aren't actively monitored, systems may be operating in a degraded state (e.g., clogged filters).

In addition, aging infrastructure poses a challenge in participating in demand response and other grid interactive programs due to older technologies and limited or absent connectivity. The ability to curtail or shift energy use of the data center based on the grid's available energy sources is a valuable opportunity in meeting net-zero sustainability objectives.

GHG emissions

Greenhouse gas (GHG) emissions include carbon emissions (CO_2), methane emissions (CH_4) as well as other gases such as PFCs and HFCs released into the atmosphere. Common sources of these emissions in operating and aging infrastructure include:

- the electrical energy consumption discussed in the prior section indirectly leads to further CO2 emissions (referred to as Scope 2 emissions[2]). The emissions factor of the electricity consumed varies based on location as well as onsite energy sources.
- combustion of fuels from backup generators (as infrastructure failures increase, backup generator use generally increases, leading to increased emissions)
- leakage of sulfur hexafluoride (SF6) from medium voltage switchgear, and hydrofluorocarbons (HFCs) released by cooling systems
- transportation of personnel and materials (i.e., service technician bringing spare parts).

[2] https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

Water

Water is a critical resource and an environmental concern in water-scarce areas of the globe. The cooling systems that reject heat generated by IT equipment are what drive water use in data centers. Traditional methods of cooling using water-cooled chillers consume on the order of 25 million liters of water per year[3] from the water-intensive evaporation process of the cooling tower. Aging data centers often use these traditional cooling methods. With growing pressure to minimize the use of water, including from regulatory bodies, this method of cooling is coming under greater scrutiny. In White Paper 132, Economizer Modes of Data Center Cooling Systems, we present alternatives to water-cooled chillers and compare the annual water consumption of each.

Other ways that data centers indirectly use water is through the energy consumed in operating the data center, and in the systems used in the data center, since water is used in the:

- generation of electricity at the utility
- manufacturing process of power and cooling systems

Waste

Data centers generate a significant amount of material waste throughout their lifecycle. There is waste generated in the raw material extraction and manufacturing processes, when installing systems (e.g., packaging materials), when consumable parts need to be replaced, and when the infrastructure reaches the end of its useful life and must be either:

- Re-manufactured – to restore the system to its original functionality
- Re-purposed – to create a secondary or alternate use for the parts
- Re-cycled – to recycle the system's raw materials for another use
- Put in landfills – when the prior 3 alternatives are not feasible

Data center operators are often unaware of how the waste from their obsolete equipment is managed once it leaves their site(s). But as sustainability becomes a higher priority, the ability for vendors and partners to document and verify circular economy practices will become a necessary selection criterion in determining who to work with.

The three approaches to modernization

With the four categories of sustainability impacts for aging data center infrastructure described, how do data center operators address them? In White Paper 272, A Framework for How to Modernize Data Center Facility Infrastructure, we discuss, at a high level, four modernization strategies including (1) digitalizing & connecting, (2) replacing modular components, (3) replacing entire systems, and (4) doing nothing. Here, in this section, ***we dive deeper into the first three approaches*** from that paper[4] and discuss how each can mitigate environmental challenges and help companies achieve their sustainability goals. As we will later discuss in "Choosing the Right Approach", since data centers are made up of varying and complex systems, it is likely you will use a mix of these approaches.

[3] https://journal.uptimeinstitute.com/dont-ignore-water-consumption/

[4] The fourth option of "doing nothing" from White Paper 272 can be appropriate in certain cases based on cost implications and age of equipment but is not included in this paper because we're focused on how taking modernization *actions* can positively impact the environment, and "run-to-fail" generally presents too much downtime and safety risk to data center operators.

Digitalize and connect systems

Some older infrastructure systems rely on humans performing manual and visual inspections of equipment to keep them running smoothly. Staff walk around, look at displays, take periodic measurements with handheld sensors, look for any visible damage or deterioration, etc. This approach has the potential for human error and is also limited in its ability to find indicators of future problems, since it is periodic, and the devices' may only display limited information. Lack of real time visibility through monitoring makes it difficult to maximize the health, safety, and longevity of the system.

Having these systems digitalized and connected can add much more insightful information to not only help improve the reliability (and reduce unexpected downtime) of the systems, but also improve the sustainability. Digitalized refers to the representation of a physical device with a digital or virtual version of the device. This is done through instrumentation with sensors (i.e., temperature, humidity, pressure, vibration). Connected refers to putting a device on a network to communicate with software management platform(s), including building management systems (BMS), electrical power monitoring systems (EPMS), data center infrastructure management (DCIM) systems, environmental sustainability management (ESM) systems, as well as 3rd party APIs. These platforms leverage the cloud, data lakes, and artificial intelligence to understand the health of systems, optimize operations and maintenance through predictive analytics, allow remote management options, provide energy reporting, and enable interaction with other systems. There are five specific sustainability benefits of digitalizing and connecting existing systems:

- Benchmark and improve on sustainability metrics – Creating a baseline to know how your data center is performing against sustainability metrics and then tracking improvement over time is essential to reaching your sustainability commitments. Data from sensors (e.g., energy and water consumption trends) can be analyzed to provide insights that allow you to make smart changes to operations to help reach targets.
- Reduce energy & carbon impact through interactions with other systems – Digitalized and connected systems have the potential to interact with other systems like the utility grid, and onsite renewable energy sources to reduce the data center's environmental sustainability impact. Actions like peak shaving and load shifting based on the energy sources available helps minimize GHG emissions. These interactions also provide an opportunity to monetize any onsite energy sources.[5]
- Increase the life expectancy (useful life) – Real time monitoring and predictive analytics increases the likelihood of identifying problems *before* they become critical. Identifying and correcting these problems can prolong the system life and improve reliability. A longer useful life delays disposing of old systems and manufacturing of new ones, both which have an environmental impact over the lifecycle of the data center.
- Avoid frequent time on generator – Predictive analytics and proactive monitoring can decrease system downtime. This avoids the need for frequent switching to standby generator power and the associated GHG emissions. For example, a diesel generator produces 714 kg CO2 / MWh, so if a typical loss of primary power event lasts for 2 hours, a data center would produce 1428 kg CO2 per MWh.
- Minimize service visits – When systems are connected, they can be managed remotely, thus minimizing the need for onsite service interventions. Analytics of the sensor data also enables condition-based maintenance where parts are replaced "just-in-time", rather than calendar-based maintenance, where parts

[5] For more information see WP274, *Monetizing Energy Storage in the Data Center*

may be replaced before they truly needed to be. This could mean less parts are needed (and the associated service visits to install them) over the lifecycle. Less travel (transportation), although a smaller impact, does contribute to lower carbon emissions.

Replace modular components

A second approach to modernization is to replace modular (upgradeable) components. Some systems in the data center are modular by design. When this is the case, as the modular components age and/or become obsolete, they are proactively swapped out while leaving other base building blocks like the frame of the system in place. Modernizing data center systems in this way is less disruptive, faster to implement, and lower cost than replacing the entire system[6]. Beyond these benefits, there are specific environmental sustainability benefits of this approach:

- Process fewer primary resources during manufacturing – By keeping certain components in use, less new equipment must be manufactured. This means less raw materials, or "primary resources", are needed over the lifecycle.
- Process fewer waste materials – Replacing only the modular components means not all materials must be processed as waste at the point of modernization. This varies by system but can preserve a significant percentage of materials (by weight).
- Leverage new technologies that are digitalized and connected – The existing components may not have the sensors to provide as much information as a new module would today. New modules that are equipped with sensors/software to digitalize and connect the system reduces resiliency risks, enables digital services, and has a host of sustainability benefits as discussed in the prior approach.
- Leverage new technologies that are more efficient, smaller and lighter – Replacement components or subsystems with updated designs often benefit from advancements in technologies that are more efficient in energy use (and its associated carbon footprint), more efficient in water use, and may be smaller, and lighter. Smaller and lighter components improve sustainability by using less raw materials and having a lower transportation impact. This could be swapping a UPS module with a more efficient one, replacing a VRLA battery with li-ion, or replacing fixed speed motors/fans with variable speed motors in CRAC/CRAH.
- Minimize the environmental risks of toxic substances – Toxic substances can have high global warming potential (GWP). One example is SF6 contained in some MV switchgear, which is a highly regulated substance at local, state, federal, and international levels. When SF6-based circuit breaker modules reach their end-of-life, vendors can replace them with SF6-free circuit breaker modules. As part of the modernization, it is important that after decommissioning, the disposal and recycling of SF6 is in compliance with IEC 62271-4 standard to minimize the environmental impact.

Replace entire system

The third modernization approach is the most comprehensive and replaces the entire aging or obsolete system(s). Initial capital expenditure is higher than the prior two approaches, but that higher upfront cost is often offset with lower operational costs. This approach generally makes sense if (1) the system is not modular, (2) if modular parts are no longer available,(3) if it is cost-prohibitive to maintain the

[6] Schneider Electric White Paper "How electrical distribution equipment retrofit services contribute to a circular economy" illustrates the typical downtime of 2-6 days to replace new switchgear vs. under an hour for retrofitting an existing switchgear (Figure 11).

system, (4) if the system needs have changed (i.e., capacity, redundancy, runtime, density), and/or (5) if advancements in technology and architectures warrant a full replacement.

Some of the environmental benefits mentioned in "Replace modular components" also apply to this approach. Key benefits include those associated with digitalized and connected components, smaller and lighter systems, and eliminating the environmental risks of toxic substances. In addition, this approach provides the following sustainability benefits:

- **Improve energy efficiency through rightsizing of systems** – Systems like UPSs that run lightly loaded are generally less efficient than ones that run close to or at the designed capacity. Improved efficiency directly impacts energy and carbon footprint.
- **Improve energy use with newer technology** – Technologies have advanced, and newer systems are more energy efficient than their older counterparts. Newer technologies include more efficient modes of operation that can lead to significant energy reduction (i.e., UPS eConversion modes or cooling system economizer modes). Newer systems are also often designed with circular economy in mind, improving life expectancy, recyclability of raw materials, and so on.
- **Reduce maintenance needs** – New systems will have minimal need for maintenance activities in their early years. As we previously discussed, fewer service visits decrease environmental impact from transportation and spare parts.
- **Provide visibility to environmental performance documentation** – Since vendors are more focused on sustainability practices in recent years, new systems are more likely to have product environmental profile (PEP), environmental product declaration (EPD) or life cycle assessment (LCA) documents readily available. These are one way for vendors to provide more transparency on their environmental footprint and to verify the systems you select align with your sustainability commitments. Vendors generally don't have this documentation for older equipment.

In the following three sections, we'll walk through specific examples to demonstrate how data centers can leverage each of the three modernization approaches and improve the environmental impact across the four sustainability categories: energy, GHG emissions, water, and waste.

Modernization example 1: Digitalize and connect

LV and MV switchgear are critical systems for powering and protecting high availability IT equipment within a data center. The lifetime of LV switchgear ranges from 15 to 25 years and for MV switchgear ranges from 30 to 40 years. If a data center has an aging switchgear installation, it is likely that it is non-communicating equipment, meaning there is no sensor data, no remote monitoring capability, etc. Without these "smart" features, there are added risks to reliability/downtime and the useful life of the system. For instance, rising heat inside electrical cabinets is often a sign of a loose connection or eroding insulation. If left unchecked, the situation could lead to a short circuit or even an arc flash incident, which, in turn, leads to prolonged downtime or even the need to replace the entire system (see **Figure 3**). Furthermore, lacking real-time visibility also leads to increased maintenance activities, staff requirements, and cost due to the manual and reactive nature of diagnostics and repair. Note, infrared (IR) windows are sometimes added to switchgear so that maintenance personnel can manually scan the bus bars without the need to open panel covers.

(a)

(b)

Figure 3
a. Arc chute electrical wear inside a low voltage air circuit breaker

b. Worn air circuit breaker contacts

The non-communicating equipment can be transformed into connected assets that allow operators to determine the real-time health of the system and predict future behavior (degradation and failures) of those same assets. Therefore, there is an increased likelihood that the heat anomaly noted above would have been detected ahead of time (vs. periodic checks), with minimal disruption to operations compared to costly unanticipated downtime. This is accomplished by adding smart sensors and connecting them to the cloud through apps/programs that perform predictive analytics using AI and enable remote 24x7 monitoring. Table 1 illustrates how these sensors and connectivity help optimize the health of the system. Once the switchgear units are digitized and performance is measured, stakeholders can develop strategies for improving uptime performance and enhancing sustainability.

Table 1

How sensors and connectivity improve switchgear health and life expectancy

Digitalization & connectivity	Description
Add temperature sensors	Perform continuous monitoring for early detection of overheating bus and cable connections, which helps detect loose connections. This allows for proactive maintenance of degraded material, avoids arc flashes, and potential fires. This could replace periodic manual IR inspection.
Add humidity sensors	Perform continuous monitoring of humidity, which helps prevent corrosion and partial discharge (leading to arc flashes).
Connect to cloud	Connect sensor data to the cloud and enable cloud-based services for insights and predictive maintenance. Remote monitoring frees up maintenance staff to perform other tasks that require attention.

Since sensors and monitoring can identify smaller problems (and alert facilities personnel) before they become critical or catastrophic, the life of the switchgear system is extended.

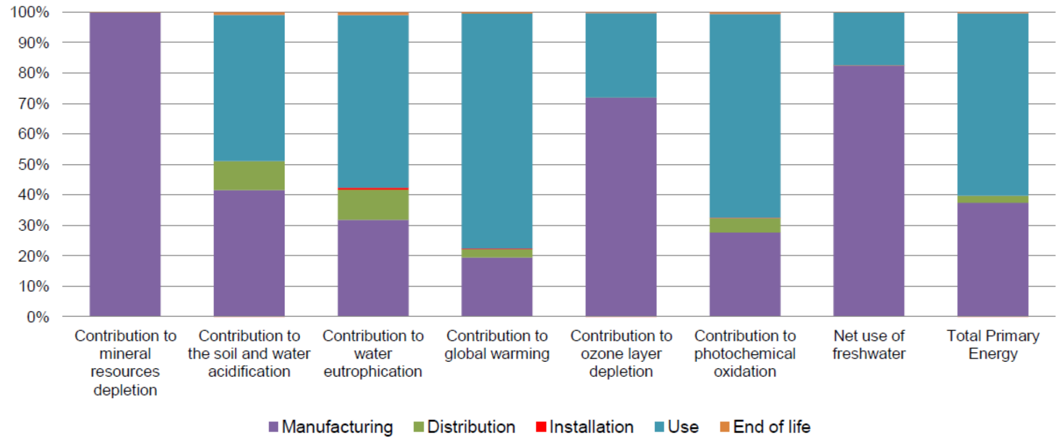
Figure 4 illustrates how each phase of the life contributes to environmental metrics including energy, water, emissions, and waste (assuming a life of 20 years). It shows how the manufacturing phase is a big contributor (purple bars). Delaying the production of new switchgear by increasing the lifespan of the existing switchgear, therefore, would have a significant environmental impact on its overall lifecycle.

In addition, through predictive analytics and remote monitoring that the connectivity enables, fewer onsite service visits are necessary, which reduces the GHG emissions associated with travel to the site.

Figure 4

Manufacturing is a significant contributor to the overall environmental impact of switchgear (noted in purple).

Source: [Schneider Electric PEP document for LV switchgear]()

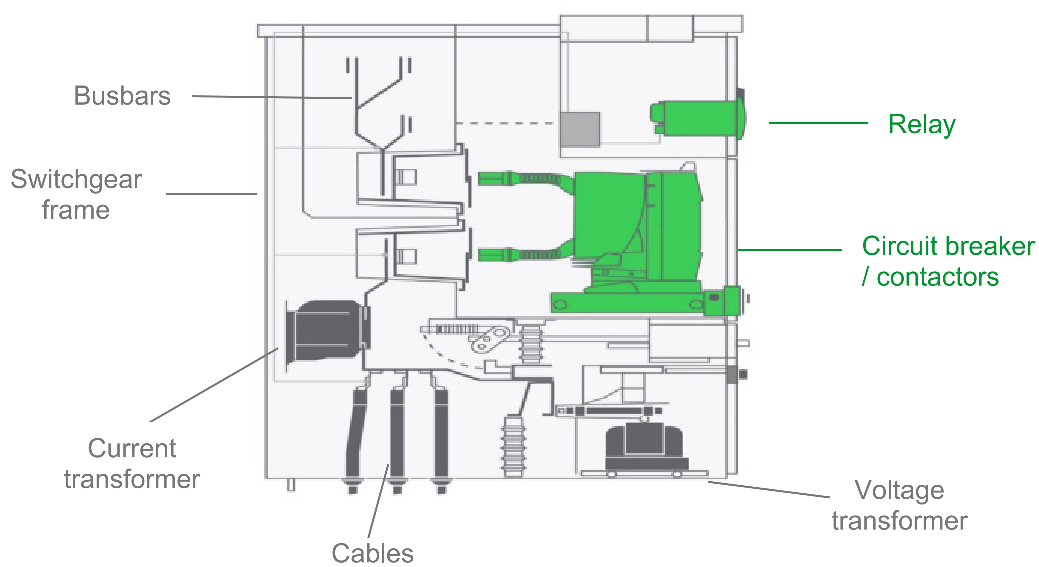


Modernization example 2: Replace modular components

Switchgear systems are made up of many components of varying life expectancies and failure rates. Some components like the steel frame, barriers, busbars, and even transformers have low failure rates and long-life expectancies of up to 40 years. Other components including circuit breakers, contactors, fuse devices, and relays, all experience state changes (i.e., opening/closing the circuit breaker for protection), which lead to an increased failure rate and shorter life expectancy (see **Figure 5**). These components are more critical to maintaining safe, reliable operation of the switchgear.

Figure 5

Switchgear components highlighted in green require replacement due to state changes, increased failure rates and criticality



Rather than replacing the entire switchgear system, when these critical components approach their end-of-life, they can be either "retrofit" or "retrofilled"[7], which has a lower environmental impact.

In the Schneider Electric White Paper, [How electrical distribution equipment retrofit services contribute to a circular economy](), we quantify the environmental impact over the life cycle of replacing only modular components vs. replacing the entire switchgear system. In that analysis, we demonstrate how retrofitting a typical 12-

[7] A **retrofit** is when new components are installed without the need for modification of the remaining components (i.e., directly install a new circuit breaker without any cubical modifications). A **retrofill** is when both new and old components must be modified to work together (i.e., a circuit breaker replacement requires modification of the cubical to install the new circuit breaker). Source – [Coastal Power Systems]()

cubicle MV installation avoids emitting 37.2 tonnes of CO2 to the atmosphere, reduces water consumption by 357 m^3 (which is used in manufacturing for paint, metalworking, and production of plastics/resins)[8], and reduces material use by 10.6 tonnes (68% of total switchgear line-up materials by weight[9]) during the manufacturing phase when compared to a complete replacement option. Recycling the replaced MV equipment, a service offered by some vendors, also results in 3 tonnes of recycled materials, which saves the extraction and use of mineral and rare resources. Lastly, we quantify the impact of the SF6 gas released to the atmosphere if the obsolete circuit breakers are not recycled appropriately (183.3 tCO2)[10]. See **Figure 6** for a summary of these savings.

Figure 6

Analysis of environmental benefits of MV switchgear retrofit vs. complete replacement

Environmental Savings by Replacing Only Modular Components and SF6 Recycling vs. Total Replacement

Saved material:	195.9	tons (t)
Equivalent to:	8	new cars produced
Saved CO_2 emissions:	225.8	tCO2eq
Equivalent to:	5	plane roundtrip London - New York
Saved water:	357.1	m^3
Equivalent to:	6	years average human water consumption
Recycled material:	3.0	tons (t)
Equivalent to:	2	new cars produced

MV Retrofit of Modular Components		
Saved material:	10.6	tons (t)
Saved CO_2 emissions:	37.2	tCO_2eq
Saved water:	357.1	m^3

SF6 Recycling		
Saved CO2 emissions:	185.3	tCO_2eq
Recycled material:	3.3	tons (t)

Modernization example 3: Replace entire system

UPSs are critical systems that provide backup power to maintain high availability of data center loads. They generally have a life expectancy of 10-15 years, although consumable parts like VRLA batteries have a shorter life. There are specific scenarios in which replacing the entire aging UPS makes business sense:

- The UPS is very lightly loaded – When a UPS runs at 25% or lower capacity, replacing it with a smaller unit allows the system to run more efficiently. Note, older generation UPSs exhibit this light load inefficiency more than newer UPSs (which have "flatter" efficiency curves).
- The UPS is near the end of its service life, and spare parts are unavailable and/or costly –The age of UPS plays an essential role in the availability and cost of spare parts. As UPSs reach the end of service life, manufacturers might discontinue spare parts production entirely or raise their prices on replacement parts. These situations are not desirable financially and make maintaining an old UPS even harder.
- The UPS is experiencing frequent failures – The unexpected downtime caused by multiple failures of an old UPS puts critical loads at risk and poses a significant threat to businesses in terms of service availability, reputation, and even loss of business.

Furthermore, advancements in technology of UPSs can make replacing the aging UPS with a new UPS beneficial. When replacing an entire UPS system, specifiers should take advantage of the advancements described in **Table 2**.

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[8] 350 m^3 of water is equivalent to 6 years of average human water consumption.

[9] Analysis of MCset air insulated switchgear AD3 type unit, which has a total weight of 1.3 tonnes per fully equipped cubicle (15.6 tonnes for 12 cubicles); Replacing only modular components saves 10.6 tonnes, or 68%.

[10] Replacing SF6 components with non-SF6 components requires careful decommissioning to prevent gas escaping during removal of the equipment. See Schneider White Paper.

Table 2

How new UPS technology improve UPS life expectancy and reduce environmental impact

UPS technology advancements	Description
Modularity	Modular systems allow data center operators to right size a UPS and then scale it as capacity needs grow. Right-sized UPSs operate more efficiently than oversized ones.
Li-ion battery technology	Li-ion batteries are smaller and lighter than VRLA batteries and have a significantly longer useful life. Li-ion also avoids the environmental hazards associated with mining and recycling of lead (health impact of contamination and human exposure). See White Paper 71, Understanding the Total Sustainability Impact of Li-ion UPS Batteries, for more on this topic.
Modes of operation that improve efficiency	eConversion mode provides UPS loads with UL-certified Class-1 performance, and typically reduces UPS energy consumption by a factor of 3 with 99% efficiency (1% loss) vs. 97% efficiency (3% loss) in double conversion. See White Paper 157, Eco-mode: Benefits and Risks of Energy-saving Modes of UPS Operation, for more on this mode of operation.
Modes of operation that enable grid connection	Grid-parallel mode and bi-directional modes of operation to participate in demand response programs, reduce loads from the grid during peak consumption hours, or connect to grid to utilize idle energy storage capacity. See White Paper 274, Monetizing Energy Storage in the Data Center, for more details on these modes of operation.

The environmental impact of a UPS occurs primarily in the "use" phase of its lifecycle. Figure 7 demonstrates this (blue bars). The energy consumption during its life (and its associated Scope 2 emissions) is one key driver.

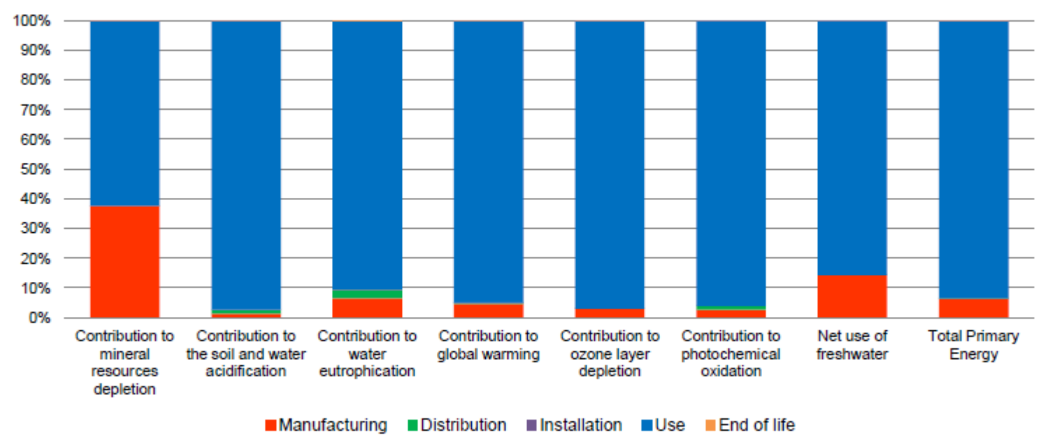

Figure 7

The "use phase" of a UPS is a significant contributor to the overall environmental impact (noted in blue).

Source: Schneider Electric PEP document for Galaxy VS integrated batteries

Therefore, replacing an aged UPS with one that is more efficient improves the overall sustainability. Figure 8 illustrates the efficiency improvement of a 1MW UPS running in eConversion mode (99% efficient) vs. double conversion mode (95% efficient), at full load. This translates to 3.1 GWh of energy savings over 10 years at 90% load.

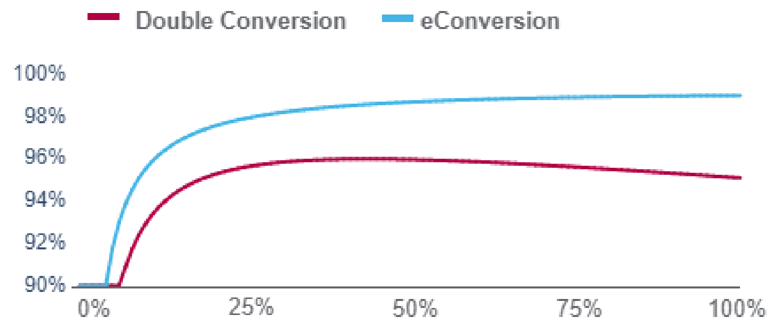

Figure 8

Efficiency comparison between eConversion UPS VS Double conversion for Schneider Electric Galaxy VX 1000 kW UPS (400V)

Source: eConversion vs. Double Conversion Calculator

This translates to a carbon footprint reduction of 1.6 kilotonnes of CO2 over the 10 years[11] (**Figure 9**). This represents a 76% reduction in energy-related carbon emissions

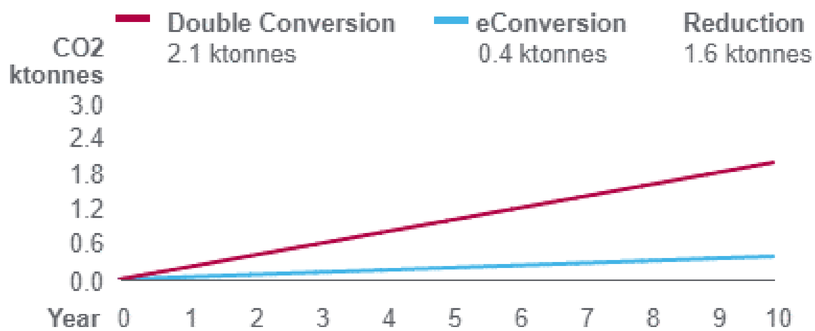

Figure 9

Carbon footprint comparison between eConversion UPS VS Double conversion for Schneider Electric Galaxy VX 1000 kW UPS

Source: eConversion vs. Double Conversion Calculator

As previously mentioned, the battery life expectancy also has a big impact on the environment. Replacing an aged UPS can reduce physical waste and water waste in the long term due to less battery replacements and consequently less manufacturing waste[12].

Another case for entire system replacement: cooling systems

When energy reduction, water reduction, or GWP are of high priority, aging cooling systems that pose operations risks should be evaluated for potential replacement. Cooling is a significant contributor to scope 2 emissions since it is the biggest energy consumer in the data center, next to the IT equipment itself. Not only do newer systems generally use variable speed motors (compressors, fans, pumps) instead of fixed-speed motors, they also commonly include free cooling modes of operation (i.e., indirect fresh air systems). This means a decreased dependence on high-energy consuming mechanical operation. **Figure 10** quantifies the power usage effectiveness (PUE) and associated carbon footprint across varying cooling architectures for a 1MW data center in Sydney, Australia, to demonstrate the potential savings of selecting an alternative architecture. A baseline chiller / tower architecture with no economizer mode results in an annual carbon emission of 7.3 kilotonnes, whereas air-cooled approaches can reduce this by 40% to 4.4 kilotonnes. This leads to a potential savings over 10 years of 29 kilotonnes.

[11] Using the Schneider TradeOff Tool, eConversion vs. Double Conversion Calculator, with CO2 emissions factor of 0.453 kg/kWh.

[12] White Paper 71, *Understanding the total sustainability impact of Li-ion UPS batteries*

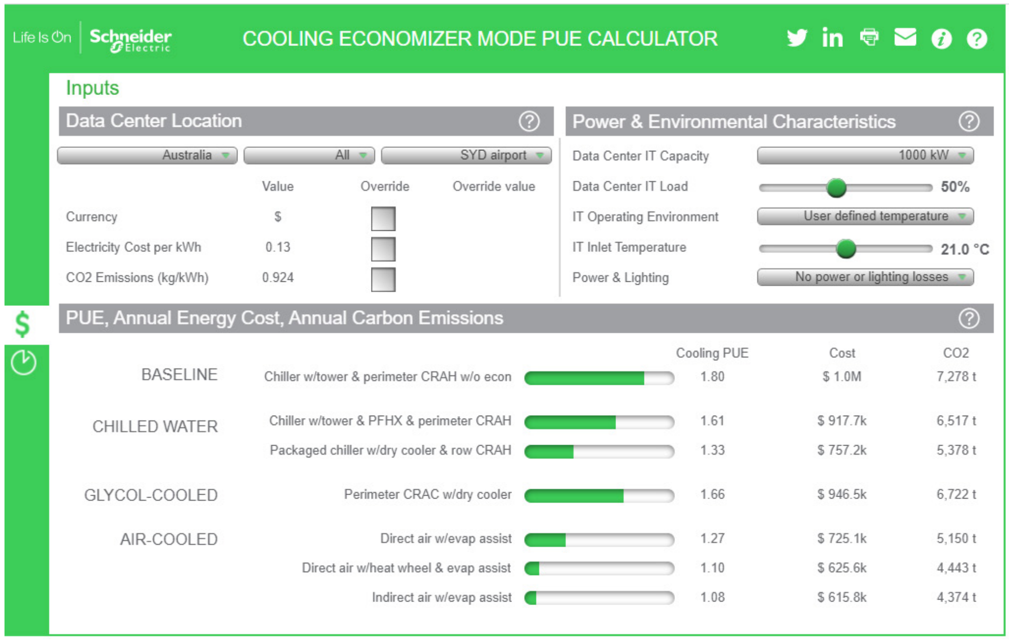

Figure 10

PUE and CO2 of modernized cooling approach.

Source: [Cooling Economizer Mode PUE Calculator]

Poor IT equipment air distribution is another significant contributor to wasteful energy consumption. Hot spots can appear at the intake of IT equipment due to inefficient air flow management like cold air leakage (i.e., bypass air) and hot exhaust air recirculation. Addressing these hot spots by increasing cooling capacity and fan speeds leads to increased energy use that can be avoided with other airflow management practices like installing containment, blanking panels, and relocating high density equipment. Therefore, when replacing a cooling system, attention must also be paid to how the airflow is managed. Trained engineers can assess current hot spots so that they are avoided with the new system.

Water is another big consideration for cooling. Uptime Institute's research showed that a 1MW data center with traditional cooling methods (water-cooled chiller and cooling tower) use about 25 million liters of water per year. This is because the evaporation process occurs continuously year-round. Regulatory pressure will raise this as an important consideration. "A growing number of municipalities will permit new data center developments only if they are designed for minimal or near-zero direct water consumption" according to Uptime Institute Global Data Center Survey 2021. Direct water consumption in data centers from cooling units can be reduced by replacing traditional cooling methods with more advanced and sustainable technologies. White Paper 132, Economizer Modes of Data Center Cooling Systems, quantifies the annual water consumption of six cooling architectures, to help decision makers make this trade-off of water, energy, cost, etc.

Lastly, newer systems are more likely to meet regulations than older systems because they use refrigerants with lower GWP. For instance, Hydrofluorocarbons (HFC) (i.e., f-gas refrigerants), such as R134a and R410a have a high GWP, but there are other refrigerants like hydrofluoroolefins (HFO) such as R-32 and R-1234ze, that reduce the global warming impact. It is also possible to keep refrigerants out of the data center entirely with water-based cooling systems.[13]

[13] Schneider Electric blog, Why Government Regulations on Refrigerants Should Have You Rethinking Your Data Center Cooling Strategy

Choosing the right approach to modernization

Now that we discussed different modernization approaches and walked through a series of examples, how does the decision maker choose which makes sense for a particular data center with a particular set of aging equipment that pose risks and problems to your operations. There is not one right answer. Every site is different, every data center has different priorities, performance needs, requirements, and so on. Below we list 7 key factors to consider that will help steer you to the right approach or approaches.

- Prioritized sustainability metrics – Aligning priorities with the sustainability risks of your aging systems helps guide you to the right approach. For example, a facility might prioritize energy savings and the associated CO_2 footprint over material waste, or in a water-scarce location, perhaps water conservation is the priority?
- Budget – Most modernization projects have a budget. The total cost of ownership (TCO), both capital and operational expense, of the three approaches should weigh into the decision. What are the electricity cost implications over time? Maintenance and parts costs? What about any new skillsets required? With this information, you can then evaluate limitations on budget versus sustainability.
- Ability to cost-effectively maintain the system – When a system ages and approaches its end of "useful life", there is an increased rate in maintenance needs, and component failures. Finding the spare parts for an aging system designed years ago gets harder and costs more. When vendors no longer support old systems with spare parts and service personnel, digitalizing and connecting, or swapping modular components may be challenging. Each system in question should be evaluated on this criterion to determine the feasibility of the modernization approaches.
- System technology – As we've previously discussed, technologies evolve over time and many newer technologies use less resources like energy or water. Does a newer replacement technology exist that can provide a better outcome? Are there big efficiency gains to be had? Do they use less environmentally harmful materials? Do they interact with other systems to enable further environmental benefits? The answers to these questions may lead you to updating modules/components, when feasible, or the entire system when not.
- Data center location – Where the data center is located has an impact on sustainability. The climate drives performance of certain types of systems (cooling economizer modes), and the sources of electricity from the grid drives, in part, your carbon emissions factor for electricity you consume. Location may also determine if there's local government incentive programs in place to help absorb some of the costs of upgrading or installing new, more efficient systems.
- Performance gaps – Understanding how business needs have evolved is a factor. Is the aging infrastructure oversized, undersized, not sufficient in runtime, redundancy, reliability, etc.? Do any of these systems violate new codes or regulations? Answering "yes" could drive you towards a system replacement, but if needs haven't changed, upgrading existing systems may make sense.
- Business disruption - the amount of disruption to day-to-day operations varies for the three approaches. Replacing a module is often much quicker and less invasive than a complete "rip and replace" project. Is the business able to withstand disruption, and if so, for how long?

As part of *any* modernization project, decision makers should confirm that any obsolete systems that are replaced are appropriately taken out of service and recycled using environmentally certified methods, to minimize the environmental impact.

It is important to partner with vendors and providers that embrace circular economy methods and can consult with you on the best approaches for your data center.

Conclusion

Data center operators face many challenges as their physical infrastructure equipment ages, including downtime, increased maintenance costs, and limited parts availability. Although reliability is of the utmost importance for data centers, they are *also* faced with aligning their operations with their corporate sustainability goals. In this paper, we presented three modernization approaches that data center decision makers can implement to address the risks of their aging infrastructure while reducing their environmental impact:

- Digitalize and connect – Adding sensors and cloud-connected software to existing infrastructure enables predictive analytics and real-time remote monitoring. This modernization can increase the useful life of a system, avoid downtime leading to genset operation, minimize service visits, enable benchmarking of sustainability metrics, and reduce energy and carbon through interaction with other systems like the grid.
- Replace modular components – Replacing critical, modular components while keeping other components in place (like a frame) improves sustainability by processing fewer raw materials in manufacturing, processing fewer waste materials, extending the useful life of the equipment, leveraging digitalized and connected (i.e., smart) modules, leveraging more efficient modules, and eliminating the risks associated with toxic substances in old modules.
- Replace entire system – Replacing an aging system with a new system enables improved energy efficiency (through rightsizing and technology advancements), reduced water use, and reduced maintenance requirements. Many vendors, like Schneider Electric, also provide transparency on newer systems' environmental performance data through Environmental Product Declaration (EPD) documentation, which helps to align procurement and design to your corporate sustainability goals.

Given the breadth and complexity of the many physical infrastructure systems within the data center, operators are likely to deploy a mix of these strategies. Choosing the right approach for a given system requires consideration of key factors like the company's sustainability priorities, business needs, age and technologies deployed, regulations, disruption and work involved, and budgetary constraints.

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