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Three innovative technologies to address UPS challenges at the edge

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Introduction

Introduction

We're on the edge of something big.

IT managers are implementing edge computing in almost every industry to support high bandwidth content distribution, the Internet of Things (IoT) and on-premise applications.

Local edge computing is part of the larger hybrid IT architecture that brings bandwidth-intensive content and latency-sensitive applications closer to the user or the data source.

With the increasing focus on local edge computing comes added pressure to select a better uninterruptible power supply (UPS) for this application.

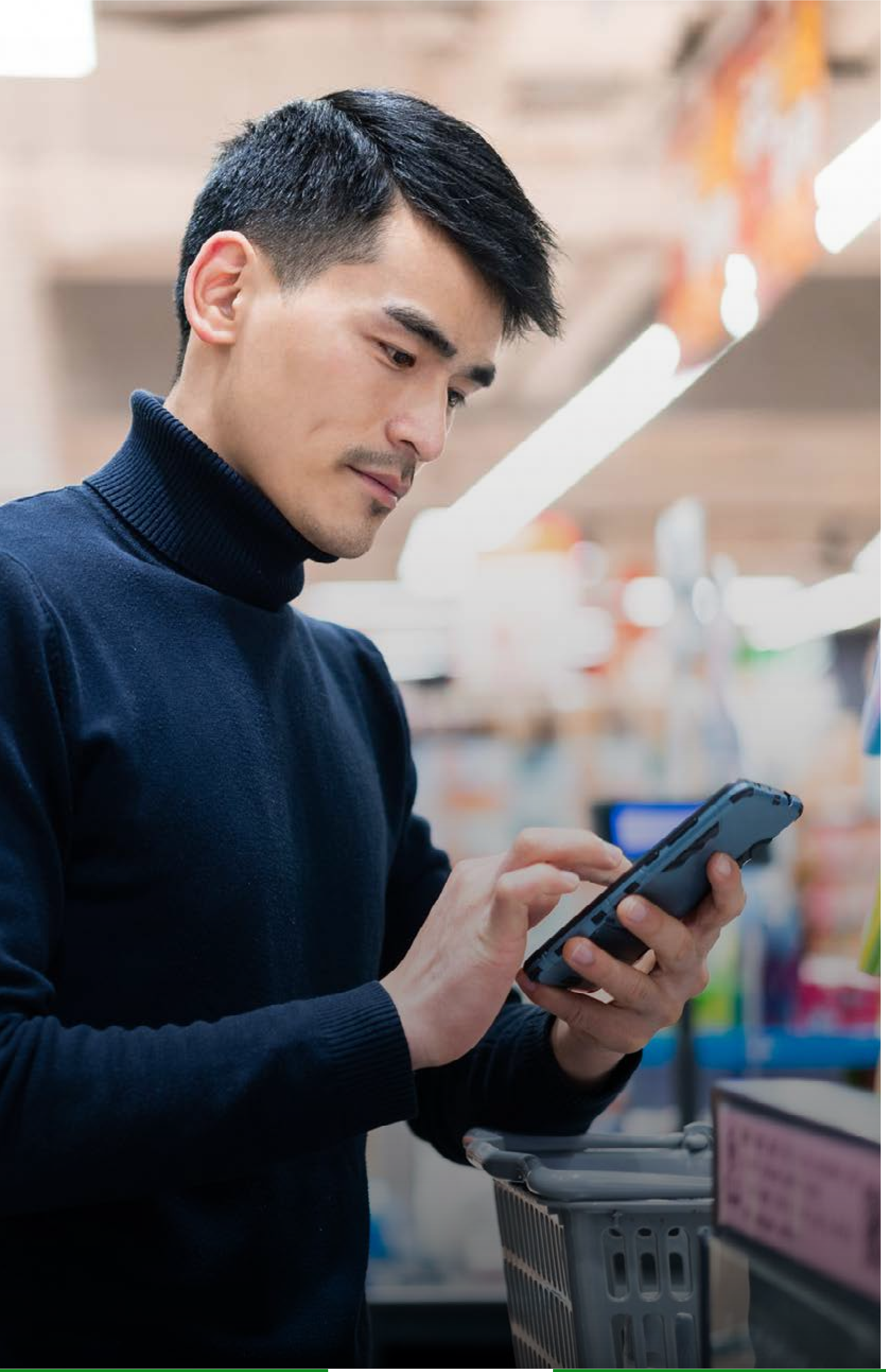
Selecting the right UPS is critical to ensure the system remains operational and secure. General UPS challenges such as footprint, weight, frequency of battery replacement, efficiency and energy cost can have a real financial consequence on businesses that deploy edge computing and need to be considered.

This e-book discusses these UPS challenges faced at the local edge and explains how the following three technologies address them:

1. **wide-bandgap technology**
2. **lithium-ion battery technology**
3. **cloud-based management and monitoring technology**

For each technology, we explain how it works and describe its specific benefits. We then introduce examples of UPSs that embody these technologies. Finally, we provide a total cost of ownership (TCO) analysis that compares a new Hybrid-Conversion On-Line UPS to a traditional, Double-Conversion On-Line UPS.

UPS challenges at the edge



UPS challenges at the edge

As IT operations become more complicated, local edge deployments continue to multiply. Unfortunately, key UPS characteristics such as the footprint, weight, efficiency, energy cost, management, and maintenance are often an afterthought.

This mistake results in some of the most common challenges that edge computing environments face. And, as edge deployments are frequently repeated over hundreds or even thousands of locations, these challenges are magnified, consuming extra time, energy, and ultimately expense. These challenges include:

- The UPS requires **too much IT rack space** (or no rack is available)
- The UPS **is too heavy** for one person to install
- Frequent battery replacements are needed due to **high temperature battery** degradation
- Periodic battery replacements are needed due to valve regulated lead-acid **(VRLA) battery service life** expectancy
- Inefficient UPSs incur a **greater energy expense** and higher carbon emissions
- Lack of UPS **fleet status knowledge** can lead to downtime
- Lack of **on-site staff** makes UPS maintenance and management difficult

We discuss each of these challenges in detail next.

The UPS requires too much IT rack space (or no rack is available)

At local edge sites, IT is often deployed in tight spaces such as closets or break rooms with small, wall-mount racks. Not having enough U space in a rack or spare space for expansion creates problems when a UPS is too tall or too deep to deploy at a site.

The UPS is too heavy for one person to install

Heavy equipment like UPSs might require additional people and resources to ensure safer equipment lifting and moving by personnel and to avoid potential damage to the equipment. Factors, such as how high and how often an object is lifted, affect the risk of injury to workers. In the United States, for example, the National Institute for Occupational Safety and Health (NIOSH) has developed a model that predicts the risk of injury and provides a maximum weight limit of 51 lbs./23.1 kg., under certain circumstances, for one-person installation. UPSs commonly exceed this limit thereby requiring multiple people for safer installation.

Frequent battery replacements are needed due to high temperature battery degradation

High ambient temperature is one factor that influences UPS battery aging and can cause premature battery failure.

Higher temperatures mean a faster chemical reaction inside traditional VRLA batteries, which also accelerates water loss and corrosion. This is one of the reasons VRLA batteries require frequent replacement compared to newer battery technologies. In locations with dedicated air conditioning, this typically isn't an issue.

50%

VRLA battery service life reduction for every 10° temperature increase above the recommended (20-25°C)

Periodic battery replacements are needed due to VRLA battery service life expectancy

Service life of a battery varies by chemistry and manufacturer, but VRLA batteries generally have a service life of 3-5 years. The life expectancy depends on a variety of operating conditions, including ambient temperature and the depth and quantity of discharges. If you assume the life of an edge computing site is 10 years, this means you will have to perform two to three battery replacements in that timeframe. If you have 1,000 edge sites, all with different operating conditions and UPS ages, you can imagine that it will become very difficult to manage battery replacement visits.

Inefficient UPSs incur a greater energy expense and higher carbon emissions

The energy consumed by a single UPS may not seem significant, but when you consider a fleet of UPSs across multiple sites, it can have a collective energy and carbon impact that is considerable. All UPSs have electrical "losses," meaning that not all the input energy reaches the critical IT loads. Examples of losses include heat generated by electronics like the inverter and rectifier, transformer heating, and battery charging losses.

Lack of knowledge of the UPS fleet status can lead to downtime

The larger the UPS fleet in an organization, the more challenging it is to comprehend the large volumes of alarms and status change notifications. Not knowing about an issue until there is an alert or downtime makes a bad situation worse. From a security standpoint, not knowing in real time if unauthorized personnel are accessing the UPS locally can lead to increased downtime risk. From a cybersecurity perspective, being unaware that UPS software and firmware is out of date and does not include the latest protection can pose security risks.

Lack of on-site staff makes maintenance and management of UPSs difficult

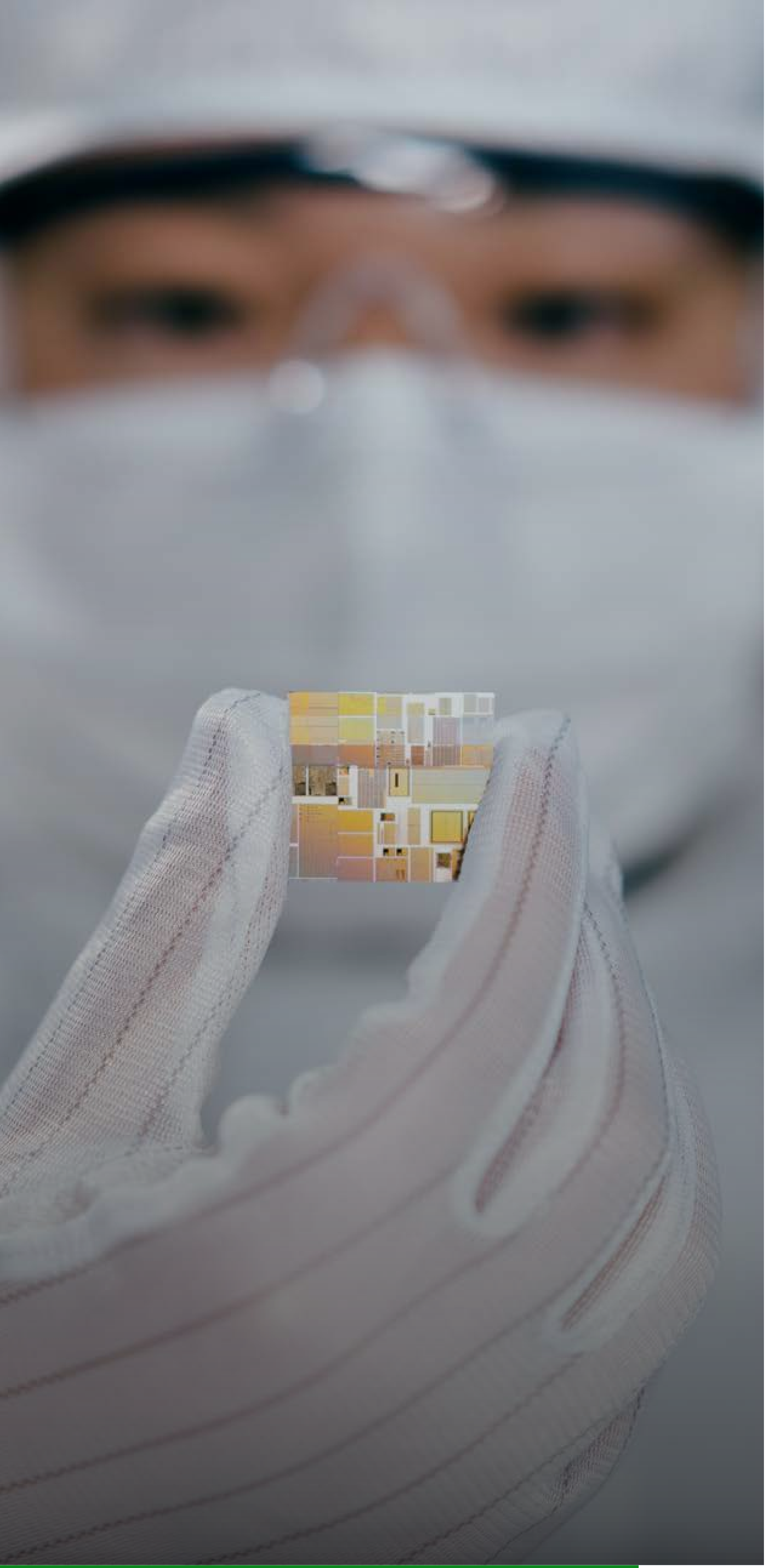
UPS components can fail for a variety of reasons. It is more difficult to troubleshoot problems without IT or facilities staff on site, which is typical of most edge sites. Maintenance is often an afterthought made worse when UPSs are spread over many geographically dispersed sites. For example, a UPS battery is shipped to a retail store for replacement in the back room, but none of the on-site staff know what it is or what it is for and the battery remains in the box and never gets installed.

The UPS challenges mentioned above can be addressed by three innovative technologies:

- wide-bandgap technology
- lithium-ion battery technology
- cloud-based management

We will cover each of these technologies in detail in the following chapters.

Wide-bandgap technology



Wide-bandgap technology

How this technology works

When the power fails, the UPS converts the battery's DC energy to AC power to supply the IT load equipment. This power conversion is made possible by power electronics – devices and circuits that control and convert electric power.

In an On-Line UPS, power electronics convert the AC input voltage to an intermediate DC voltage and then back to an AC voltage on the UPS's output. These conversions are performed by a series of high frequency switches. In most UPSs, these switches are either silicon-controlled rectifiers (SCRs), insulated-gate bipolar transistors (IGBTs), or metaloxide semiconductor field effect transistors (MOSFET), which are made from traditional silicon semiconductor materials.

Semiconductors are key to applications that switch energy flows (e.g., on and off) because they can act as both insulators and conductors. In other words, they can both resist and enable the flow of electrons.

The issue with semiconductors is that they are not perfectly efficient devices. Therefore, they experience power losses in the form of heat. In fact, the faster they are switched, the higher their losses become. This fact runs counter to a UPS's goals of generating a **smooth sinusoidal AC*** output voltage while minimizing losses.

So, how do we address this challenge of faster switching leading to increased switch losses?

☑ *The faster you switch a DC signal into an AC signal, the smoother the AC sine wave becomes.

The answer lies in a semiconductor's bandgap.

The bandgap is an energy gap between electrons in a substance where electrons are not free to move (the valence band) and where they are energized and free to move (conduction band). Traditional silicon-based materials require a physically thicker semiconductor layer. This increased thickness leads to higher resistance and associated higher conduction losses.

Another limitation of silicon-based power electronics is their poor performance at higher temperatures, resulting in current leakage and power loss. The typical maximum temperature limit of silicon devices is around 150°C.

Silicon devices have reached their limit in today's technology world and advancements in power electronics with improved characteristics have emerged by a new technology in the semiconductor industry called wide-bandgap.

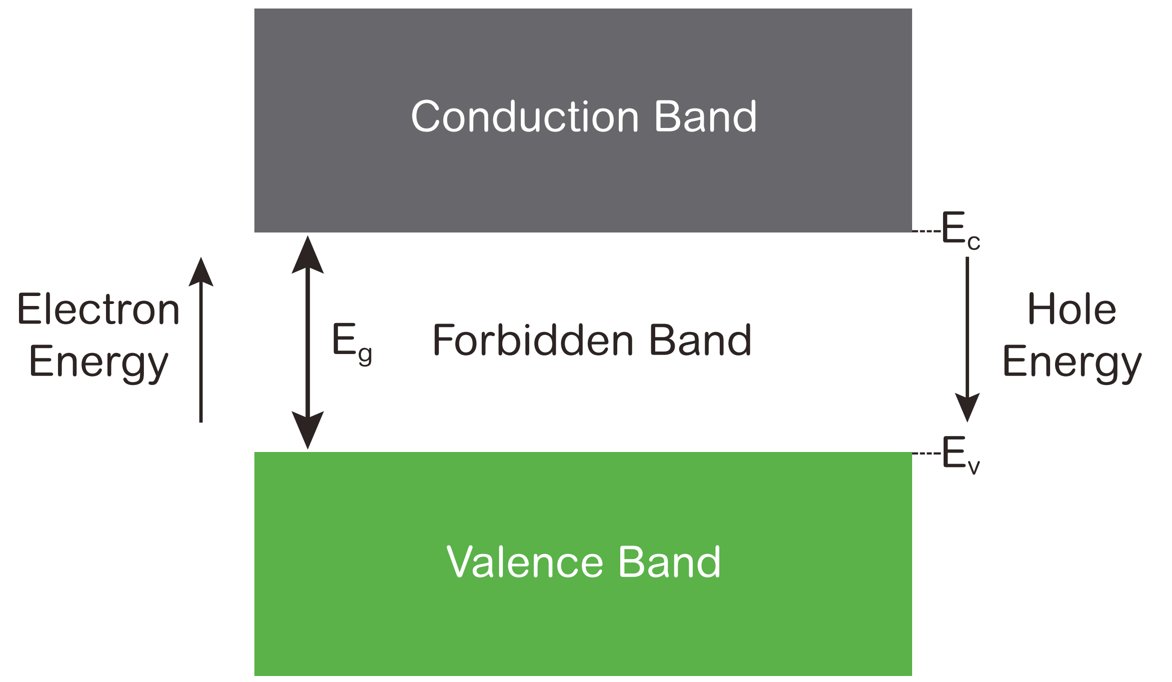
Wide-bandgap semiconductors such as Silicon Carbide (SiC) and Gallium Nitride (GaN) compounds differ from pure silicon by having a wider energy gap between valence and conduction bands. This wider energy gap brings in more electron mobility and makes them an excellent candidate to operate at higher switching frequency compared to silicon-based semiconductors.

Also, this technology leads to less heat generation in high-voltage applications without being damaged because the energy loss is drastically minimized compared to silicon materials. SiC and GaN can reach a higher thermal capability than traditional silicon for a given voltage. As a result, cooling requirements can be minimized in systems with wide-bandgap devices.

Up to 90%

of losses can be eliminated during AC-DC and DC-AC conversion

Figure 1
Simplified energy band diagram of a semiconductor



Source: Oak Ridge National Laboratory, "Comparison of Wide-bandgap Semiconductors for Power Electronics Applications" December 12, 2003.

How this technology addresses challenges at the edge

Supports smaller power electronics

Wide-bandgap technology allows for more compact and power-dense electrical devices than silicon-based devices. The higher switching frequency of these compounds enables them to have physically smaller switches, lower power losses, and heat sinks take up less space making thermal management easier. Ultimately, the UPS benefits from the smaller size power electronic devices, allowing it to occupy less U space in the IT equipment rack.

Enables lighter power electronics

Switching converters based on wide-bandgap technology work at higher frequencies. Not only does this result in a smaller footprint, but drastic weight reduction contributing to an overall lighter UPS that is easier to install. Note, the exact UPS weight depends on the type of wide-bandgap power electronics used but, in all cases, the weight is a reduction compared to Si-based electronics.

Improves efficiency of power electronics

Wide-bandgap semiconductor devices allow power electronic devices to operate at higher voltage and higher frequency with lower power losses. This means that power electronic modules using these devices are more powerful and energy efficient than those made with conventional semiconductor material, resulting in lower electric bills.

Lithium-ion battery technology

Lithium-ion battery technology

How this technology works

VRLA batteries have been the most used energy source for UPSs. Compared to newer technologies available in the market today, lead-acid batteries have some challenges, most notably a shorter life span in the range of 3-5 years, excessive weight, and size.

Advancements in the battery industry, specifically lithium-ion battery technology, address these challenges.

Some lithium-ion batteries use metal oxide in the positive electrode (cathode), graphite in the negative electrode (anode). The lithium-ions are the key component of these batteries. They are tiny and able to move through a separator between the anode and cathode, resulting in the charging and discharging of the battery.

Many variations in performance between one battery and another battery of the same type exist because of differences in their chemistries along with the quality of materials that are used and cell construction, but they all have one thing in common, "lithium-ion." These variations in the battery design affect the battery's overall performance as we discuss next.

"Lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest specific energy per weight."

Source: Battery University

How this technology addresses challenges at the edge

Supports smaller footprint compared to traditional batteries

Lithium-ion batteries generally **occupy 50-80% less space** compared to lead-acid batteries because of the high energy density characteristics of these batteries.

Enables lighter battery weight

The higher energy density of lithium-ion batteries leads to their lighter weight, with a typical **reduction of 60-80%** compared to VRLA batteries of equivalent energy capacity.

Minimizes battery replacements due to longer life expectancy

The lifetime of a battery is impacted by the number of cycles that a battery is fully charged and discharged in a specific operating temperature range provided by the manufacturer. A typical VRLA battery lifetime is in the range of 3-5 years, while lithium-ion technology provides an expected **lifetime of up to 10 years**.

Also, in UPS applications, lithium-ion batteries have double or more the calendar life – the estimated time a battery will last if it were to remain **trickle charged*** for its entire life with no power outages at a specified temperature, usually 25°C (77°F) – than lead acid batteries. Lithium-ion batteries degrade less than VRLA batteries under similar operating conditions, leading to less impact on battery life compared to VRLA.

Improves efficiency of battery charging

The energy loss of a battery occurs in two conditions: fixed loss from trickle charging the battery and transient loss from discharging or charging the battery after a power outage. A lithium-ion battery requires less energy to maintain the charge compared to lead acid batteries. The energy cost of the lithium-ion battery on steady state charging, including cooling requirement to dissipate the heat from energy losses, is **50% less than that of VRLA**.

***Trickle charge** is charging a fully charged battery at a rate equal to that of its self-discharge rate.

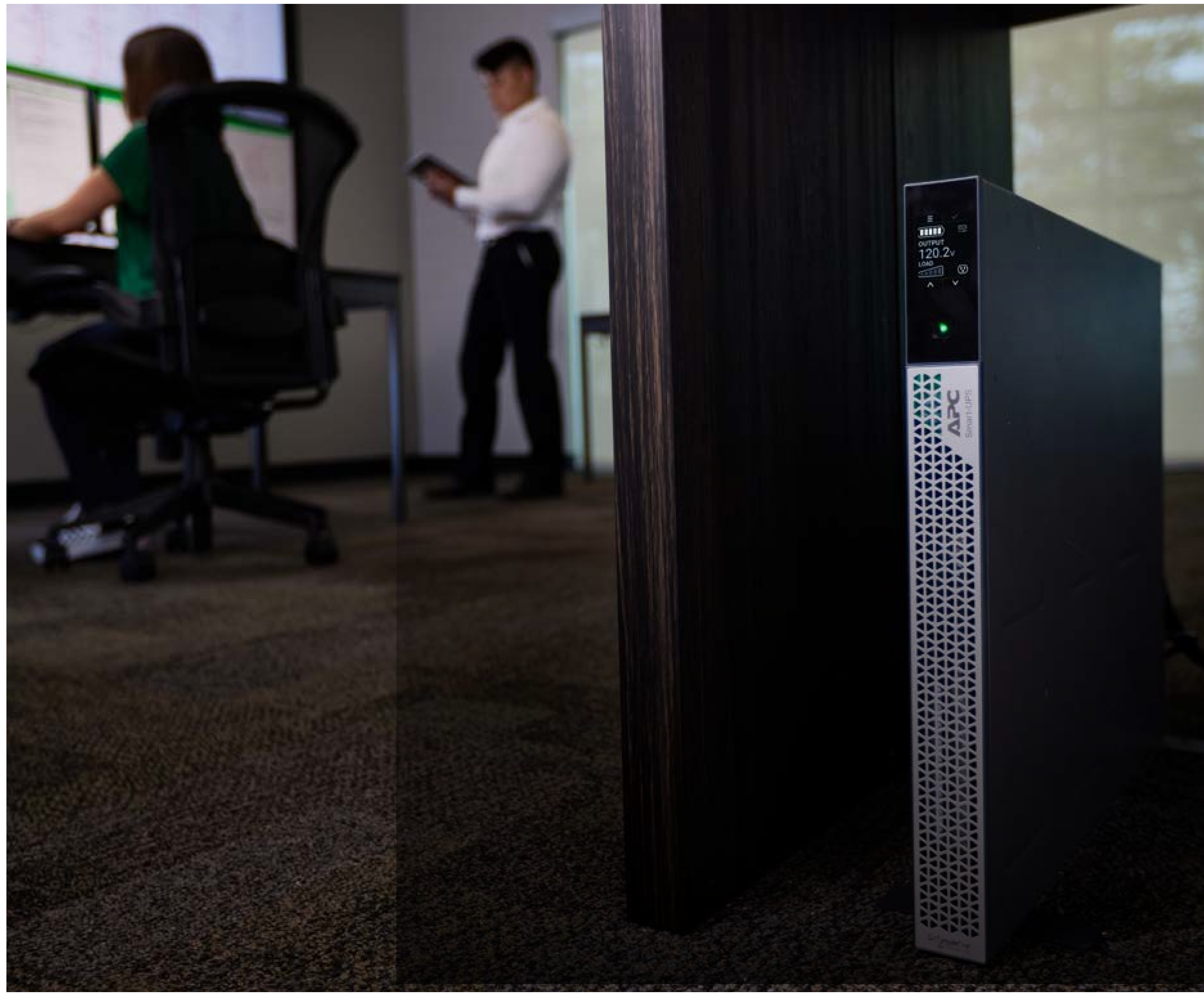
Cloud-based management software technology

Cloud-based management software technology

How this technology works

With the growth of businesses that rely more on edge computing, the availability of IT services has become more critical as it has a great impact on the business. During a power failure, significant risks are posed to important data and costly equipment. Therefore, a reliable system for management and services is essential to ensure critical equipment such as a UPS is available and to protect the IT services from downtime. **It becomes even more important to have an efficient management system integrated into a UPS when a company has multiple UPSs distributed across the world,** the site personnel are not sufficiently trained, and the UPSs are of different ages.

Cloud-based management and monitoring is an advanced technology that improves and optimizes system management, regardless of resources and number of sites through analytics and new automated services. The software technology integrates current management apps and maintenance services, such as third-party monitoring, building management systems, and electrical monitoring systems to the cloud and gathers all the data input for real-time monitoring and maintenance.



In local edge computing, multiple approaches can improve UPS management, such as servicing and monitoring. Third parties can provide support to a system ideally in advance to prevent any potential risk or by reactively providing maintenance when a failure in the system may have already happened. Cloud-based technology offers businesses with local edge deployments the opportunity to evolve their management from very basic monitoring and alarms to a simple system that is more proactive and predictive.

Monitoring technologies provide solutions by different approaches to track UPS status, such as on-premise software or cloud-based applications, which can provide proactive monitoring to ensure availability and resiliency.

Cloud-based infrastructure can be utilized in edge applications to help achieve availability objectives. The UPS industry has adopted a cloud-based approach to improve the quality of the system's status by evaluating battery status or UPS load, detecting the root cause of the incidents and predicting any future failures. This is generally accomplished via a smart connect ethernet port on the UPS that connects to cloud infrastructure to monitor and manage alarms, maintain uptime and check IT infrastructure status on site or remotely.

How this technology addresses challenges at the edge

Improves visibility and knowledge about UPS fleet status to minimize downtime

Experts knowledgeable about UPSs can remotely monitor it by taking advantage of secure and intuitive connected systems. Also, the data sent to the cloud provides users with predictive analytics and a dashboard view of their UPS fleet. They can comprehend large volumes of alarms and status change notifications, identify issues *before* downtime results, and know in real time who is accessing the system locally and remotely. Cloud-based monitoring and management software technology provides vendor agnostic remote visibility by read-only connections to the UPS to monitor UPS status, alarms in real time, asset tracking, data analytics, and visualization.

Eliminates need for on site staff to maintain UPS

Cloud-based technology enables fleet management services to troubleshoot problems without IT or facilities staff on site. This comprehensive remote management interface provides automatic notifications, firmware updates and advanced support. It manages dispatch of staff when maintenance services are needed across multiple locations.

Examples of UPSs with these technologies

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Examples of UPSs with these technologies

Wide-bandgap, lithium-ion battery and cloud-based management and monitoring software technologies address the common UPS challenges experienced at the edge and represent valuable benefits to edge deployments when they are leveraged in new UPSs. For example, these three technologies have been designed into two new UPSs by Schneider Electric called APC™ Smart-UPS™ Ultra (see **Figures 2 and 3**). These new 3kW and 5kW single-phase connected UPSs are designed to deliver more power in a smaller footprint while improving efficiency by implementing wide-bandgap technology and lithium-ion batteries.

Benefits of the APC Smart-UPS Ultra

In the edge environment where space is limited, UPSs with lithium-ion batteries and smaller power electronic devices occupy less space, providing the flexibility of mounting anywhere such as a rack, tower, ceiling or on a wall, which may have not been possible previously. Note that while the wide-bandgap and lithium-ion battery technologies reduce the size and weight of a UPS, as capacity increases, so will the size and weight to the point where a two-person installation is needed. In this case, both the 3kW and 5kW UPSs allow for a **single-person installation**.* Finally, the APC Smart-UPS Ultra offers insights by using cloud-computing technology to identify defective devices or configurations, enabling the operator to monitor and manage the UPS system remotely anytime and anywhere.

Figure 2
3kW 120V APC Smart-UPS Ultra

Figure 3
5kW 208V APC Smart-UPS Ultra

*"Note in the case of the larger UPS, the battery may need to be removed before installation to comply with weight constraints and then installed after the UPS is mounted. Refer to your national, local and company health and safety regulations/ policies to ensure the UPS is below the specified weight limits."

A traditional UPS in these local edge applications tends to be a Double-Conversion On-Line UPS. While the 5kW APC Smart-UPS Ultra is a Double-Conversion On-Line UPS, the 3kW APC Smart-UPS Ultra uses a new Hybrid-Conversion On-Line UPS topology.

The APC Smart-UPS Ultra has lithium-ion batteries with a 10-year lifetime. Traditional UPSs use VRLA batteries, which need more frequent battery replacements due to their shorter life expectancy (3-5 years). Also, the VRLA batteries need more replacements in higher temperatures due to battery degradation while lithium-ion batteries have a higher heat tolerance of 40°C (104°F). Another advantage of the APC Smart-UPS Ultra over traditional UPSs is the cloud-based management and monitoring technology that enables remote monitoring capability, improving visibility of critical loads and remote UPS management.

For more information about the topology differences, read our white paper The different types of UPS systems.

Figure 4
On-line normal mode – Double Conversion On-Line UPS topology

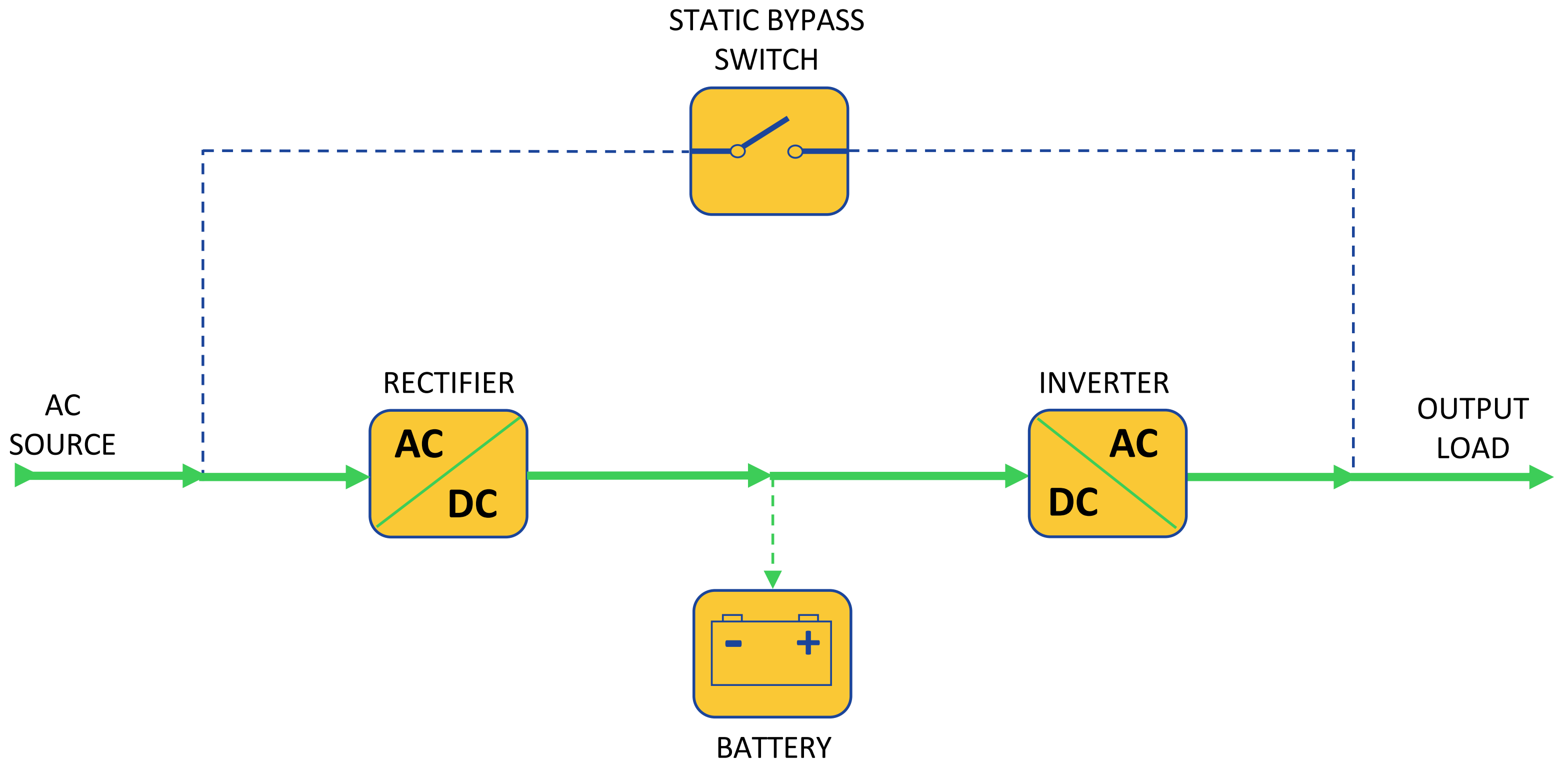
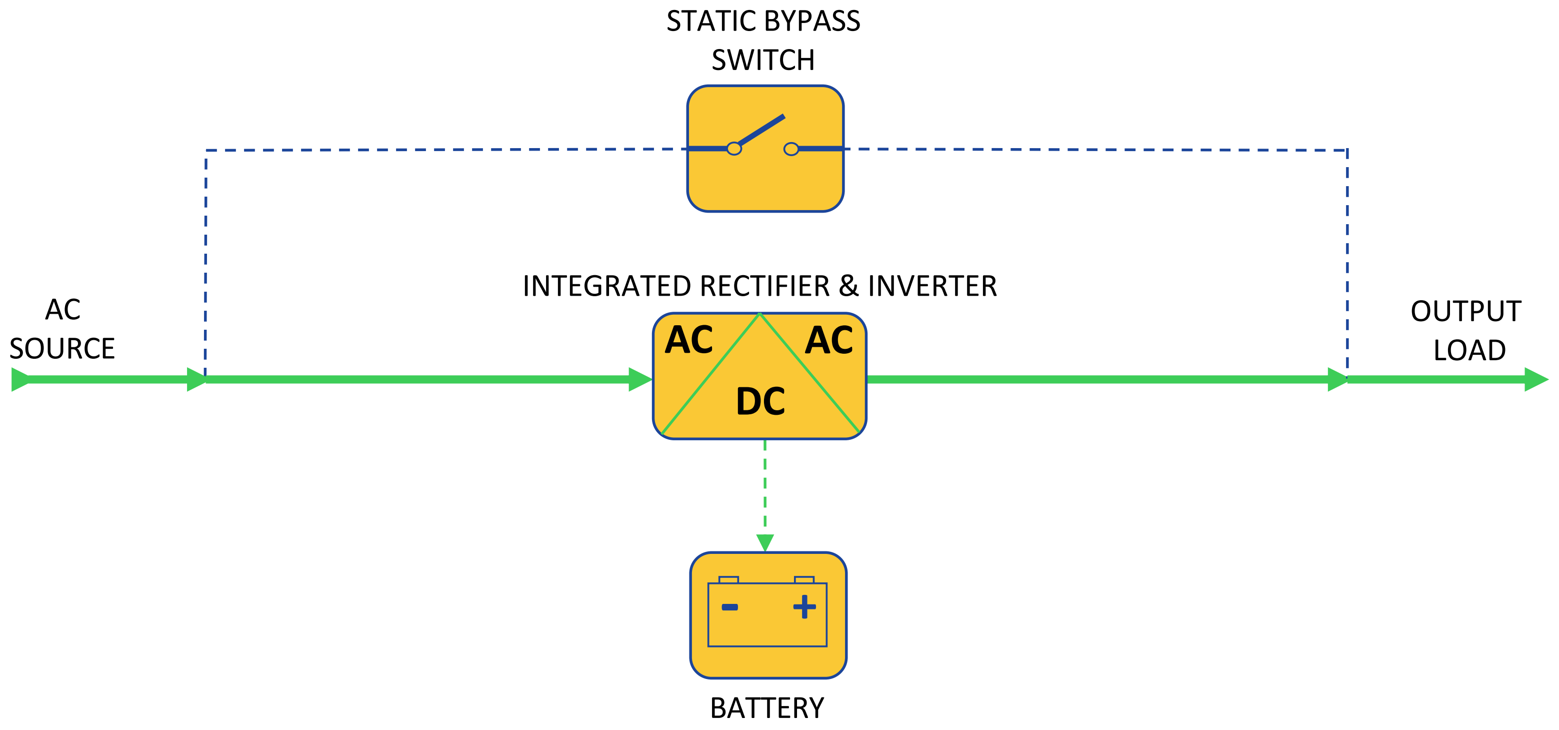


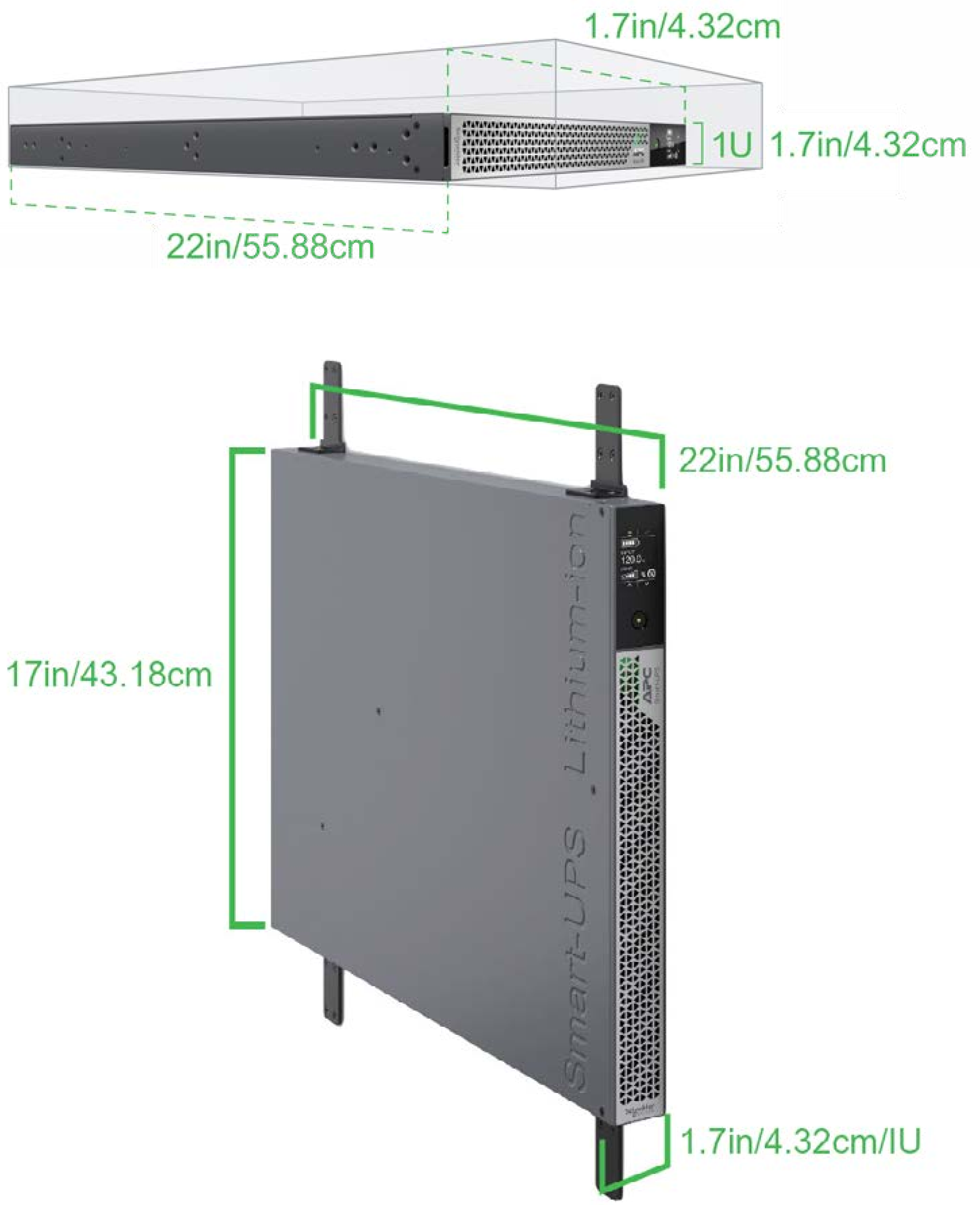
Figure 5
On-line normal mode – Hybrid-Conversion On-Line UPS topology

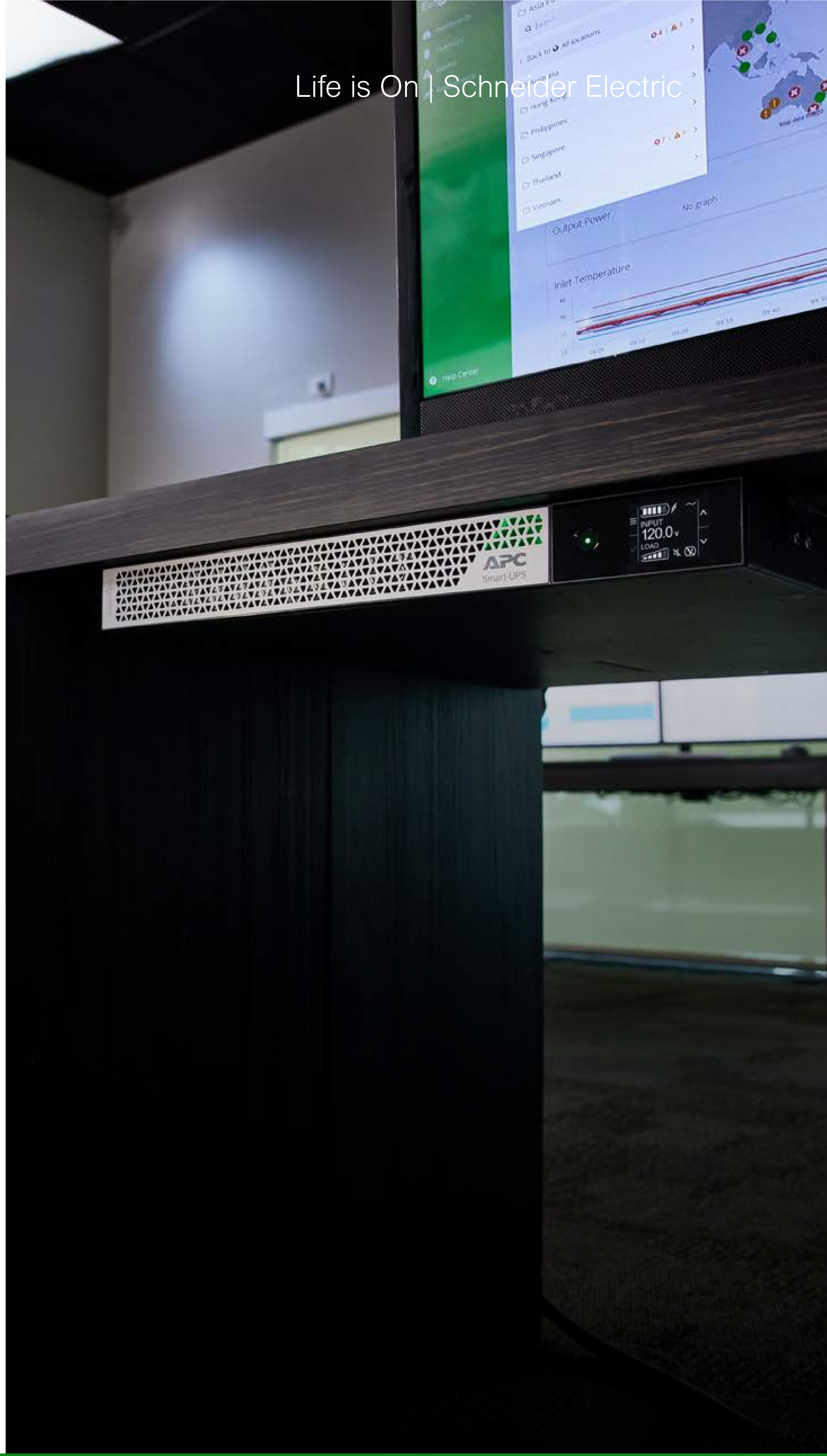


Applications of this UPS

The APC Smart-UPS Ultra UPSs are an ideal fit for edge applications such as retail, education, enterprise IT, healthcare, and finance. Another application for this UPS is backing up individual racks in colocation facilities. Also, in space-constrained environments where there is no available rack or floorspace, the 3kW APC Smart-UPS Ultra is well suited to wall- or ceiling-mount installation.

These UPSs are also suitable for on-table or desk installation where the UPS is free-standing next to the desktop server. The UPS can also be installed out of the way, such as under a desk or on the ceiling with under mounting options. The UPS can also mount in a typical 4- or 2-post rack with or without a rack PDU. In the absence of a rack PDU, the UPS can be installed below IT equipment with direct connection to the UPS outlets.





Financial analysis

Financial analysis

Total cost of ownership (TCO) is often used to compare the lifetime cost of one UPS versus another. In this case, we compared the TCO of a APC Smart-UPS Ultra to a traditional APC Smart-UPS SRT over a 10-year period; a typical lifespan range of a UPS before replacement is needed. **Table 1** compares the attributes of these two UPSs.

Table 1
UPS attribute comparison

UPS attribute	APC Smart-UPS SRT	APC Smart-UPS Ultra
Model number	SRT3000RMXLA	SRTL3KRM1UNC
Topology	Double-Conversion On-Line	Hybrid-Conversion On-Line
Dimensions (H x W x D)	85mm x 432mm x 635mm (3.35in x 17in x 25in)	43mm x 432mm x 560mm (1.75in x 17in x 22in)
Rack U height	2U	1U
Battery type	VRLA	Lithium-ion
Battery runtime	3 minutes at 2,700W	4 minutes at 3,000W
UPS weight	31.3kg (69lbs)	15.9kg (35lbs)
Capacity	2,700W	3,000W

Methodology and assumptions

- This TCO analysis calculates the capital expenses (CapEx) in year 0 and the operational expenses (OpEx) in years 1 through 10.
- The operational cash flows are discounted using the net present value (NPV) formula and added to the capital expense, thereby calculating the UPS's TCO over a 10-year deployment.
- The CapEx includes the UPS purchase and installation costs.
- The OpEx includes three categories: electricity, space cost, and battery replacement.
  - The electricity and space OpEx start at year 1 and every year thereafter (IT load electricity is not included).
  - VRLA battery replacements occur at years 3, 6, and 9.
- For the Smart-UPS Ultra, we assume no battery replacement is required in years 1-10.

Methodology continued

- In distributed environments such as IT/edge data centers with multiple locations, the battery replacement labor can cost approximately $200.
  - These environments rarely have on-site service personnel. Therefore, a managed service provider can be contracted to procure replacement batteries, travel to the site, replace the battery and recycle the old batteries.
  - Even if in-sourced, expect to pay about $200 per replacement.

Tables 2 and 3 provide a list of assumptions relevant to this TCO analysis. In addition to these assumptions:

- The UPS space lease cost does not include cost of service clearances.
- The costs associated with battery troubleshooting, spare parts storage, and replacement transportation costs are not included.
- The cooling system uses 0.33 kW of energy for every 1 kW of heat rejected by the UPS system.
- UPS installation costs $200/person per hour and includes: one-hour roundtrip to site; unpackage UPS; connect battery; set up web card; configure UPS; assemble mounting brackets; de-trash; move UPS to IT environment; install cage nuts; mount UPS in rack; and plug in loads and UPS.

Table 2
TCO analysis assumptions unique to each UPS

Assumption	APC Smart-UPS SRT	APC Smart-UPS Ultra
Load	2,700W (100%)	2,700W (90%)
Efficiency	92.4%	93.0%
Annual UPS electricity consumption	1,932kWh	1,789kWh
Annual cooling electricity consumption	644kWh	596kWh
UPS purchase cost	$2,263	$3,395
UPS installation cost	$560	$400
Battery service life	3 years	10 years
Quantity of battery replacements	3	0
One-time battery replacement cost	$539	$1,075 (not incurred)

Table 3
Common TCO assumptions

Common assumptions	
UPS service life	10 years
Battery replacement labor cost	$200
Electricity cost per kwh	$0.15
Cost of capital	2%
Monthly cost of rack space	$23.81 per U space
CO_2 emissions factor	525 kg CO_2/MWh

TCO results

With a 10-year service life, the APC Smart-UPS Ultra OpEx dominates the TCO compared to APC Smart-UPS SRT in the following analysis:

- Replacement frequency: VRLA battery replacements have a significant negative impact on a UPS TCO given that VRLA batteries must be frequently replaced compared to lithium-ion batteries.
- Lease cost: The APC Smart-UPS Ultra takes only 1U of space versus 2U by the APC Smart-UPS SRT. The cost per U to lease rack space may be difficult to determine as a charge-back in edge locations like retail environments. For this analysis, we assumed a $1,000 monthly cost for a 42-U rack ($23.81/U). While this is less than what the average colocation facility charges, it demonstrates the impact a compact UPS has on TCO.
- Wall-mountable: Another factor that favors less U space and potential cost saving for APC Smart-UPS Ultra is that this UPS can be wall-mounted without any additional hardware, while APC Smart-UPS SRT can not be mounted on a wall.

Table 4 breaks down the TCO for both APC Smart-UPS SRT and APC Smart-UPS Ultra. The APC Smart-UPS Ultra UPS has a 30%-lower 10-year TCO than the APC Smart-UPS SRT. The cash flows for this analysis result in a payback of 2.3 years to break even from the higher APC Smart-UPS Ultra capital expense at year 0. Finally, the APC Smart-UPS Ultra has 7%-lower 10-year CO_2 emissions than APC Smart-UPS SRT.

Table 4
TCO results

Results	APC Smart-UPS SRT	APC Smart-UPS Ultra	% change
CapEx	$2,823	$3,795	Smart-UPS Ultra CapEx is 34% higher than Smart-UPS SRT
10-year OpEx	$10,886	$5,780	Smart-UPS Ultra OpEx is 47% lower than Smart-UPS SRT
10-year TCO	**$13,709**	**$9,575**	**Smart-UPS Ultra TCO is 30% lower than Smart-UPS SRT**
10-year CO_2 emissions	13,527 kg CO_2	12,523 kg CO_2	Smart-UPS Ultra CO_2 is 7% lower than Smart-UPS SRT

Conclusion

Conclusion

The world is becoming more digitized and many organizations are focusing on IoT, cloud computing and mobile applications, which all require resilient edge computing. However, traditional UPSs pose challenges at the edge, including footprint, energy cost, and downtime risk. Fortunately, three technologies can be combined to overcome these challenges:

1. innovative power electronics based on **wide-bandgap technology** that results in smaller, lighter, and more efficient components
2. **lithium-ion battery technology** that delivers smaller and more efficient batteries with a longer service life
3. **cloud-based management and monitoring software technology** that provides remote monitoring and alerts, diagnostics with useful recommendations, predictive analysis, remote management capability, and connection to service experts

With this backdrop and the analysis presented in this e-book, APC Smart-UPS Ultra offers persuasive benefits over traditional UPSs:

- Doesn't require a battery replacement over a 10-year deployment
- Lowers energy loss
- Lowers space lease costs and frees up more space for more IT or other equipment

While the initial purchase cost of the 3kW Smart-UPS Ultra is higher, in this scenario it presents a **30% 10-year TCO savings.**

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To learn more about addressing your
UPS Challenges at the Edge, visit:

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