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Decarbonizing Technology in Commercial and Industrial

Hi,

Our technology has been adopted in NYC and Boston as part of their first step in decarbonizing City buildings. We provide data along with the real time technology to regulate incoming power to a building and reduce overall energy consumption by (3 to 5%). Is there a window to introduce ourselves and our role as a first step in decarbonizing?

Additional submitted attachment is included below.

FEBRUARY | 2021

ACTIVE POWER MANAGEMENT AT THE GRID EDGE

The Role of Distributed Voltage Control in Building Sector Decarbonization: A Key Sustainability Investment Opportunity

JARED RODRIGUEZ | Emergent Urban Concepts
MARK KLEINGINNA | Integral Energy

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01 ABOUT THE AUTHORS

JARED RODRIGUEZ

Jared is Principal and Founder of Emergent Urban Concepts, a consultancy dedicated to providing key technical and planning support to private industry and public organizations in the fields of urban design, zoning, energy and sustainability, capital planning and decarbonization, market transformation, technology, real estate, and economic development. His clients include municipalities like the Village of Haverstraw and the Village of Ossining in New York, public agencies like the New York State Energy Research and Development Authority (NYSERDA), and real estate companies like Ginsburg Development Companies and the LeFrak Organization. Jared holds an M.S. in real estate development from New York University and a B.S. in Civil and Environmental Engineering and a concentration in architectural studies from Tufts University. He has over ten years of experience in leading energy procurement, conservation, new technology deployment, and distributed energy resource development efforts for over 40 million square feet of commercial and residential buildings. Jared serves as Citizen's Representative alternate for the North Jersey Transportation Planning Authority, Chairman of the Village of Haverstraw Comprehensive Plan Committee, and Vice President of Garner Arts Center in the Hudson Valley.

MARK KLEINGINNA

Mark has over 30 years of experience in the retail and wholesale energy business and is the founder of Integral Energy, a sustainability and energy consulting firm. His areas of expertise include product development, pricing, risk management, operations, supply acquisition, planning, marketing, manufacturing, sales, and finance. He was responsible for the dynamic removal of a 535 MW load from a control area in Ohio to a control area in Illinois in 2000. Mark was responsible for the development and first launch of the retail electricity industry-leading managed product. He developed an innovative power procurement process for which he received a U.S. patent. Mark has advised many large utility, industrial and commercial clients over the course of his career on energy procurement and risk management. These clients include PPL, City of Richmond, Equitable Gas Company, AlCoA, US Steel, Bloomberg, TD Bank, Home Depot, Albertsons and Simon Properties. Mark has testified before 5 state utility commissions and at the Federal Energy Regulatory Commission. He received his Master's and Bachelor's Degree in economics from Penn State in 1990 and 1988 respectively. He will complete his Master's in Professional Studies in Renewable Energy Systems and Sustainability in Spring 2021. Mark is a technical advisor to the Hybrid Optimization and Performance Platform (HOPP) effort under development by the National Renewable Energy Laboratory (NREL).

With Special Thanks to Contributions From: The Building Electrification Initiative builds on the work of leading cities, supported by the Urban Sustainability Directors Network and the Carbon Neutral Cities Alliance, to pilot strategies to scale up the electrification of building heating and cooling systems. Over the past four years, a growing number of cities have become active in this work to equitably transition their buildings away from fossil fuels. Eight pioneering cities have led the way as participants in the Building Electrification Initiative. Additional cities will be added in the coming years. www.beicities.org

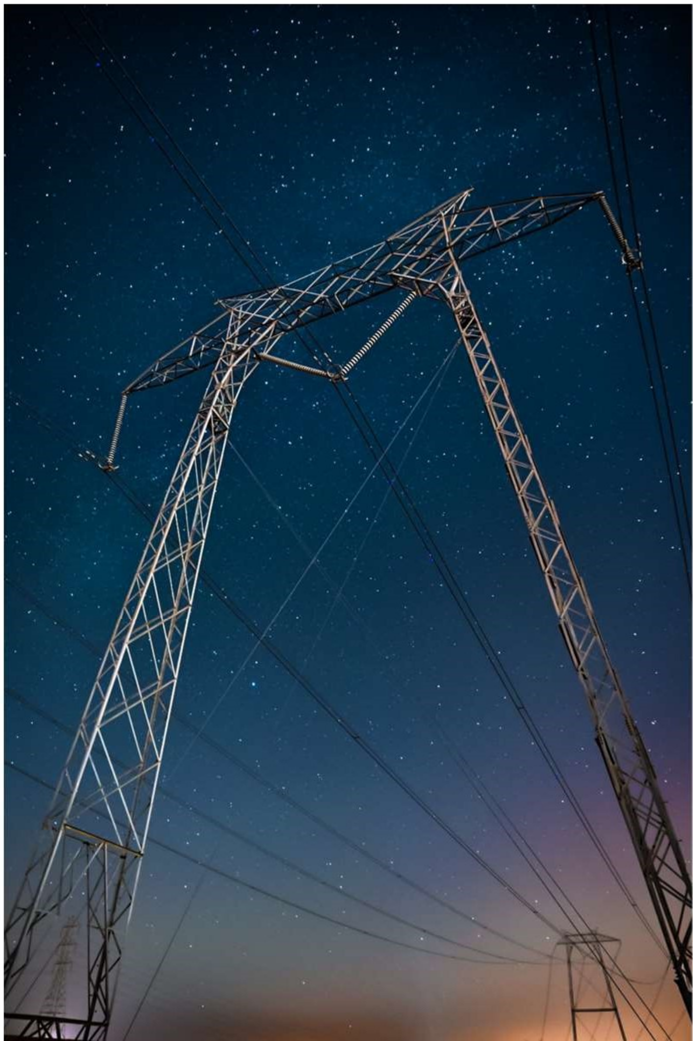
BEI Building Electrification Initiative
CITIES DRIVING CHANGE

02 ACTIVE POWER MANAGEMENT

A KEY CLIMATE CHANGE SOLUTION ENABLER

As real estate trends like decarbonization and electrification grow, it is imperative for building owners to understand the range of implications for their buildings, the people who rely on them, and the financial wellbeing of their organizations. This whitepaper demonstrates the short- and long-term impacts of **Active Power Management** (APM) on the electric grid, building systems, occupants, as well as the value APM delivers with regard to electrification and decarbonization.

When **Distributed Energy Resources** (DER) like solar and battery storage proliferate the built environment, electric grid stability decreases, and the likelihood of negative impacts on buildings and owners, operators, and occupants increases. APM is a powerful tool that, if appropriately utilized, helps buildings avoid the worst of these impacts and potentially save energy in the process. In addition, this paper outlines how building owners and operators can deploy APM to advance corporate Environment, Sustainability, and Governance (ESG) goals while protecting their assets and improving economic performance.



03 INTRODUCTION

BACKGROUND

In order to meet the international Paris Accords requirement of limiting global temperatures to an increase of 1.5 degrees C, power generation and the entire electric power sector must not produce additional greenhouse gas emissions, reaching neutrality by or before 2050.[1] Large buildings consume vast amounts of energy and are responsible for a significant portion of total emissions in the real estate sector and also economy-wide. According to the United States Energy Information Administration's (EIA) 2012 Commercial Buildings Energy Consumption Survey (CBECS), [2] there were 135,000 buildings over 100,000 square feet in the U.S. contributing a significant portion of total sector greenhouse gas emissions. This building typology is equivalent to 30 billion square feet of real estate with a total electric power load of 500 TWh per year, which is expected to increase as these buildings move toward deeper electrification of heating and cooling systems.

Electric consumption, procurement and management is the central component of a successful ESG and greenhouse gas emissions reduction strategy. A strong ESG platform has the ability to significantly improve the overall financial performance of an organization. This includes the following efforts by government and the real estate sector:

1. *Buying, consuming, and enabling renewable energy at grid-scale and behind-the-meter within buildings, including deploying DER like solar or battery storage*
2. *Pursuing electrification of fossil fuel-fired building or tenant equipment, including the installation of electric heat pumps and EV charging facilities*
3. *Reducing energy use through efficiency and conservation measures*

Resilient and efficient buildings have lower operating costs, while also providing occupants, customers and guests with a high-quality environment based on a positive mission. These high-performing attributes increase rental rates, attract more reliable tenants, increase satisfaction, bolster tenant retention, improve net operating income, and overall asset value.

1. 2021. [online] Available at: <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement> [Accessed 20 January 2021].
2. Eia.gov. 2021. Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data. [online] Available at: <https://www.eia.gov/consumption/commercial/data/2012/> [Accessed 12 December 2020].

04 TRENDS IMPACTING BUILDING OWNERS & OPERATORS

RENEWABLE ENERGY & DISTRIBUTED ENERGY RESOURCES

Traditionally, electricity is generated by large fossil fuel power plants, but this model is shifting due to rapidly evolving power generation economics. The shift to renewable energy sources for power generation is accelerating. Renewable power is now the least expensive form of electricity available in North America[3] and is being deployed at scale in nearly all regions. However, because most new renewable power is intermittent, grid operators may face challenges providing consistent power supply to customers. A more dynamic electric grid, supported by energy storage, is needed in order to mitigate negative customer impacts stemming from more turbulent power generation sources like wind and solar.

Buildings can be part of the solution when they function as a grid asset capable of providing enhanced power regulation and reducing power demand to maintain grid stability. Through APM, buildings can enable a decentralized and renewable power grid by providing power regulation local to the building and relieving the grid or utilities of a portion of this power management burden

ELECTRIFICATION

Space heating and transportation are primarily fossil fuel driven. Switching gas-fired heating systems to electric heat pump-based systems and providing electric vehicle charging capacity to encourage E.V. adoption can have a dramatic impact on building power demand, cost, and associated greenhouse gas emissions.

Modern electronics that drive the building electrification trend require more precise power management than the grid operator or utilities can provide. Electrification increases power demand and puts strain on aging power systems within and outside the building. APM is central to large building electrification strategies given its vast potential for reducing emissions, power cost, and stabilizing the grid. APM is a key enabler of emerging electric grid dynamism, examples of which include more connected DER, grid-interactive buildings, and better reliability with increased demand on electric distribution systems from building and transport electrification.

EFFICIENCY

With an average reduction in building power consumption of 8% resulting from deploying APM, a total of approximately 18 million metric tonnes of U.S. carbon emissions[4] could be avoided annually. All experts conclude that one of the most effective pathways to meeting our climate goals is via building systems energy efficiency. Though emissions associated with power production are declining in the United States, greenhouse gas emissions coefficients still hover around 1 lb per kWh of power generation. Every kWh avoided through energy efficiency solutions results in reduced greenhouse gas emissions.

3. World Energy Outlook 2020. (2021). Retrieved 20 November 2020, from https://webstore.iea.org/world-energy-outlook-2020
4. Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA). Retrieved 16 November 2020, from https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

05 PRIORITIZING ACTIVE POWER MANAGEMENT

Owners of large buildings will meet emission reductions, efficiency goals and compliance requirements in an economical manner:

Procuring Renewable Power

Leveraging Distributed Energy Resource Assets

Relying Heavily on Energy Efficiency & System Controls

Owners of large buildings will meet emissions reductions, efficiency goals, and compliance requirements in an economical manner by procuring renewable power, leveraging distributed energy resource assets, electrifying building systems, and heavily relying on energy efficiency and systems controls.

All these investments should be preceded by deploying APM and deep grid edge control. APM is central to large building electrification strategies given its vast potential for reducing emissions and power cost and stabilizing the grid. APM is a key enabler of emerging electric grid dynamism, examples of which include more connected DER, grid-interactive buildings, and increased demand on electric distribution systems from beneficial building electrification.

Building electrification necessarily increases local electric distribution system stress and peak period demand. This combined with more widespread DER, will require further grid edge control via APM. All pathways to achieve carbon-neutral buildings should include a priority to incorporate APM systems first.

06 WHAT IS ACTIVE POWER MANAGEMENT?

APM is an electrical engineering technique which adjusts the power coming from the electrical distribution system in real-time to ensure that the electricity delivered to the installation's downstream equipment is within a more appropriate voltage range.[5] Because of the proliferation of intermittent energy resources, greater stress and loads, and shifting demand patterns, today's electric grid is ever more reliant on systems and devices that regulate voltage and improve distribution or transmission stability.[6]

Modern APM systems provide the following benefits to building owners:

- *Reduces energy consumption*
- *Reduces building operating expenses by rejecting overvoltage from local utilities, which building owners pay for*
- *Reduces power demand*
- *Reduces greenhouse gas emissions from associated power consumption*
- *Positively impacts building power systems and downstream equipment reliability,*
- *Reduces costs required for potential upgrades to metering, internal distribution & controls*
- *Increases life expectancy of downstream building equipment*
- *Improves tenant-owner relations and satisfaction, providing the ability to ask for higher rental rates*

5. Yao Liangzhong, Zhu Lingzhi, Zhou Ming, et al. Prospects of coordination and optimization for power systems with high proportion of renewable energy[J]. Automation of Electric Power Systems, 2017, 41(9): 36--43.
6. A. Q. Huang, S. Bhattacharya, M. Baran, B. Chen and C. Han, "Active Power Management of Electric Power System Using Emerging Power Electronics Technology," 2007 IEEE Power Engineering Society General Meeting, Tampa, FL, 2007, pp. 1-7, doi: 10.1109/PES.2007.386146.

ACTIVE POWER MANAGEMENT & ENERGY CONSERVATION

For decades, utility companies have used **Conservation Voltage Reduction** to manage network loads. Conservation Voltage Reduction is a tactic to deliver electricity at the lower "range of acceptable voltages. Delivering electricity closer to the lower end of this voltage range can result in energy savings because some equipment operates more efficiently at voltages in the lower end of the acceptable range." [7] Utilities deem it safer and more profitable to set substation voltages higher than a level that optimizes customer usage.

Because voltage decreases as the distance from a utility substation increases, which is more pronounced during times of higher loads (a phenomenon known as "line drop"), setting voltage higher helps avoid brownouts at the furthest reaches of the utility network. This network management strategy aligns with utility incentives because it increases energy consumption and revenues and provides more system-wide reliability. Delivering higher voltage also avoids customer complaints and political issues due to voltage or line drops and power outages.[8]

Conservation Voltage Reduction, traditionally implemented by power utilities on the grid side, is a core tenet of APM, which occurs on the customer or building owner side of the utility meter. The ability to save energy while providing power stability differentiates APM from existing Power Quality solutions. The pace of change and level of innovation in building connected digital equipment is so much faster than innovation at the utility. Utilities are not positioned to adequately respond to this rapid pace of change, particularly as more DER are introduced to the marketplace. Building owners must consider managing this themselves via APM strategies.

According to the California Public Utilities Commission, an approach that places APM systems closer to building loads provides the lowest operating voltage to buildings and, therefore the greatest amount of savings.[9]

7. Conservation Voltage Reduction/Volt VAR Optimization EM&V Practices. U.S.E.P.A., 19 JAN 2017: https://www.energystar.gov/sites/default/files/asset/document/Volt%20Var%20and%20CVR%20EMV%20Best%20Practice%2006-01-17clean%20-%20508%20PASSED.PDF (download)
8. Skov, Thor. Trending Toward Distributed Voltage Optimization: A Simple Solution Overlooked. 4 JUN 2013: https://www.tdworld.com/test-and-measurement/article/20963123/trending-toward-distributed-voltage-optimization-a-simple-solution-overlooked
9. Conservation Voltage Reduction (CVR) Program, Calendar Year 1985. California Public Utilities Commission Evaluation & Compliance Division – Energy Branch – San Francisco California – February 1987, p. 16.

EQUIPMENT RELIABILITY

Connected devices and equipment in commercial or large multifamily buildings are designed to function optimally and efficiently at their nameplate voltage. However, because voltage delivered by the utility is never static, equipment is designed to continue operating within a range above or below its nameplate voltage.

Therefore, if voltage is fluctuating at the building utility service, whole-building energy efficiency is impacted because equipment is no longer functioning optimally. Utilities are not positioned to adequately respond to this rapid pace of change, particularly as more DER are introduced to the market. Again, building owners and operators and even some tenants must consider managing this themselves via APM strategies.

CAPITAL EQUIPMENT PROTECTION

With building electrification and the proliferation of grid-interactive buildings, the value at risk for connected assets/equipment is increasing. Preserving equipment life expectancy becomes more important as the value of building equipment assets increases and as the value of the services that equipment provides increases. It is recognized that optimizing voltage substantially lessens equipment maintenance costs.

The service life of electrical equipment is roughly halved with each 10ºC increase in operating temperature. Each volt increase in voltage raises the operating temperature of most appliances by approximately 0.5ºC. Additionally, each 1% of voltage imbalance increases three-phase motor winding temperature by 10ºC." [10] Battery storage and management systems are particularly sensitive to voltage fluctuations.

As investment margins are compressed due to diminishing returns, it is more important than ever to preserve equipment performance and life. Equipment downtime, unfortunately, results in reduced returns on DER projects with fragile economics.

10.Skov, Thor. Trending Toward Distributed Voltage Optimization: A Simple Solution Overlooked. 4 JUN 2013: https://www.tdworld.com/test-and-measurement/article/20963123/trending-toward-distributed-voltage-optimization-a-simple-solution-overlooked

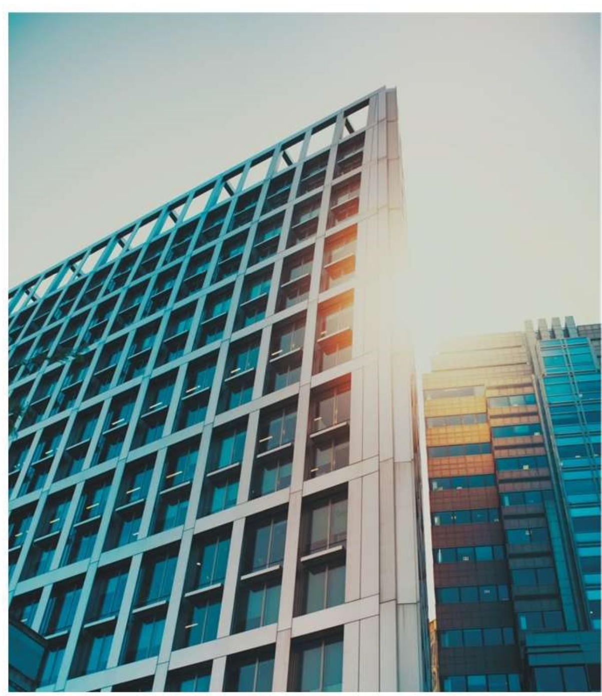
09 ACTIVE POWER MANAGEMENT KEY INDUSTRY PLAYERS

Power quality and APM systems were targeted at manufacturing and industrial power users because prior to current information technology capabilities, such systems were not considered economic for commercial building applications. Few APM companies have focused on serving smaller commercial buildings. These buildings, however, dominate commercial activity greenhouse gas emissions in North America. APM at the commercial building scale represents a potentially very beneficial GHG reduction strategy. The effort requires packaging and pricing the technology properly to increase its accessibility to the commercial building segment. This repackaging reduces barriers to adoption by the targeted building owners. Fortunately, there is an emerging group of active power management firms conducting business in North America, providing this important service to commercial and large residential building owners.

The primary manufacturers and solution providers in the active power management space for buildings in North America are **Schneider Electric, Utility Systems Technologies**, **Legend Power Systems**, and **Power Sines**. The companies generally focus on specific market segments and provide solutions for particular end-users, whether they be industrial facility operators or commercial building owners. There are several key considerations for these solutions:

SEVERAL KEY CONSIDERATIONS FOR EACH SOLUTION

1. **Capacity**
2. **System Features**
3. **Efficiency and Energy Impact**
4. **APM Equipment Dimensions**
5. **System Costs**



ACTIVE POWER MANAGEMENT KEY INDUSTRY PLAYERS (CONTINUED)

An outline of these considerations for each of these providers is given below. For each consideration, we will provide a relative index compared to a building electrical distribution system containing no APM as a baseline.

1. **Capacity**: Building electrical services can vary from a single 100 kVA feed to multiple large 4000kVA services in major metropolitan centers. Appropriately sizing an APM system to the load is critical. Smaller systems are designed for building distribution circuits (100-500 kVA) rather than buildings service entrances (500- 5,000kVA).

2. **Features**: As there are 7 major categories of power quality disturbances (transients, interruptions, sag / under voltage, swell / overvoltage, waveform distortion, voltage fluctuations, frequency variations), the matrix below will include a number which corresponds to the number of features covered by the APM provider.

3. **Efficiency and Energy Impact**: 3. Efficiency and Energy Impact: With the goal of reducing energy consumption, each system will be rated on a score of 0-5, with 0 describing energy consumption increases and 5 meaning large energy consumption reductions.

4. **APM Equipment Dimensions:** Given the high cost per square foot of modern buildings, the physical size of these solutions is critical. Fitting into electrical rooms is challenging when the " add-on" equipment is larger than the core equipment like switchgear. For example, a rating of 2X means the size of the APM solution is twice as large as the corresponding switchgear.

5. **System Costs**: As these systems require full engineering design and electrical contractor installation, rates can vary widely from region to region, and therefore rough turnkey cost ranges in the following bands for a single system are provided:

$	$50k - $150k
$$	$150k - $300k
$$$	$300k - $500k
$$$$	$500k and up

THE KEY PLAYERS

SCHNEIDER ELECTRIC

Schneider Electric's primary business is in producing power distribution systems, controls and power management platforms and is one of the largest companies of its kind in the world. The largest APM provider, Schneider Electric is particularly relevant for industrial facilities or manufacturers that rely on stable and dependable power supply. These customers are often manufacturing high-value products or using expensive equipment that must be protected from voltage fluctuations since the cost of interrupted production processes can be extremely high. The cost of these systems is generally high given their targeted customer and Schneider systems are deployed not at a whole building level but targeted at critical loads. Schneider's APM systems are typically operating at electric services of 400 kVA or larger and often take up a large section of a switchgear room. These large APM systems provide good protection against a wide variety of power quality issues for critical loads in exchange for poor efficiency and high cost. In this case, systems of this type are typically deployed as a power quality service for critical circuits delivering power to high-value production lines or to expensive equipment.

UTILITY SYSTEMS TECHNOLOGIES

UST provides a range of APM products that target large industrial customers to commercial building owners. According to its website, " UST offers electrical engineers and facility managers at power-critical facilities around the world industrial-grade options for protecting equipment and processes against unavoidable voltage anomalies." The company focuses primarily on voltage regulation and power quality and is also focused on industrial users. While the cost of UST services and products is less than the cost of Schneider Electric systems, commercial and residential building owners typically find costs are prohibitive unless critical power systems are in need of protection. Some commercial building owners provide critical power services to tenants, like laboratory or high-value financial services tenants, and are in need of UST APM products. UST products require dedicated space in electric service rooms near the main power service and building switchgear. It's often difficult for commercial building owners to justify installing these systems given the real estate necessary to host these systems.

PACIFIC VOLT

Pacific Volt targets utilities and distribution network owners only, installing equipment on the utility side of the meter and at the secondary network. The company offers voltage regulation technology that not only protects customers from voltage fluctuations, albeit on a larger network scale, but also protects the network itself from unmanaged power backflow from distributed energy resources like pervasive solar and battery storage deployments. While Pacific Volt does not specifically target building owners as customers, the technology could be applicable to the building scale and could work in tandem with behind-the-meter systems to further optimize efficiency stemming from voltage regulation. Cost is the primary barrier, and the systems sold by Pacific Volt are tailored specifically for installation within the utility distribution network.

THE KEY PLAYERS (CONTINUED)

LEGEND POWER

While not the largest player in the APM space, Legend Power focuses its products and services on commercial and large residential building owner customers. The company locates its compact equipment at the building power service in the main electric room and provides APM services to the entire building. The equipment is designed to provide protect against the most common and high-impact power quality events while also providing energy savings benefits via APM. This focus allows Legend Power to provide full/ high-capacity systems that are smaller sized equipment at lower cost. The company is primarily concerned with full regulation of voltage on each phase discretely for protecting building equipment and providing optimized energy conservation.

POWERSINES

PowerSines is one of the smaller APM providers functioning as a retail provider and offering its products at a low cost. The company's product focus is mainly on small compact APM systems sized for a single electrical load. The company is primarily concerned with protecting high-value equipment in buildings instead of providing APM services building-wide. Power Sines limits its product to smaller circuits and smaller buildings, typically protecting smaller loads than other APM providers. According to the company's website, PowerSines:

> *. . [our] products provide optimized and pure sinusoidal voltage to the load. In other words, our products take the bulk utility provided to the facility and apply the right energy or the right voltage and deliver it to the right application. As a result, only the right amount of energy required to maximize efficiency is delivered to controlled [downstream] devices.*

APM Provider Comparison

Provider/Consideration	Schneider Electric	UST	Legend Power Systems	PowerSines
Capacity (kVA)	100-400	5-3,000	400-4,000 ✓	40-800
Features	7 ✓	6	5	5
Efficiency	0	3	5 ✓	3
Dimensions	3X	2X	0.5X ✓	1X
Cost	$$-$$$$	$-$$$$	$-$$ ✓	$$-$$$

Important Note: Pacific Volt is grid scale technology and was not assessed for inclusion in the comparison.

✓ Indicates Top APM Category Leader

ACTIVE POWER MANAGEMENT DRAWBACKS & HOW TO DEPLOY

Opportunities to deploy APM technology and realize significant energy efficiency gains are not equally distributed across a utility service territory. Overvoltage is a problem in limited geographies in a distribution network, and given the dynamic nature of power distribution, overvoltage conditions are not always present or significant, and could therefore reduce the economics of installing an APM system. APM system installation is often disruptive, and in particular cases where APM is installed for an entire building, extensive full building power shutdowns are required.

In general, there is a lack of awareness among building owners about APM technology as well as lack of awareness of the problems associated with grid stability impacts from renewable energy, DER, and electrification. Many stakeholders are unaware of the energy efficiency opportunities provided by APM. Often, building owners are wholly unaware they face power irregularities leading to reduced energy efficiency and equipment life. APM solution providers must also further communicate to building owners the need for implementing APM strategies prior to advancing other energy conservation measures, electrification, or building decarbonization efforts at their properties.

Many APM solution providers offer a data-driven power impact review as a starting point with a goal of identifying power quality problems before this evolves into system reliability issues or damaged equipment. Typically, diagnostic metering equipment is deployed to capture power data across a portfolio of buildings. Advancements in automated intelligence, machine learning, and data analytics enables rapid scoring of overall power and building distribution health to further help identify power challenges and justify APM. The scope of an APM project, and even other technical ESG initiatives, is often determined through the power impact study. A detailed data-driven study is a recommended staring point.

Often, commercial building owners repeat a common misconception: “There’s no ROI on power quality regulation,” given the fact tenants are often unaware a reliable power service is due to APM technology. Tenants expect reliability as a base service, a basic condition of leasing their space. Building owners, too, are often unaware they are paying for this overvoltage in the form of reduced building equipment life and increased power cost. APM solution providers must find ways to better communicate the value

their products provide to building owners, and they can begin by performing real power service quality analysis to building owners as a means of justifying the upfront investment in APM systems.

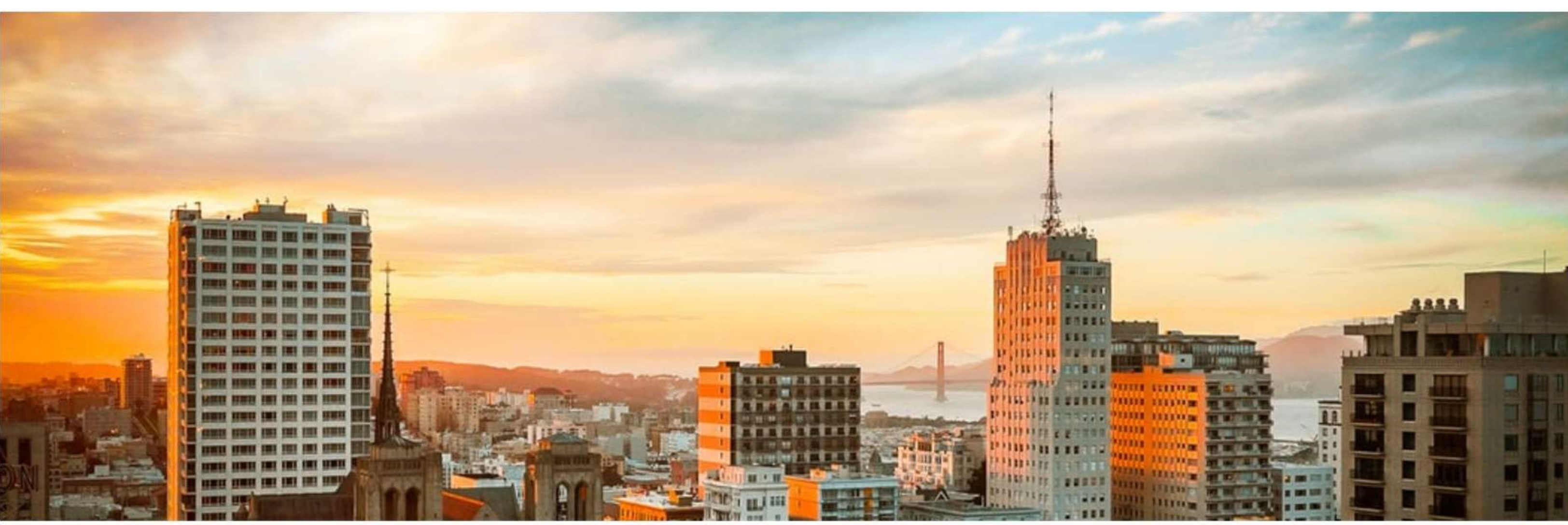
APM solution providers must also further communicate to building owners the need for implementing APM strategies prior to advancing other energy conservation measures or building decarbonization efforts at their properties.

Due to a lack of knowledge, it is also imperative APM providers communicate to government agencies, regulatory bodies, and politicians to ensure APM strategies are present in wider decarbonization plans and policies.

A COMMERCIAL BUILDING CASE STUDY

A commercial building in New York City has a peak power demand of 2,000 kW with a load factor of 60%. This building uses about 10.5 million kWh annually, and therefore, the building's total electric bill for one year is roughly $1.4MM[11,12] and generates carbon equivalent scope 2 emissions from electricity of 3,038 tonnes per year . Installing APM equipment lowers the power demand at the meter by 8%, resulting in a projected power cost savings of approximately $110,000 per year and reduced carbon emissions of 243 tonnes per year. This is a significant reduction in power cost and emissions. By 2024, New York City will impose a carbon emissions fine of $268 per tonne per year above a particular threshold. Installing APM equipment would yield an additional savings of $65,124 in fines per year.[13]

Impacts	Before APM	After APM	Improvement
Electric Charges	$1.4m	$1.29m	$110,000
GHG	3,038 tonnes	2,795 tonnes	243 tonnes
Phase Imbalance	1.1%	.5	.6%
Voltage Fluctuations	62	18	44



11. Schedule for Electricity Service - Tariff. (2012). Retrieved 19 November 2020, from https://www.coned.com/_external/cerates/documents/elecPSC10/electric-tariff.pdf
12. Installed Capacity Market (ICAP) - NYISO. (2021). Retrieved 18 December 2020, from https://www.nyiso.com/installed-capacity-market
13. NYC Local Law 97 of 2019 - Climate Mobilization Act. (2019). Retrieved 10 November 2020, from https://www1.nyc.gov/assets/buildings/local_laws/ll97of2019.pdf

BUILDING DECARBONIZATION AS A CLIMATE CHANGE SOLUTION

Humans emitted 49 billion tonnes of greenhouse gases (GHGs) in 2016. Of these 49 billion tonnes, 17.5% or 8.6 billion tonnes came from energy consumption in residential and commercial buildings. This represents a significant opportunity for GHG reduction worldwide via interventions in the built environment. [14]

Looking more closely at the U.S. market we find that in the context of commercial buildings there were a total of 909.4 MMT CO_2 Eq. coming from commercial buildings in 2015.[15] Of this 663.1 MMT CO_2 Eq. was through the combustion of fossil fuels related to electricity generation. This is out of a total of 4740.3 MMT CO_2 Eq. or 14% of all GHG emissions in the U.S. were due to the consumption of electricity by commercial buildings. From a carbon avoidance perspective this represents a significant addressable market. If there were options to reduce electricity usage at the load by utilizing proven and financially sound technologies, the reduction in GHGs would be significant.

Another factor which must be considered in the push to decarbonize the commercial built environment is the unrelenting push toward beneficial electrification. This will undoubtedly be among the first steps taken toward decarbonizing commercial buildings. As the move away from fossil fuel combustion on-site pushes the electric loads in commercial buildings higher for heating, the efficient utilization of power at these buildings becomes even more critical. The gain in decarbonization through the shedding of fossil fuel loads must not be ceded back through the inefficient use of electrical power at the bus.

Power conditioning becomes more important on the supply side of the CO_2 equation over time. Natural gas and renewable electricity generation significantly penetrated portions of the electricity supply dispatch curve previously held by coal. This penetration delivered a 12% reduction in CO_2 emissions from 2005 to 2015.[16] The decarbonization which occurred as a result of the coal to gas switch will need to be pushed even further as society moves to replace older inefficient gas-fired generation and uneconomical nuclear generating stations with renewables. Ultimately, at the margin, there will always be some fossil fuel (and therefore carbon-producing) generation. If, by power conditioning the load is reduced, we can reduce the amount of carbon produced by these generation sources, thereby lowering the carbon footprint of the built environment.

14. Climatewatchdata.org. 2021. Climate Watch. [online] Available at: <https://www.climatewatchdata.org/data-explorer/historical-emissions?historical-emissions-data-sources=cait&historical-emissions-gases=all-ghg&historical-emissions-regions=All%20Selected&historical-emissions-sectors=total-including-lucf&page=1> [Accessed 20 January 2021].
15. Epa.gov. 2021. [online] Available at: <https://www.epa.gov/sites/production/files/2017-02/documents/2017_executive_summary.pdf> [Accessed 20 January 2021].
16. Eia.gov. 2021. [online] Available at: <https://www.eia.gov/todayinenergy/detail.php?id=26152> [Accessed 20 January 2021].

OVERCOMING KEY BARRIERS TO BUILDING ELECTRIFICATION

Building decarbonization is hindered primarily by technical and economic difficulty with electrifying end-use building systems. Electrification of fossil fuel combustion-based systems in buildings is key to reducing GHG emissions reductions necessary to slow climate change and defray its worst impacts. According to the **National Renewable Energy Laboratory** (NREL), building electrification [17] :

> *. . . coupled with decarbonization of electricity generation has been identified as one of the key pathways to achieving a low-carbon future in the United States. By lowering the carbon intensity of the electricity generation and substituting electricity for higher-emissions fossil fuels in end-use sectors, significant reductions in carbon dioxide emissions can be achieved.*

Major barriers to building electrification as summarized in a report from Berkeley Lab in 2018, include but are not necessarily limited to the following: [18]

1. *Financial*
   - a) Fuel & Operating Costs
   - b) Capital Costs of Switching
     - i. Equipment Replacement
     - ii. Upgrade to the Electricity Service Feed
2. *Consumer Acceptance*
   - a) Electrical Appliances Do Not Provide Identical Experience as Fossil Appliances
   - b) Familiarity with Fossil Technologies By Staff
   - c) Familiarity of Engineering Designers, Contractors and Tradespeople
3. *Building Energy Codes*
4. *Electric Delivery infrastructure*
5. *Vulnerability to Power Outages*
6. *Incumbent Utility and Supplier Pressure*

While the move toward electrification of commercial buildings is over time inevitable, these barriers are significant. The financial barrier is significant, particularly where there is no cost associated with carbon emissions and where fossil fuels are inexpensive and plentiful. Electric and gas rate design can provide further hindrance to electrification where appropriate rate design could move electrification forward. Cost of capital is important if equipment is recently sourced and has a long useful life ahead. It may be very difficult to install new equipment before the current equipment is fully depreciated.

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OVERCOMING KEY BARRIERS TO BUILDING ELECTRIFICATION (CONTINUED)

Consumer acceptance could slow down electrification as there are not identical amenities provided by electric appliances, for instance, in the case of gas for cooking. The maintenance staff, as well as contractor familiarity with fossil technologies, also could provide resistance. Building energy codes in certain jurisdictions may not allow large enough electrical services to allow for complete electrification.

For full electrification, in winter heating-dominated markets, the current electricity distribution infrastructure may be significantly under-sized. It has been estimated that a complete electrification of markets in the northeast would require certain circuits to need to double or even quadruple in capacity. Another reason that building owners have been reluctant to electrify is that there is a greater perceived vulnerability to power outages, although most HVAC systems require electricity to start the furnace and run the air handling.

A final barrier to building electrification is the pressure exerted by incumbent entities serving customers with fossil fuels. These incumbents take the form of natural gas local distribution companies, oil and gas suppliers, and even local ESCOs. These incumbents do not want to lose their customers, and in turn, their revenue streams as much of their plant in service or investment will be stranded in a full electrification scenario.

THE FUTURE OF ACTIVE POWER MANAGEMENT

As building owners and property managers begin prioritizing decarbonization and electrification of heating and cooling systems, APM will continue gaining a presence in large commercial and residential buildings. With continued regulatory approval for wholesale market participation of DER and grid edge resources, buildings will become more and more a platform for grid interactivity to support economy-wide decarbonization. Opportunities to participate in retail and wholesale markets will be ever more present as utilities, and grid operators continue to seek and support strategies to balance the grid, especially as generator intermittency increases.

Significant advantages in obtaining highly detailed power consumption data will inform important building optimization decisions, including wholesale power price sensitivity, and support DER management in real-time. With further development, the technology in combination with BMS systems could eventually push instructions to downstream devices to manage local power frequency response or surge suppression systems for device level or network scale protection. Fleets of APM devices can be aggregated and paired with generation and various energy storage technologies to further balance the grid as a monolithic, virtual resource. APM is a primary low carbon retrofit technology because it lowers power consumption, reveals fine-grained consumption patterns, and preserves the reliability and life expectancy of increasingly sensitive downstream equipment and power systems. Increasingly, the technology will be incorporated into buildings, and this effort will be driven by DER providers and buildings owners as well as utilities, some of which may mandate APM installation.

CONCLUSION

Over the coming decades, North American owners of large buildings will take part in a major transformation of their real estate assets. Building electrification and deployment of advanced DER will transform building performance and the relationship between consumers, distributors, and producers of electricity. This requires a heightened awareness of power consumption and production at large buildings and an enhanced ability to regulate voltage at the grid edge. APM is the keystone of large building electrification and enabler of high levels of grid interactivity. It is not a radical notion to expect APM devices to become as commonplace in large buildings as utility power meters.