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Smart Building Systems: Unlocking Value with IoT Technology

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Executive Overview

As our planet faces an urgent need to tackle climate change, smart buildings are the future. Smart building systems can help reduce energy consumption, lower greenhouse gas emissions, improve worker productivity, and contribute to economic growth and environmental sustainability.

According to the Organization for Economic Co-operation and Development (OECD), buildings account for up to 28% of the total greenhouse gas (GHG) emissions generated in the energy sector globally. IoT technologies for building energy management play a key role in reducing energy usage and improving operational efficiency.

In this white paper, you'll learn about:

- The importance of smart buildings in the modern economy
- Three smart building case studies, including challenges and results
- How to plan for IoT integration into new or existing buildings

Smart Building Systems: Unlocking Value with IoT Technology

Digital transformation for buildings has been advancing at a higher rate than expected in the last decade. While the Internet of Things continues transforming the way hardware and software systems are applied in smart buildings, innovation remains the main catalyst fueling building digitization across the globe.

A market analysis published by the Market Research Future (MRF) indicated that the smart building market would continue registering an average Compound Annual Growth Rate (CAGR) of 17.44% until 2025. North America, which includes the USA, takes the largest market share compared to other regions. It is further projected that North America will continue dominating the smart building market with a projected average CAGR of 13.29%.

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Modern smart buildings provide a convenient environment for occupants while enhancing resource planning and effective energy management. Improved connectivity between different building systems and efficient wireless communication allows users to effectively monitor and manage building functions such as electricity consumption, heating, and water use remotely.

The indisputable advantages of intelligent buildings include improved occupant comfort and productivity, energy savings, and increased safety and security levels.

According to the American Council for an Energy-Efficient Economy (ACEEE), building assets digitization presents an opportunity to save up to 18% of the total energy used in a building. However, as pointed out by ACEEE, other research has shown that the energy savings can be increased to 50% with the adoption of fully integrated smart building automation systems.

It's vital to explore the importance of smart building technologies and provide a pathway to building digitization. There is a plethora of research on the topic, and by reviewing these findings and case studies, you will better understand how the Internet of Things can be applied to increase the efficiency of building operations, improve energy management, and save millions of dollars.

What is a Smart Building?

A smart building is a modern structure equipped with interconnected intelligent components that gather data and use it to control different building operations automatically to optimize performance. This allows users to manage building services, resources, and assets efficiently.

Integration of smart building technologies into new or existing buildings improves thermal comfort, security, lighting, sanitation, and air quality. Also, smart technologies enhance energy management, thus reducing the total energy cost and environmental impact. Smart buildings range from hospitals, hotels, education facilities, offices, residential buildings, stadiums, malls, and other commercial facilities.

Smart Buildings and the Internet of Things

With the increasing complexity, high energy demand, and the need to achieve maximum operational efficiency in modern buildings, innovative technologies such as the Internet of Things have become necessary. Building owners and facility managers are increasingly adopting data-driven methods and analytical tools to reduce energy waste, optimize operational efficiency and minimize related costs.

Building digitization is actualized using an IP network backbone and purpose-built software and hardware tools that collect and process data from building systems such as Heating, Ventilation, and Air Conditioning (HVAC), lighting, IT, security, and sanitation.

Smart buildings' hardware tools and components include actuators, networked sensors, microchips, energy meters, and other automated controls. Other systems and tools include advanced lighting control, building management systems, data analytics, and information systems.

What are Smart Building Systems?

Smart building systems are intelligent systems installed in smart buildings to gather and analyze data, provide valuable insights and automate different building operations to optimize performance. Smart building systems can be categorized as follows:

- **Information systems:** Gather and aggregate data from smart devices and other systems and subsystems, and provide insights using visualization tools. This allows users to review data trends, make informed decisions and take the right actions at the right time.
- **Analytics systems:** On top of data acquisition, analytics systems provide additional data points and metrics such as occupancy data and weather data. The systems analyze raw data to identify issues and generate actionable insights. Some systems, such as fault detection and diagnostics, apply modeling to provide additional capabilities, including measurement and verification.
- **Automation systems:** These connect and control different building systems such as HVAC and lighting to improve performance. Automation systems use scheduling or other methods to control building conditions by adjusting respective setpoints. As a key element of smart building systems, the Internet of Things (IoT) provides a platform for automatic control, monitoring, management, and optimization of building systems, space, and operations.

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The IoT is a network of intelligent, interrelated physical objects embedded with smart devices and software to enhance interconnectivity and automatic communication through the internet.

Digitizing your Building Portfolio is more Affordable than Ever

The technology required to enable IoT in smart buildings is available at fairly competitive prices. For instance, different types of IoT sensors can be purchased at relatively low prices.

Based on the statistical data published by Statista Research, the prices for IoT sensors have been on a sharp decline since 2004.

The data shows the average price for an IoT sensor is about $0.38 USD. Therefore, it is possible to install multiple sensors in different controlled environments to allow users to monitor and control building operations at a granular level.

IoT sensors can measure and maintain continuous feedback on building space conditions such as temperature, air pressure, carbon dioxide, and relative humidity. IoT devices, software, and systems are connected to a centralized open IP network. The user interface provides a friendly display of building parameters through a desktop screen, laptop, tablet, or smartphone. With this capability, users can view graphical data, study insights on building performance, and use the findings to make strategic decisions.

IoT data analytics involves using machine learning algorithms and artificial intelligence to enhance self-diagnosis and data optimization. A scalable IoT platform delivers actionable insights and provides an opportunity to optimize the operational efficiency of the smart building.

What are Smart Building Systems? *(continued)*

Building Management Systems (BMS) and IoT

A BMS is a centralized building automation system used to control and manage building operations and services. Facility managers may use BMS to automate building operations such as lighting, heating, and ventilation through scheduling.

Although BMS contributes to significant energy saving, it is not a perfect choice for energy management. This is because the BMS design objective largely supports automation of building processes rather than energy optimization.

A newer and more effective system with better performance is the Building Energy Management System (BEMS). Although BEMS closely resembles BMS, it has more advanced functionalities that make it a better energy management tool for commercial buildings. For instance, BEMS can respond to a power reduction in the utility line by dimming lights in specific locations or shifting the power source from mains to a power backup system such as battery or electricity generator.

Despite the advanced functionalities of the traditional BEMS, it cannot support strategic decision-making due to a lack of predictive capabilities. Due to the shortcomings of these traditional building management technologies, the future of energy management in modern smart buildings is IoT-based systems.

While some of the existing buildings continue relying on BMS and BEMS for energy management, most facility managers have opted to take advantage of IoT to achieve better energy savings and operational control.

IoT-Enabled BMS

The emergence of the IoT has revolutionized the way energy management systems are applied in modern buildings. To achieve maximum energy savings and optimize operations in existing buildings running on BMS, facility managers can use a combination of IoT and BMS.

Integration of IoT sensors with an existing BMS can be actualized using an Application Enablement Platform (AEP). With an AEP, an array of IoT sensors and other devices can be interconnected to gather and provide disparate data to the user. AEP also allows the integration of IoT with standard communication protocols for BMS, including BACnet and Modbus.

Since AEP provides a common destination for BMS data and IoT data, it can address issues related to legacy BMS. This is achieved by providing the data analytics capability, which is a critical requirement for smart buildings.

What are Smart Building Systems? *(continued)*

BMS Upgrade with IoT vs. Replacement

For buildings with existing BMS or BEMS, a choice has to be made on whether to replace or upgrade the traditional systems with IoT. While capital cost may play an important role in decision making, it is important to take into account the long-term benefits based on the following factors:

- System efficiency, scalability, interoperability, and future flexibility
- Continuity of data and salvaging existing investments
- Maintenance and operating costs
- Data access and centralization
- Data security and access management
- Uptime, management requirements, and redundancy

To achieve long-term benefits in terms of savings and efficiency, BMS replacement with IoT is recommended. However, if capital cost is selected as the guiding criterion, BMS upgrade with IoT can suffice.

The Importance of Smart Buildings in the Modern Economy

Smart buildings are energy-efficient structures with reduced energy consumption and low greenhouse gas emissions. By improving worker productivity and saving substantial energy costs, smart buildings contribute to economic growth and environmental sustainability.

Enhancing Environmental Sustainability

According to the Organization for Economic Co-operation and Development (OECD), buildings account for up to 28% of the total greenhouse gas (GHG) emissions generated in the energy sector globally. Between 2000 and 2017 alone, global GHG emissions from buildings increased by 25%.

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With the ever-increasing energy consumption in the building sector, environmental sustainability remains a significant challenge.

The Paris Agreement, a climate change treaty signed by 196 countries in 2015, has developed policies and frameworks to guide all signatories towards environmental sustainability. The landmark agreement is an ambitious socioeconomic transformation initiative by member nations to lower GHG emissions by 30% before 2030. The treaty received a significant boost in January 2021, after the United States rejoined following the election of President Joe Biden.

As the world seeks to achieve environmental sustainability by reducing GHG emissions, there have been relentless efforts by governments to embrace green building technology. Also, it is worth noting that the adoption of smart building technologies can be a major step towards energy saving and overall reduction of GHG emissions in line with the recommendations of the Paris Agreement.

A combination of green building concepts and smart building technologies can yield highly efficient, comfortable, safe, and sustainable buildings that consume less energy.

Improving Working Conditions

Building digitization provides optimum working conditions for workers and enables efficient management of building operations. By availing usage data to the facility managers and emergency alerts to occupants, smart buildings enhance the following:

- **Prioritization of services and features:** Since facility managers can tell which rooms, floors, or facilities are not in use, they can reassess the building services for those areas and make the necessary adjustments to prevent wastage. Also, it is possible to identify less utilized spaces and decide whether to rearrange or rent them out.
- **Security and privacy control:** Occupants of a smart building enjoy higher security levels compared to those in conventional buildings. It is possible to lock doors automatically, restrict access to certain building areas and protect sensitive data from unauthorized

The Importance of Smart Buildings in the Modern Economy *(continued)*

persons. Security levels are further beefed up by smart security systems such as gunshot detection and Artificial Intelligence (AI) threat detection.

- **Safety monitoring and control:** Smart buildings are equipped with automated safety systems such as smoke detection, automatic firefighting, power surge protection, and alarms. These systems improve safety through prevention or by providing early emergency notifications.
- **Property management:** Using the intelligent systems installed in smart buildings, facility managers can effectively monitor and manage critical building functions ranging from HVAC, electricity, and sanitation.

How are Smart Buildings changing Building Design and Construction?

Digital transformation in the building sector has affected the design and construction of modern buildings significantly. For instance, provisions for automated equipment need to be provided at the architectural design stage. Other smart building features such as envelopes, green roofs, and windows also have to be considered at the design stage.

With the current advancements in 3D architectural modeling and rendering, it is possible to develop a smart building model, examine its behavior and make the necessary design adjustments before construction. Also, engineers can apply Computational Fluid Dynamics (CFD) to test and determine the optimum operating conditions of HVAC, drainage and sewerage, plumbing, and firefighting systems.

At the construction stage, site teams need to adopt new construction methods to achieve the required design specifications. The construction process may also be characterized by new construction materials, new, unusual features, and provisions for installing intelligent systems and their accessories.

Smart Buildings Case Studies

As technology advances every year, smart buildings have become part of the global innovation trends. The IoT defines the future of smart buildings, from offices to hotels and factories. Examples of smart buildings include:

- MGM Resorts International in Las Vegas, USA
- Las Vegas Sands Corporation in Nevada, USA
- The EDGE green office building in the Netherlands
- Grand Hyatt hotel in San Francisco, USA

This section explores the advantages of smart buildings based on a few selected case studies.

MGM Resorts International

MGM, a smart resort based in Las Vegas, is a member of the Better Buildings Alliance (BBA) committee of the U.S. Department of Energy (DOE). BBA is responsible for all activities of the Better Building Initiative (BBI) that has been in operation since 2011.

In 2016, MGM upgraded and automated their lighting in more than 49,000 parking spaces available for their customers. They installed 1600 LED lighting fixtures connected to an intelligent lighting control system. This resulted in a substantial annual energy saving of 18 million kWh – equivalent to more than $2.1 million.

As reported by BBA, the integration of smart technologies at MGM contributed to a cumulative energy saving of 420 million kWh for a period of 5 years. Also, the resort increased its recycling rate by up to 355% within the same period.

By installing an advanced energy monitoring system at the main energy plant in Aria, the resort managed to achieve a higher plant efficiency and better process control. The intelligent system controls heating and cooling processes to optimize plant performance. The heat dissipated from the plant provides hot water to other hotel facilities such as pools.

Other qualitative benefits accrued from smart building and green technologies at MGM include:

- Improved operational efficiency
- Better resource management
- Improved customer experience
- Higher worker productivity
- Enhanced environmental sustainability

Digitization Challenges

MGM faced a myriad of challenges in its journey to building digitization. With multiple smart Building Automation Systems (BAS) installed across different facilities, data collection became a bottleneck. As a result, maintaining the 24-hour operation became complicated.

Smart Buildings Case Studies *(continued)*

Retro-commissioning (RCx) resulted in significant improvements in operational efficiency and energy savings. However, the following two critical challenges could not be addressed through RCx.

- Degradation of operational improvements over time
- Difficulties scaling the RCx across a huge portfolio

To address the challenges, the implementation of smart building analytics was proposed to augment the RCx. Also, Fault Detection and Diagnostics (FDD) software were installed to provide the data analytics capability. FDD acts as an Energy Management Information System (EMIS), which receives and analyzes data from BAS. The installation was carried out in nine properties with a total floor area of 39 million square feet.

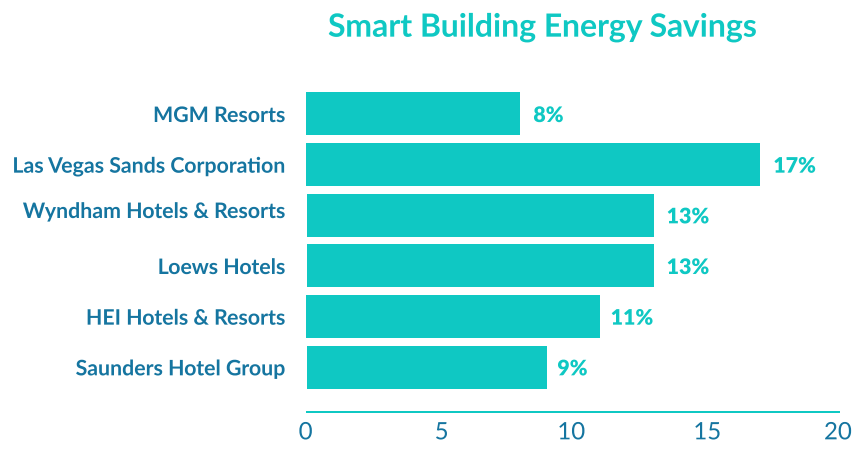
The addition of building analytics resulted in a significant reduction in energy wastage across facilities. Besides changing how energy is managed at MGM, analytics provided accurate data, which allowed operators to make timely actions whenever necessary.

Owing to the success of building analytics, further FDD implementation was carried out in the central plant. The aim was to benchmark the efficiency of chillers and optimize the operation of the water-side economizer. The analytics could also detect any system controls that are in the "Override" state.

The smart systems help the management remain proactive by tracking portfolio performance and taking the right actions whenever an operational problem occurs.

Comparison with other High-Performing Smart Buildings

According to BBA, there were other smart buildings in the U.S. hospitality industry with higher energy savings. The chart below shows the percentage of annual energy savings achieved by each smart building due to IoT integration. Sands Corporation registered a high annual energy saving percentage at 17%.



Smart Buildings Case Studies *(continued)*

The EDGE

The EDGE is a smart office building located in Amsterdam, Netherlands, with a total floor area of 40,000 square meters and a high BREEAM-NL sustainability rating of 98%.

The EDGE is a modern building designed and constructed following the IoT and green building practices principles. The IoT powers all aspects of the building resulting in improved energy management, security, safety, and occupant comfort.

The architectural design of the EDGE goes beyond conventional practices to address common challenges faced in traditional office buildings. It features flexible office spaces, open floor plans, a glass exterior, and a 15-floor atrium surrounded by multiple balconies and illuminated with natural night.

Installed Smart Technologies and their Benefits

The EDGE is equipped with modern integrated energy and facility management solutions connected to a single network backbone. This includes extensive IT infrastructure, power monitoring systems, networked control devices, purpose-built software tools, among others.

The EDGE has 30,000 IoT sensors installed to control the LED lighting system in different areas of the building, including technical rooms and ceilings across all floors. Other field IoT devices installed in the building to support BEMS include actuators, valves, and intelligent energy meters.

- **Improved security:** IoT sensors collect security-related data from the building and transmit it to the security management system. The processed security information is then relayed to the occupants through an autonomous security robot. The robot also patrols the building at night to gather security information and provide relevant insights to the security staff.
- **Comfort, productivity, and safety:** To create a comfortable and highly conducive environment, IoT sensors collect space data and share it through a dedicated app. Using this app, workers can easily navigate the building, find colleagues, services, and facilities such as gyms, locate unoccupied office desks, and get access to restricted areas when necessary. The IoT software interface also allows workers to adjust working space conditions such as temperature to maximize comfort. Such a flexible and strictly controlled environment improves comfort and increases worker productivity and safety levels.

Green Energy Generation and Energy Savings

The building produces green energy from a photovoltaic (PV) system to power all building operations. The PV system comprises a staggering 65,000 square feet of solar panels spread across roofs and facades of the building. Some of the solar panels are also installed at the neighboring University of Amsterdam to harvest more energy.

Smart Buildings Case Studies *(continued)*

The Building Research Establishment (BRE) asserts that the EDGE is a neutral energy building and a highly energy-efficient building. According to BRE, the building boasts a reduction of up to 70% in electricity consumption than other conventional office buildings of the same class.

Advanced Lighting Control for Intelligent Buildings – Field Study

An Advanced Lighting Control (ALC) involves using IoT sensors to control and manage lighting in a building to optimize occupant experience and save energy. ALC is actualized based on a set of control strategies:

- **Demand response:** Lights are controlled based on the power demand in the local utility grid.
- **Daylight harvesting:** Adjusts the lighting in specific building spaces depending on the available natural light levels.
- **Scheduling:** This involves turning lights on and off based on a predetermined schedule.
- **Personalized control:** This strategy allows occupants to adjust lighting within their working areas to meet their personal needs.
- **Occupancy-based control:** Occupancy sensors are used to control lighting in the building space. Lights are turned off when the space is not occupied and vice-versa.

Lighting Energy Savings – Selected Buildings

To save maximum energy in building lighting, a combination of energy-efficient lighting fixtures such as LEDs and advanced control using IoT is required. According to the U.S. Department of Energy (DOE), the adoption of LED lighting alone across all sectors in the U.S. can result in a 5% reduction in the total U.S. energy budget. With IoT integration, building lighting can be further optimized to save more energy.

Data gathered from the DOE research findings on the performance of ALC across selected buildings in the U.S. shows that an office building can save up to 70% of lighting energy when ALC is integrated.

The buildings were retrofitted by replacing fluorescent lamps with LED lighting fixtures. Also, an ALC system was installed in each of the buildings, and the energy savings were compared. The data shows that changing the lighting fixtures from fluorescent lamps to LED saves lighting energy by between 29% and 50%. When the control system is integrated, the energy savings are increased further to between 62% and 70%.

U.S. Department of Energy research shows that an office building can **save up to 70%** of lighting energy when advanced lighting control (ALC) is integrated.

Smart Building Systems: The Path to Implementation

When an opportunity to save money arises, nobody wants to be left behind. Furthermore, every business aims to achieve maximum efficiency and productivity. Also, when safety is prioritized in a built environment, the risk of injuries and damage to property is minimized. This is why smart building systems are the present and the future.

How to Plan for IoT Integration into New or Existing Buildings

When planning to integrate IoT for improved building energy management and other benefits, there are factors to consider and best practices to be followed. Implementing proven IoT integration methods ensure high building performance and enhance gradual digital transformation to a fully smart building.

- **Employ a modular approach:** To successfully revamp the building systems with IoT, it is good to reduce the complexity by starting small. Different building needs should be identified, all aspects mapped, and a pilot project carried out on the key aspects such as lighting or HVAC. It is also good to keep in mind that in the end, each subsystem needs to seamlessly communicate with other building systems and subsystems. Therefore, ensuring end-end configurability with other systems is recommended.

- **Define the key building requirements:** By identifying key measurable objectives to be achieved, building owners or managers can develop a solid IoT integration plan. For this to be effective, the plan should be created at the beginning of the project. The requirements may range from software, hardware, and infrastructure to safety and security.

- **Adopt an all-inclusive approach:** To develop a reliable IoT integration master plan, all stakeholders must be involved starting with operations, security, finance, and maintenance personnel. The stakeholders can participate by defining sustainability requirements, operational goals, and productivity targets.

- **Evaluate the return on investment (ROI):** Based on the defined requirements, it is possible to assess the return on investment and develop an effective strategy. This can start with the pilot project and later expanded to the entire IoT scope.

- **Collaborate with reliable vendors or contractors:** Select a qualified vendor or contractor based on factors such as expertise, cost, service accessibility, and organizational goals. Some IoT companies have their own IoT brands for smart buildings and experienced teams of experts. Such companies can deliver IoT services with maximum quality, efficiency, and reliability.

Smart Building Systems: The Path to Implementation *(continued)*

Critical Factors to Consider during IoT Design for a Smart Building

A successful IoT integration into the energy management system of a smart building requires good planning and adoption of a proactive approach by the designer.

- **Interoperability and integration with other systems:** a holistic approach should be implemented to ensure maximum efficiency of the IoT energy management system. The multiple devices selected for IoT integration should have essential attributes such as adaptability and scalability. They should also be able to integrate perfectly with other systems and operate as a single unit. Due to new advancements in IoT technologies used in smart buildings, future expansion provisions should be provided.

- **Privacy and cybersecurity:** IoT increases the rate and volume of data exchange between devices and systems through a wireless backbone network, which introduces the risk of data breaches, unintended leaks, and hacking. The IoT Institute has developed IoT data protection frameworks for implementing smart building systems to address cybersecurity and data privacy issues. These privacy frameworks should be followed starting from the design stage.

Upgrading Legacy Building Management Systems with IoT?

A complete replacement of the legacy BMS with new IoT-based technologies can be a challenge because the capital expenditure involved in purchasing and installing these legacy systems is relatively huge. However, owners of existing buildings equipped with legacy BMS need not worry. A solution that makes economic sense is to add IoT functionalities to the BMS without replacing it. This can be achieved through the use of AEP tools.

Smart Building Systems are Vital Moving Forward

Based on the discussed benefits of smart building systems, it can be concluded the future of commercial buildings includes IoT integration. Using intelligent devices, systems and tools such as analytics, building owners can unlock value by improving efficiency and saving energy.

Maximizing IoT Data Analytics

Once the IoT has been integrated into the BEMS, the operators and facility managers have an opportunity to start using data analytics and other tools to improve their decision-making. However, while IoT energy management systems have the ability to aggregate, analyze, filter, and interpret vast volumes of data, facility managers and operators can only maximize the benefits if they know how to utilize the generated insights to make the right decisions.

To make such data-driven smart decisions, the personnel should be trained well by the experts from the contracted IoT Company. Usually, smart building companies with their own IoT brands have dedicated IoT trainers for this purpose.

Unlocking Value with IoT Technologies

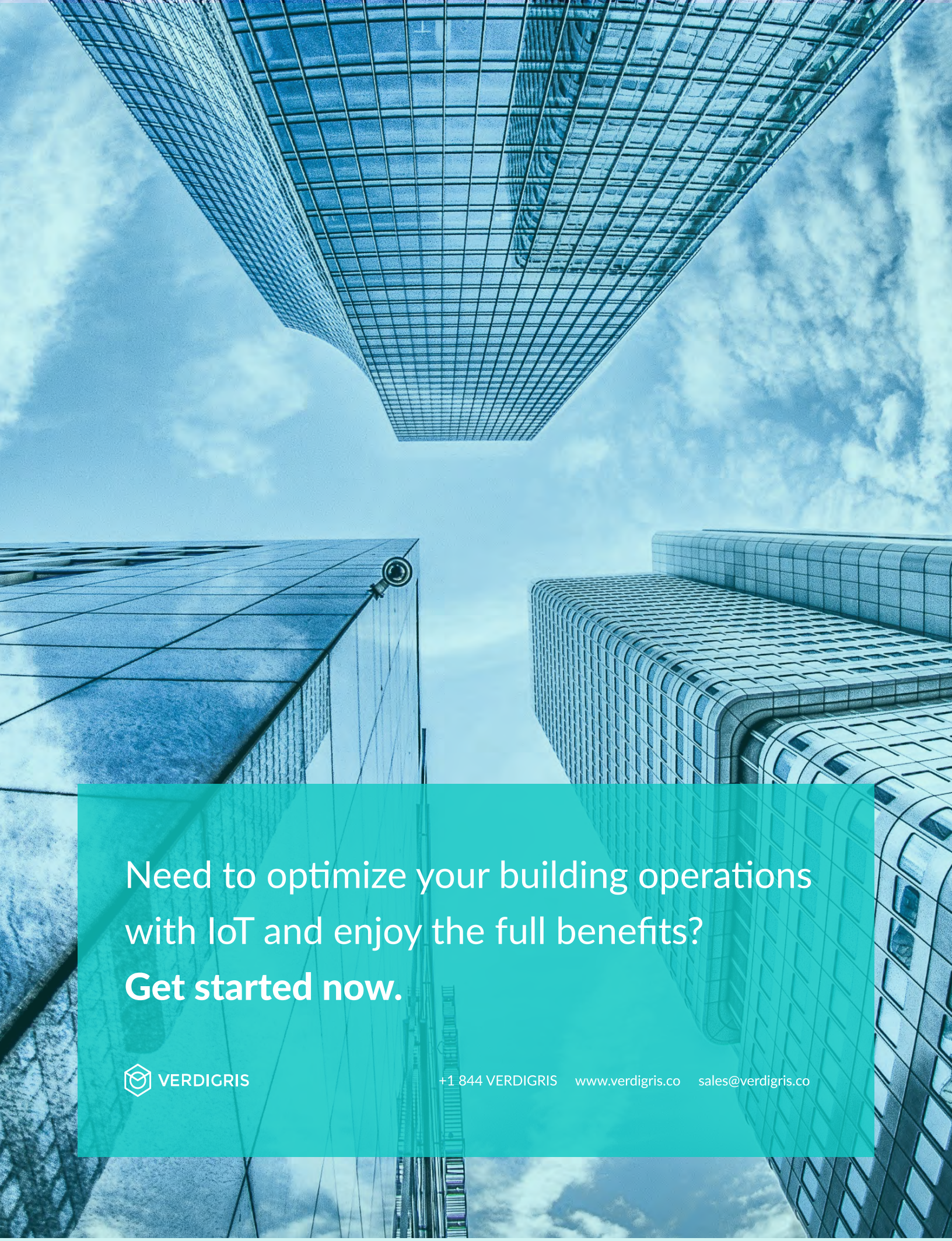
IoT technologies in building energy management are the key to reduced energy cost and improved operational efficiency. Studies show that IoT technologies can save up to 38 cents per square foot of floor area. Since many commercial buildings have large floor areas to the tune of thousands of square feet, this can translate to millions of dollars in cost savings.

An optimized working environment improves comfort and increases worker productivity. This translates to increased revenue and business profitability. When implemented in the manufacturing sector, IoT can increase process efficiency, minimize losses and errors, increase safety, and significantly improve products' quality. Building digitization promotes environmental sustainability by reducing GHG emissions and reducing energy demand.

Smart building systems are the future. When it comes to saving money and improving working conditions, everyone wants to be on board. It is important to note that you can experiment with IoT technologies and get value quickly and cost-effectively with IoT technologies. For instance, it is possible to digitize your building portfolio within two weeks for less than $10k. Some of the companies that have enjoyed measurable benefits with IoT integration include:

- ARM Holdings: Transformation of passive buildings
- Grand Hyatt: Implementation of adaptive automation technology
- JLL: Uncovering energy inefficiencies and cost savings
- Katerra: Improved energy management using IoT energy meters
- S&P Global Factory: Building monitoring and energy storage control

Need to optimize your building operations with IoT and enjoy the full benefits? **Get started now**



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