Energy-Smart Buildings

Demonstrating how information technology can cut energy use and costs of real estate portfolios

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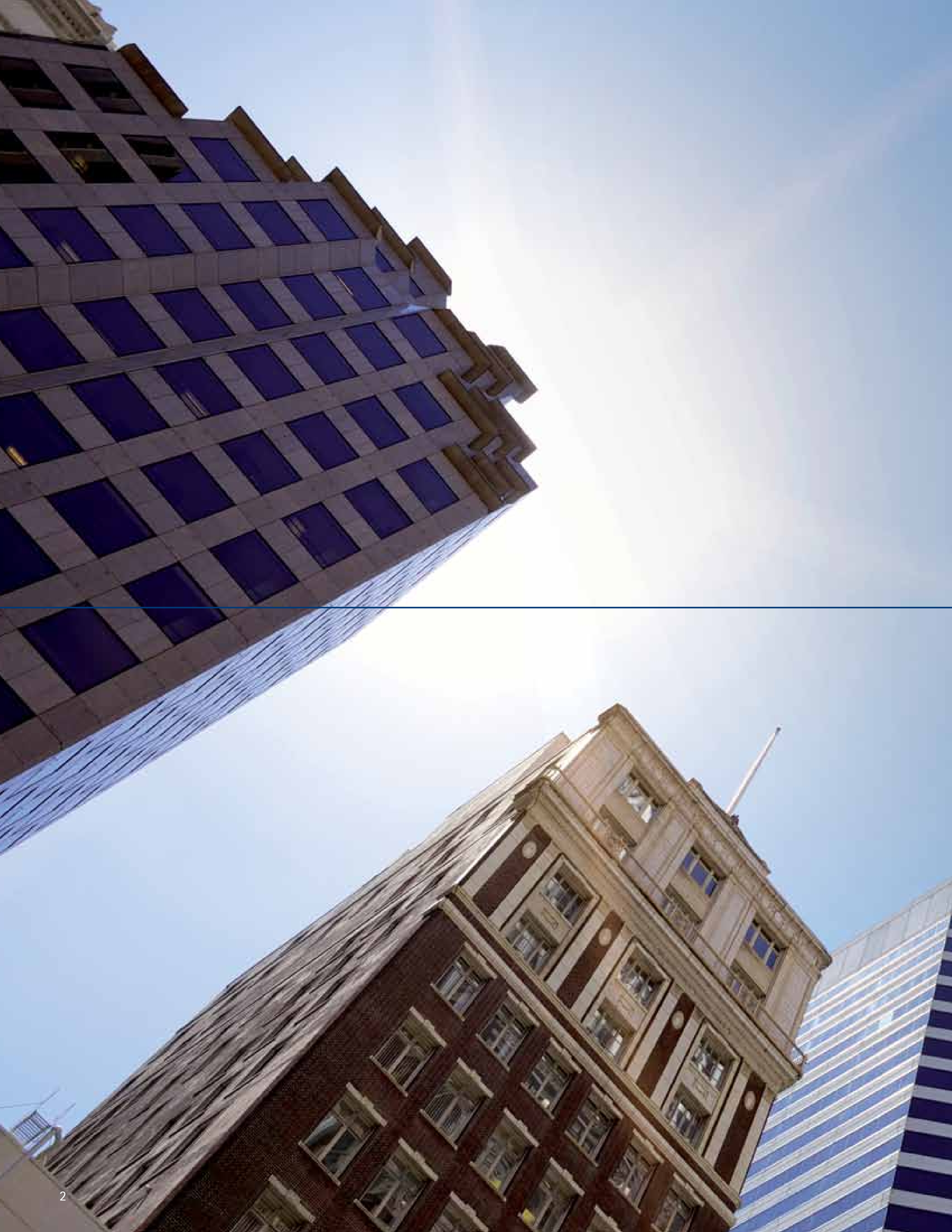

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Executive Summary

Information Technology (IT) enables unprecedented efficiencies for businesses. Powerful analytics are helping firms better manage supply chains, improve resource allocation, detect fraud and optimize many core business functions. The real estate portfolio is no exception. Worldwide, buildings account for about 40 percent of total energy consumption and contribute a corresponding percentage to overall carbon emissions. Buildings used by businesses and public service organizations make up a large part of this footprint, whether they are office buildings, retail stores, hotels, schools or hospitals. In the US alone, businesses spend about US$100 billion on energy for their offices every year. In Asia, economic growth and a gradual shift toward service-based economies will expand the need for commercial buildings significantly over the coming years.

This provides scope for substantial cost savings. For the US, estimates predict that smarter buildings could save US$20-25 billion in annual energy costs. This opportunity is largely untapped today, as many building owners and operators are not yet aware of how data-driven optimizations can reduce energy consumption. Buildings may be equipped with hundreds of sensors and controls, but companies are leaving money on the table if they do not use this data more holistically to optimize their infrastructure. By applying analytics to make buildings smart (or energy-smart, to be more specific), companies can save billions and significantly reduce environmental impact.

This report, authored in collaboration between Microsoft, Accenture and the Lawrence Berkeley National Laboratory, examines how building owners, operators and occupants can achieve significant energy and cost savings through the use of smart building solutions. It is based on insights from a detailed case study of a smart building pilot program being conducted by Microsoft at its corporate headquarters' campus.

What was done?

The pilot program by Microsoft's Real Estate & Facilities organization evaluated smart building applications from three vendors across 13 buildings within the company's main 118-building campus. In essence, these applications added an analytical layer on top of existing building management systems, without the need to replace existing infrastructure.

This new layer enables Microsoft to aggregate and analyze its building data to generate actionable insights that save energy and cut costs. In its initial stage, the program addresses energy consumption and cost in three specific ways:

• **Fault detection and diagnosis** to enable timely and targeted interventions in cases of faulty or under-performing building equipment.

• **Alarm management** to prioritize the many notifications generated by existing building systems and point engineers to the most impactful issues.

• **Energy management** through systematic tracking and optimization of building energy consumption and performance over time, while changing the behavior of building occupants with visual dashboards and benchmarks.

What was achieved?

Microsoft's experience thus far demonstrates that a smart building solution can be established with an upfront investment of less than 10 percent of annual energy expenditure, with an expected payback period of less than two years.[1] By collecting and analyzing millions of data points (samples) per day, the company has been able to embark on multiple improvements that are reshaping the way its buildings are managed.

Microsoft's building engineers have become far more productive: instead of "walking around" to find issues, they're now "walking to" the problems that have the greatest impact on cost or comfort. By itself, the ability to continuously identify issues and optimize the performance of building equipment is expected to deliver annual savings of more than one million dollars. Furthermore, as building engineers can analyze data collected over time and occupants become more aware of individual energy use, Microsoft hopes to save several million dollars by optimizing base load (from building systems directly controlled by the building engineers) and by reducing plug load (from devices used by occupants) across its building portfolio.

How can others replicate this?

Microsoft's pilot program demonstrates how corporate real estate organizations can collaborate successfully with IT, putting smart building technology to use in cutting costs and securing environmental benefits. Its experience has helped define a set of key design principles that can be used in any such rollout. These are outlined in more detail in this report, in summary they include:

• **Identify, collect and aggregate relevant data**: This involves setting up automated aggregation of building, weather, utility and organizational data from building systems and other sources to feed into the smart building solution. Cloud computing, combined with on-site building management technology, can provide a powerful platform to gather, store, exchange, and process diverse datasets in a secure and scalable way.

• **Employ industry-leading analytics to identify savings**: The core of the smart building solution is the analytics engine consisting of rules and algorithms that identify and prioritize interventions to maximize savings. Vendors differ in their approaches and capabilities and should thus be evaluated thoroughly.

• **Present results in a consumable and actionable form**: The user experience needs to strike the right balance between ease of use and flexibility. Solutions need to improve an engineer's day-to-day productivity with better real-time information and access to data, while also providing a strong toolset for deeper analysis.

• **Centralize monitoring operations**: A centralized operations center can effectively monitor building conditions across a campus or multi-site portfolio and communicate directly with building engineers.

• **Engage the organization**: Greater awareness of energy use and benchmarks, displayed via dashboards on the intranet or in hallways, can encourage employees and business leaders to save energy, reducing overall demand.

• **Avoid disruptive change**: Existing building management systems do not need to be replaced. By deploying an analytics layer on top of these systems, prior investments can be significantly enhanced with minimal capital expenditure. Engineers can adopt new tools while still working directly with more familiar systems. Strong cross-organizational project management and a tailored change management approach are key to success.

2
Introduction: The case for smart buildings

2.1 Building efficiency meets information technology

Buildings are the largest contributor to global carbon emissions, accounting for about 40 percent of the world's total carbon footprint.[2] In developed countries, commercial buildings alone represent close to 20 percent, about half of the total.[3] Commercial buildings are also costly. After salaries, buildings are one of the biggest operational expenses for organizations. Energy plays a significant part in this.[4] A more efficient building portfolio can improve the value of real estate assets, help the bottom line, cut emissions, and bolster the corporate image.

Executives have different choices to reduce the energy consumption of their building portfolio. Buildings can be designed more efficiently at the outset, but these opportunities are obviously limited. For existing infrastructure, the primary focus has usually been on retrofitting projects, which are often capital-intensive and disruptive to operations. But using software to ensure infrastructure runs more efficiently requires minimal capital investment and results in little or no disruption for occupants. From an economic standpoint, this should make it the preferred starting point for increased energy efficiency in a real estate portfolio.

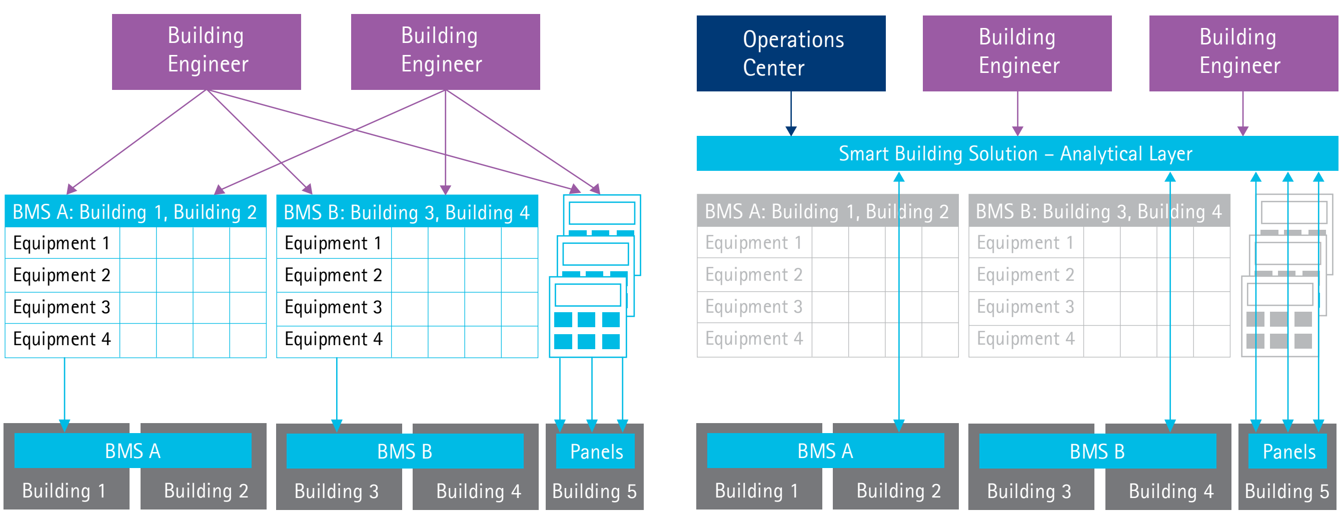
Analytics software can help detect and address numerous sources of waste, such as:

- HVAC (heating, ventilation, and air conditioning) equipment that is simultaneously heating and cooling a given space due to a failed sensor or other fault.
- Technicians dealing with low priority or false alerts about building anomalies, while the notification system fails to highlight more impactful issues.
- Default configurations for all systems and pieces of equipment, meaning they run at suboptimal set points and are rarely updated after initial configuration.
- Lack of visibility and attention to energy waste on the part of occupants and building engineers.
- HVAC and lighting systems running at full capacity during periods when buildings are largely unoccupied.

In recent decades, most commercial buildings have been equipped with an increasing number of sensors, controls and other devices. Modern buildings have built-in control systems, referred to as building management systems (BMS) or building automation systems (BAS), allowing building engineers, facility managers and real estate management to control their infrastructure.

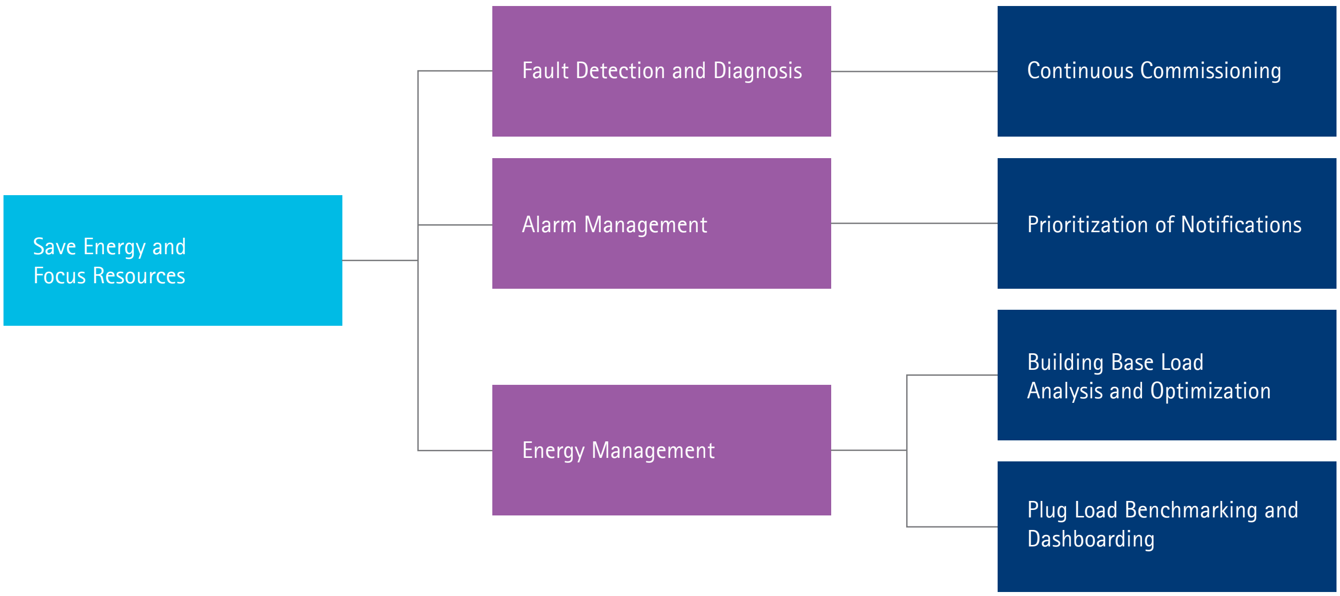
In this model, disparate building management systems and control panels are the access points to observe and manage building equipment, as illustrated in Figure 1 (left side). By introducing a smart building solution that provides an additional analytics layer (right side), a single data repository for all buildings is created and engineers are equipped with a powerful toolset to analyze data. In addition, this provides a foundation for tighter integration with a smart utility grid that manages energy supply and demand dynamically on a local or regional level.

Figure 1: Building management: traditional approach (left) vs. smart building approach (right)



* BMS = Building Management System

Figure 2: Basic smart building program components



2.2 How analytics can cut energy waste

• **Fault detection and diagnosis**: Through sophisticated fault detection and diagnosis rules, issues with building equipment across an entire real estate portfolio can be automatically identified and prioritized for building engineers. Conducting equipment maintenance on a continuous basis – so-called continuous commissioning – avoids waste and dramatically improves resource allocation. Engineers do not have to walk around looking for issues and money is spent where it is most needed. This also frees up engineers' time to address issues with smaller subsystems, which can add up to a large potential savings opportunity.

• **Alarm management**: By prioritizing and structuring the numerous notifications generated by building systems, a smart building solution focuses engineers' attention on the most critical events. They can concentrate on urgent and impactful interventions from the perspective of occupant comfort, energy consumption, cost and business impact.

• **Energy management**: Smart building solutions are able to centralize and correlate data from building systems, corporate data warehouses, and external sources, such as utilities and weather data feeds. Through analytics tools, building engineers can find anomalies and manage energy use holistically. Likewise, employees can be encouraged to save energy through information sharing in the form of dashboards, as well as energy benchmarks that create internal competition.

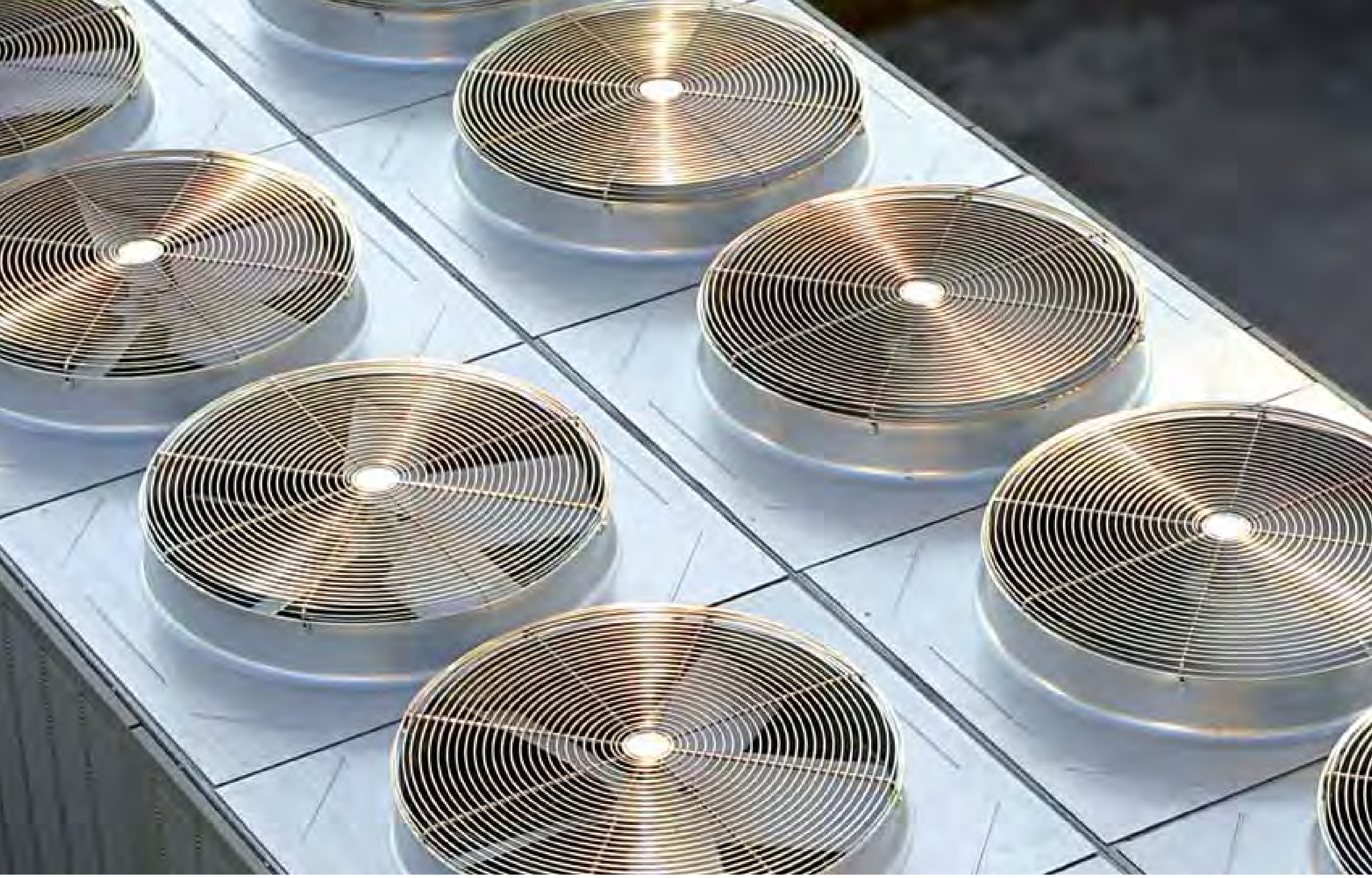
Microsoft's case study described in this report highlights the improvements made from each of these.

2.3 Successes in the corporate environment so far

Smart building programs are emerging as an effective solution for companies to save energy. Some early adopters have successfully transitioned to continuous commissioning, where building maintenance is conducted whenever the analytics engine detects a fault, rather than on recurring multiple-year cycles that rely on spot checks.

One example, featured in a study by the Lawrence Berkeley National Laboratory, comes from Sysco, a US$37bn food services company with over 140 facilities across North America. During a three-year energy efficiency program launched in 2005-06,[5] the company used analytics as a critical component in cutting its portfolio energy use by 28 percent—a monthly saving of 18 million kWh. Importantly, the first 18 percent savings came from low or no cost fixes, with only the latter 10 percent requiring capital investment and upgrades.

Another study by the Berkeley Lab[6] benchmarked the impact of continuous, or monitoring-based, commissioning across 24 buildings, showing average energy savings of 10 percent, with as much as 25 percent in some cases.



In its work with corporate clients, Accenture's smart buildings practice[7] observes that deployments usually pay back in 18-24 months, with energy savings in the 10-30 percent range. In markets where energy management is encouraged through policy incentives, the business case for deploying a smart building solution can be even better.

2.4 Inhibitors to smart building adoption

Despite such benefits, corporate uptake of smart building implementations has remained relatively limited to date. This is due to a range of challenges that have inhibited adoption. These typically include:

• **Connectivity and integration**: The most immediate challenge lies in accessing the data from the existing building management systems. This is made more difficult by the disparity of systems, varying ages of the assets and different communication protocols. Also, as the smart building solution may be hosted externally, a secure connection may need to be established, which can complicate the data exchange and delay the rollout. Data volumes can be significant and can conflict with available capacities for extraction, transfer, storage and processing.

• **Depth and breadth of available data**: A second issue is collecting data that is sufficiently granular, both in quality and quantity. Firms need to ensure that all relevant equipment is networked and sends regular updates (e.g. in five-minute increments). Contextual information is also needed. For example, air conditioning usage needs to be mapped against weather conditions to distinguish savings simply due to favorable weather from real improvements. Internal data, such as the number of occupants, is similarly needed for meaningful analysis.

• **Usability**: Usability challenges have been a common barrier to adoption, as many engineers have had limited exposure to advanced analytics tools. Some applications run the risk of overwhelming users with too many features, presented via a non-intuitive or unfamiliar user interface.

• **Organizational support and change management**: Implementing a smart building program can take several months and relies on many stakeholders. One particular challenge is the need for full commitment and close collaboration between all stakeholders – executives, building engineers, IT staff and external vendors. Engineers can be faced with conflicting workloads from both old and new responsibilities, which can inhibit uptake and delay payback periods.

• **Budget challenges**: Although the cost of implementing a smart building solution can be modest compared to the operating cost of the building, budgets are often tight and facilities teams may find it challenging to secure funds for such programs. Real estate leaders face the challenge of demonstrating both cost and sustainability benefits in their business case. Implementations for small portfolios are harder to justify as they lack economies of scale.

3
Case study: Smart buildings at Microsoft

3.1 Microsoft's sustainability objectives in the built environment

Data centers, employee travel and buildings are the top three contributors to Microsoft's overall carbon footprint, with buildings accounting for nearly 40 percent. As part of its efforts on environmental sustainability, the firm is addressing the first two by building energy-efficient data centers[8] and promoting the use of remote collaboration technology. To address the environmental impact of its building portfolio, Microsoft is investing in the deployment of new technologies to improve performance.[9] Beyond cutting its own emission footprint and reducing operational expense, Microsoft also sees its role in enabling the IT industry to develop smart building solutions. The underlying approach for the company is based on its fundamental belief that IT can help improve efficiency in all areas of energy and resource use.

As part of this, the firm's corporate headquarters in Redmond, Washington, is being used as a living lab to pilot several smart building solutions in parallel. Microsoft is working closely with vendors to test their solutions in a real-life setting, while applying a number of Microsoft's own products as part of the overall architecture. One key aim is to allow both vendors and Microsoft to improve their technologies for the broader market. Some highlights, outcomes and key learnings from this pilot approach are shared here.

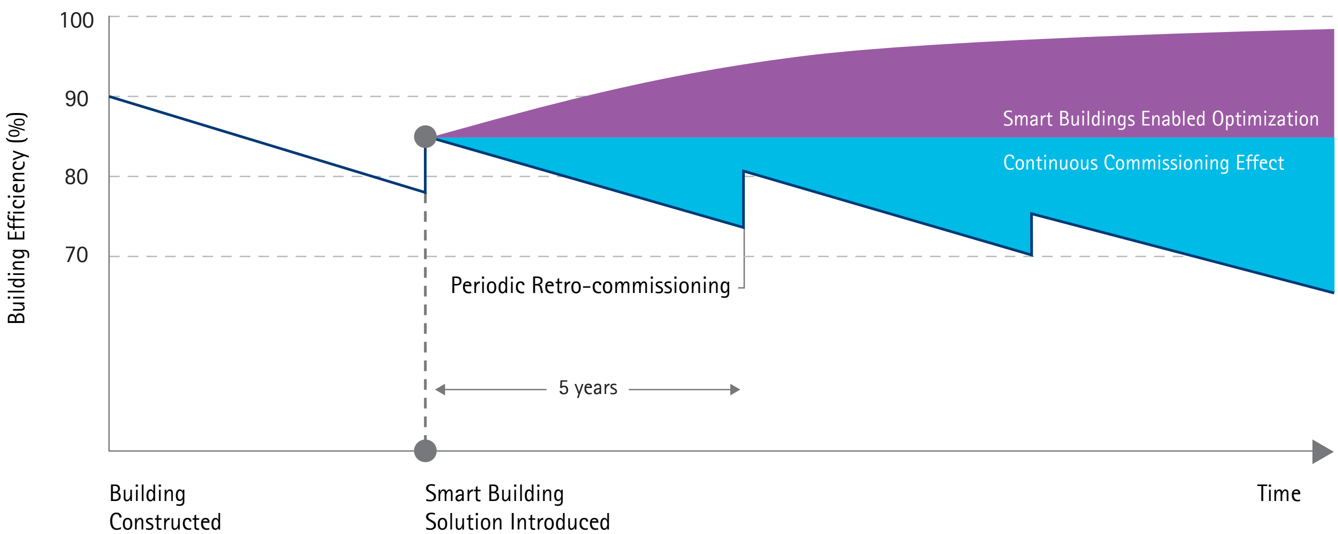
3.2 Introducing smart buildings at Microsoft

Microsoft's Real Estate and Facilities organization began its smart building program in 2009 with an initial analysis on how the company and its partners could use technology to significantly cut energy use in the built environment. In the first half of 2011, Microsoft rolled out smart building solutions from three different vendors at its corporate headquarters. The size of its main campus gives ample opportunity for simultaneously testing multiple solutions at scale. The campus consists of:

- 118 buildings with 14.9 million square feet (1.38 million m^2) of office space, approximately half of Microsoft's global real estate portfolio.
- 30,000 pieces of mechanical equipment to be maintained.
- 7 major building management systems used by engineers to manage equipment.
- Average daily consumption of 2 million kWh of energy, producing about 280,000 metric tons of carbon emissions annually.

In its initial pilot phase, Microsoft's smart building project focused on 13 buildings, representing 2.6 million square feet (about 240,000 m^2) of space—about the same floor area as the Empire State Building in New York. The age of the buildings varies from over twenty years old to almost new. For historic reasons, a variety of

Figure 3: Continuous commissioning benefits (illustrative)



building management systems are in place, resulting in building engineers having to deal with a multitude of disparate systems.

Introducing a smart building solution that provides an analytical layer above existing building management systems creates a consolidated view of granular energy and operational data across Microsoft's building portfolio. This allows buildings to be managed holistically through a unified interface, instead of many disjointed systems (as illustrated in Figure 1). This approach does not replace existing building management systems, but aggregates and complements them with an analytical layer.

3.3 Program components and impacts

In its initial phase, Microsoft's smart building program focuses on the three main areas described in Figure 2:

- Fault detection and diagnosis
- Alarm management
- Energy management

At the time this report was published, the three solutions being piloted had introduced new capabilities and produced a range of promising results, but their evaluation was still in progress. Microsoft intends to publish more detailed data in the future. Nevertheless, the preliminary findings already provide useful insights for anyone considering the implementation of a smart building solution.

It's worth noting that Microsoft's corporate headquarters benefits from very low utility rates and carbon intensity thanks to the abundant hydropower supply from the nearby Columbia River. Savings in cost and carbon emissions achievable by businesses in other geographic regions may be several multiples higher than those on Microsoft's main campus.

Fault detection and diagnosis

One of the biggest single impacts the program has facilitated is the ability to identify building faults and inefficiencies in real-time by analyzing the data streams extracted from building systems. Most importantly, the software is able to quantify wasted energy from each identified fault in terms of dollars per year.

Previously, issues were typically found through periodic spot checks, an approach known as retro-commissioning. But with 30,000 pieces of equipment on the campus, this is a major effort, even if limited to only large HVAC systems. Historically, the firm's engineers spot-checked about one-fifth of the campus each year, or about 25 buildings. On average, a building would thus operate for five years before it got inspected

Figure 4: Illustrative example of fault detection and diagnosis output (simplified)

Building	Bldg. Cluster	Equipment	Fault and Diagnosis	Priority	Estimated Savings*
Bldg 58	Cluster E	AHU - 012	Leaking chilled water value	High	$11,291
Bldg 58	Cluster E	AHU - 003	Damper position fault	High	$4,782
Bldg 53	Cluster E	VAV - 022	Over cooling	High	$2,235
Bldg 58	Cluster E	CHI - 002	Changes to set points	Medium	$895
- - -	- - -	- - -	- - -	- - -	- - -
Bldg 54	Cluster E	VAV - 006	Air temperature sensor failure	Low	-

* Estimated savings potential, expressed an annual cost of wasted energy if not fixed.

and tuned again, despite degrading equipment and potential changes in use and occupancy. The saw tooth line in Figure 3 illustrates how building efficiency declines between retro-commissioning efforts.

Through this prior approach, Microsoft typically achieved energy savings of about 4 million kWh each year, cutting costs by about US$250,000. Now, the introduction of automated fault detection and diagnosis provides an entirely new tool for Microsoft's building engineers, enabling them to identify and prioritize faults as they occur.

The smart building solution provides engineers with a table similar to the simplified example in Figure 4, where equipment faults are prioritized and the cost of wasted energy is automatically estimated. Engineers can quickly decide which faults to address in which order and can predict whether the savings justify the expense for labor and spare parts.

Fault detection also identifies issues that a conventional building management system would miss. One example encountered at Microsoft was an air handler's chilled water valve with a faulty control code issue. This meant that the valve was always 20 percent open, wasting several thousand dollars in energy. This issue was not easily visible before, but the analytics software was able to detect it immediately.

As its smart building program evolves in coming years, Microsoft intends to quantify the exact benefits of this continuous commissioning approach. It is already evident that engineers save significant time on inspections and can adopt a highly focused approach to maintaining equipment. The software also allows them to detect smaller faults that could have been missed in traditional inspections.

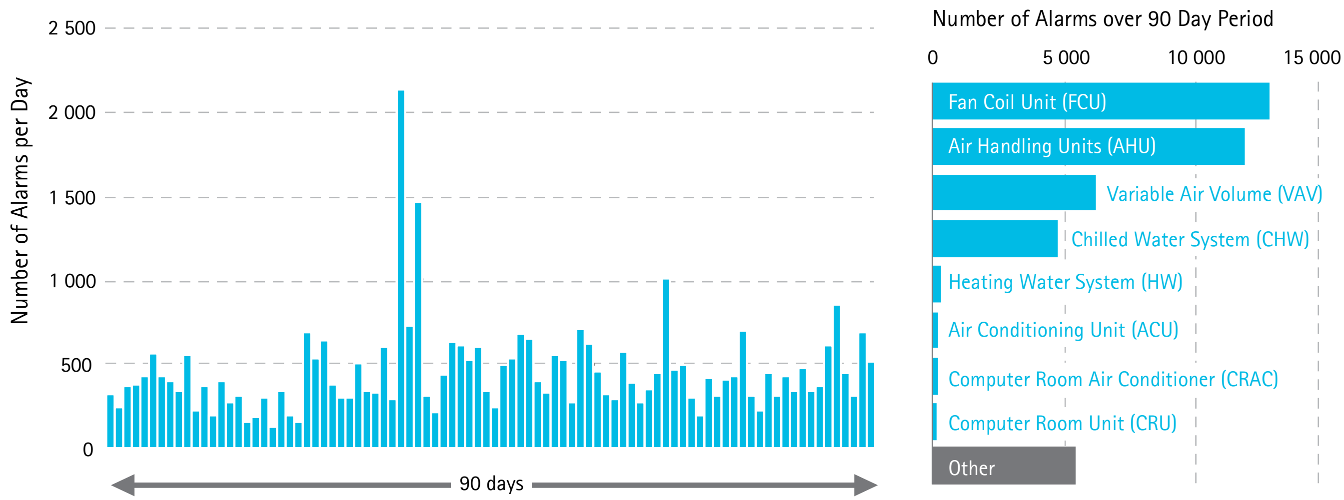
Microsoft expects that interventions equivalent to a full 5-year retro-commissioning cycle for the entire campus can now be accomplished in just one year. Annual energy cost savings from continuous commissioning enabled by automated fault detection alone may thus exceed US$1 million.

Alarm management

Microsoft's existing building management systems generate hundreds of alarms on a typical day, flooding engineers' email inboxes with automated notifications. Alarms range from major issues, such as a power outage, to insignificant messages, such as a notification that a self-test has started. Figure 5 shows sample statistics of Microsoft's building alarms over a 90-day period.

A key challenge is recognizing the importance of a given alarm, as well as correlations between messages from related events. Interpreting these requires deep knowledge of the building infrastructure and occupancy. Errors can lead to issues being missed and inadequate prioritization of interventions.

Figure 5: Alarms over 90-day period and distribution among equipment types



One example is when a casualty scenario occurs, a large-scale failure such as a recent substation fire in Redmond where several Microsoft buildings lost all or partial power. While recovering from such a scenario, alarm noise is excessive and prioritization is very difficult, with countless notification messages being generated by multiple systems trying to get back to a normal state. Without any automated grouping and prioritization of alarms, engineers may miss important alarms and inadvertently delay the response to an urgent issue.

Furthermore, analyzing thousands of alerts systematically to detect patterns over time is nearly impossible without a smart building solution. Here, analytics tools help engineers identify opportunities for efficiencies and cost savings.

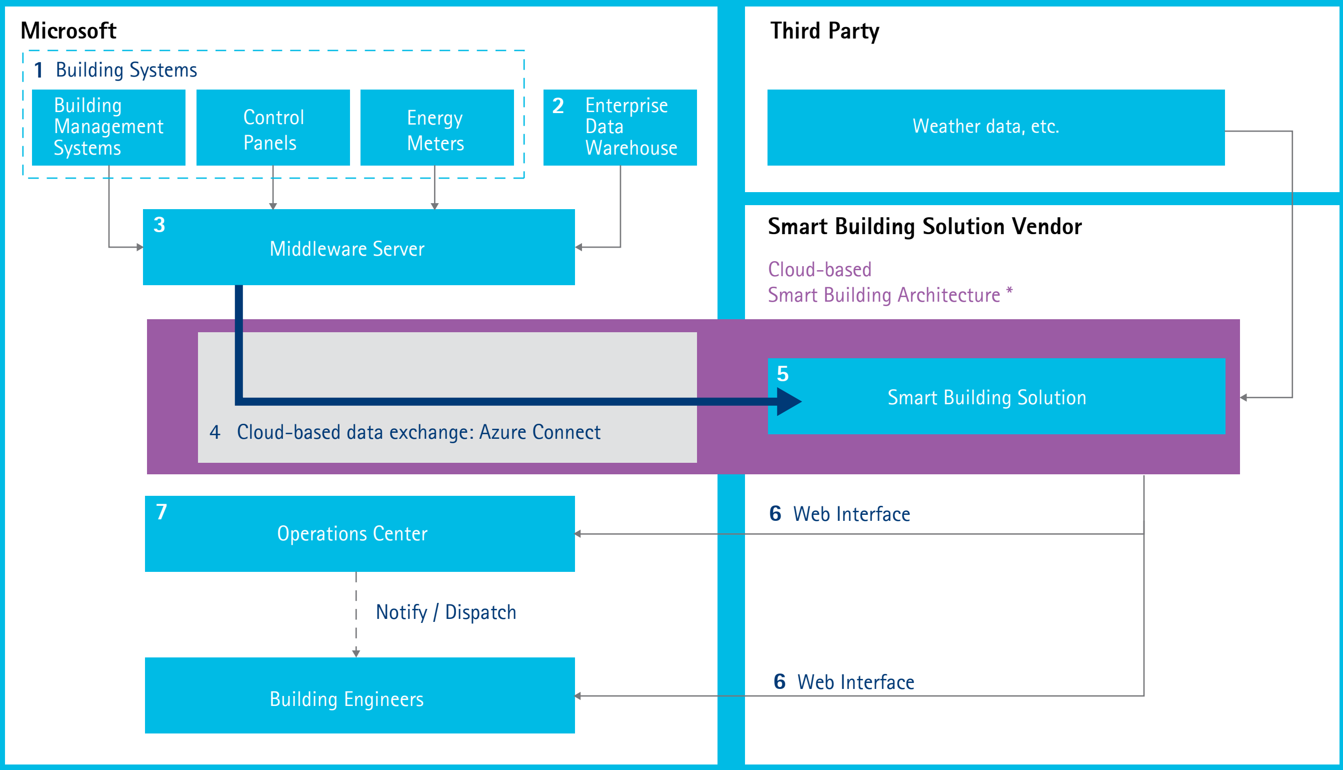
Energy management

The third strand in Microsoft's smart building rollout affects its ability to manage energy consumption more holistically. With the help of a smart building solution, engineers can optimize building base load, the power consumed by the major building systems, such as HVAC or lighting. Supported by analytics, they can tune set points and schedules, isolate wasteful equipment and address other opportunities by getting a much better understanding of energy use and trends across the building portfolio.

Microsoft anticipates that the smart building program will also help reduce the company's plug load – the electricity consumed by occupants' devices – which accounts for about the same amount of energy as the building base load. To encourage better habits, Microsoft is planning to publicize energy consumption data internally, using dashboards that track and compare how much energy is consumed over time. For example, kilowatt-hours consumed per employee as a performance indicator can be benchmarked across organizational units and observed over time. Energy costs can be accurately broken down by organizational unit to define ownership and create incentives for managers to save energy. Grassroots efforts can more effectively educate and motivate employees when accurate energy consumption data is readily available. For example, Microsoft's internal Sustainability Champion Program[10] is expected to reduce plug load by 3-5 percent and will be leveraging the smart building solutions automated reporting features.

The foundation for this is the consolidated repository of building and contextual data held by the smart building solution. Once Microsoft has collected several months of reliable data for energy management, measures to address both base load and plug load could contribute savings worth millions of dollars. This can be a significant factor in the overall business case for smart buildings.

Figure 6: Microsoft's smart building architecture



* The use of cloud-based architecture varies between the three vendors in Microsoft's pilot implementation, but most of the elements shown in this high-level view apply to all of them.

3.4 Microsoft's smart building architecture: a technical overview

The pilot program's architecture can be broken down as follows:

1. Equipment level data is collected and either sent directly from the control panel or from the BMS servers to a middleware server. For some buildings, this is done over an open protocol (BACnet). For most buildings, a protocol conversion was necessary, with additional scripting to extract the data.[11] Energy meters provide sub-metered electricity consumption data that complements the utility data (see point 5 below).

2. Microsoft's internal enterprise data warehouse provides a feed of contextual information, such as building type and headcount,[12] to the middleware server.

3. The middleware server acts as an aggregator for all on-site data. It also houses an Azure Connect endpoint to transmit the data to the relevant vendor application, hosted off-site.[13]

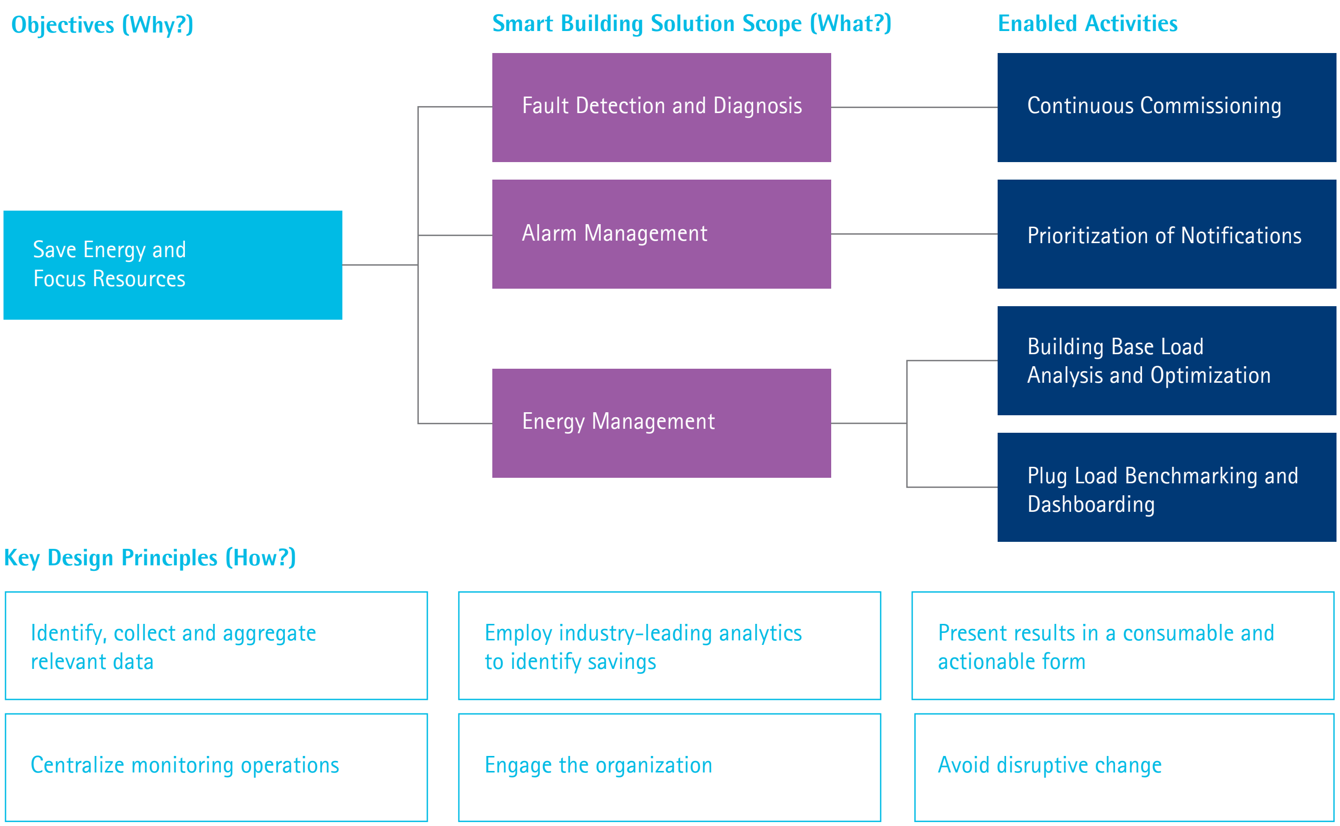
4. The Azure Connect service provides secure data transfer over the cloud. It is designed for applications that rely on a hybrid environment of both cloud-based and on-premise servers.

5. The vendor's application collects data from Microsoft and aggregates it with third party weather data and building-level electricity consumption data provided by the utility. Analytics are run by the vendor's software, applying the rules engine and algorithms against the collected data from multiple sources.

6. The output is shared with Microsoft's building engineers via an interactive graphical interface accessible via the web. Single sign-on through Active Directory Federation Services simplifies access to the externally hosted solutions. Future plans include mobile devices as endpoints.

7. In the newly established operations center, a team reviews the faults and alarms that have been identified and notifies engineers accordingly. The center is designed to support locations beyond Microsoft's main campus.

Figure 7: Smart building objectives, scope and key design principles



3.5 Key design principles of the smart buildings architecture

As outlined in section 2.4, introducing a smart building solution does not come without obstacles. In its approach, Microsoft has emphasized six design principles to overcome the most common barriers, while maximizing the program's impact. These principles underpin the smart building solution and its objectives.

Identify, collect and aggregate relevant data

The most important data in smart building architecture is collected either from existing building management systems or directly from installed control panels and energy meters. But to put this data into context, a range of additional private and public data is also needed. This includes building layouts, occupancy levels, and organizational information. For example, among the 45,000 employees[14] on the Microsoft main campus, more than 30,000 individual office moves can take place in one year. A daily data feed from the enterprise data warehouse can automatically keep track of building occupancy and other key parameters. Weather and utility information is gathered from third party providers. This collection of contextual information is necessary for normalizing energy consumption data, allowing for a better understanding of current performance and future potential. It also allows for demand forecasting and management.

Employ industry-leading analytics to identify savings

A smart building solution's value depends directly on its analytics engine. Algorithms that detect faults, prioritize alarms and identify optimization opportunities amid vast amounts of data enable building engineers to unlock savings that are not addressable with traditional methods. Rules need to be customized by vendor resources or building engineers that are familiar with the software. Microsoft's pilot enabled it to experiment with three different analytics engines and determine what features were most important for its needs.

Present results in a consumable and actionable form

Smart building solutions can produce very large volumes of complex data. To interpret the data, it is important to have an intuitive and customizable user interface that includes visual features, such as editable charts with drill-down functionality. Getting this right can make a major difference in enabling engineers to quickly identify irregularities. For example, by using Microsoft's Silverlight technology or the new HTML5 standard, rich

browser-based user experiences can be created that work across multiple devices. This can provide engineers with user-friendly access to critical information wherever they are, on PCs and mobile devices.

Centralize monitoring operations

A key implementation challenge is the fact that building engineers often lack the time to familiarize themselves with analytics tools and make use of them in their daily routine. For large-scale deployments, one solution is to set up a central operations center that connects to engineers via their PCs and mobile devices. In this center, dedicated employees monitor the whole real estate portfolio, finding and prioritizing faults and dispatching building engineers accordingly. This is less disruptive to the engineers' role, and adds value by focusing their attention on high-priority issues.

Keeping engineers engaged is essential to a smart building deployment, especially during an introductory phase, when the analytics engine is being fine-tuned. For smaller firms, a remote monitoring provider that communicates directly with on-site engineers can be an alternative.

Engage the organization

One aim of a smart building program should be to influence occupant behavior, by providing employees and other stakeholders with information about their energy footprint. Visual benchmarks or graphical renderings showing consumption trends help make such metrics understandable for employees and management, and drive behavior change. Microsoft uses SharePoint to publish metrics internally, allowing tailored dashboards for specific user groups.

Avoid disruptive change

As an additional analytics layer rather than a replacement of an existing system, a smart building solution constitutes a low-risk IT project with little disruption to ongoing business. Given its cross-organizational nature, smart building programs need strong project management functions and executive buy-in. New tools come with a learning curve requiring training and expectation management. With appropriate change management efforts, the adoption of the new toolset can be accelerated and processes adjusted. Running an extensive pilot program helped Microsoft's organizations get familiar with the technological and operational aspects of smart buildings prior to full rollout.

4
Future smart building opportunities

4.1 A cloud-based approach

Cloud computing is set to transform information technology, by making third party applications readily available as a service over the internet. For smart building solutions, this will deliver several benefits:

- **Accessibility**: Aggregating and analyzing data from disparate sources is at the core of any smart building solution. The cloud is ideally suited to providing a universally available platform for managing building data mashed up with contextual information and made accessible for a variety of users and devices.

- **Scalability**: With thousands of sensors and controls, modern buildings generate large volumes of data. Microsoft's main campus generates about half a billion data records per day from two million data points across 118 buildings. As the data volume and diversity of sources increases, a cloud-based architecture provides the scalability required to process massive volumes of data at an affordable cost. Abundant computing power allows complex modeling, such as correlating external temperature, cloud cover, and wind conditions with building access activity to refine heating, air conditioning and lighting patterns.

- **Ease of deployment**: Cloud technology can provide a secure and uncomplicated connection between off-site servers and on-site equipment. With Microsoft's Azure Connect the IT team was able to exchange data with the vendor solutions within minutes, avoiding the complexities associated with setting up a VPN.[15] Once connected, the cloud's elastic capacity enables vendors to serve new customers and increase the number of buildings managed without installing physical servers.

For two of the three vendors that are part of Microsoft's pilot, the cloud already plays an essential part in enabling a secure data exchange through Azure Connect. One of them hosts its solution on a public cloud, while the others are currently hosted on the vendor's premises and at Microsoft.

4.2 Automation and real-time analytics

We anticipate that the next generation of smart building solutions will allow organizations to automatically adjust building controls based on real-time data. For example, by monitoring the security badge access information for a building (as a proxy for the number of employees present), HVAC systems could be automatically adjusted to account for increased or decreased conditioning requirements. As an alternative, location and presence data from laptops or mobile phones could be used. Such solutions will rely on real-time analytics applied to incoming data streams, along with complex event processing, to execute automated adjustments to building controls. Microsoft StreamInsight, a component of the SQL Server software, can accomplish this task and is part of one pilot vendor's solution.

Future tools might even use machine learning to optimize algorithms over time, realizing even greater energy savings. For example, statistical analysis, simulation and predictive modeling can be applied to determine how many chillers need to be turned on, based on forecast occupancy levels and outside weather conditions. Researchers are also working on solutions that shape electricity demand curves of HVAC systems by using buildings as a form of energy storage and applying complex algorithms to optimize energy consumption through the course of the day.[16]

4.3 Integration with utilities and city infrastructure

With increasing adoption of smart building solutions, the built environment will achieve new efficiencies in energy use and improvements in occupant comfort. But this is only part of the story. Electricity grids are being upgraded with intelligent controls and two-way communication. As individual nodes of the smart grid, buildings will become active participants in managing energy demand and supply in a connected environment that includes power plants, transmission infrastructure and even electric vehicles.

For example, if a substantial share of Microsoft's employees were to use electric cars that are plugged in during the day, the campus could use the combined battery capacity to lower peak demand drawn from the utility at certain times during the day.[17] Likewise, demand response technology[18] can be used to shed loads in buildings when electricity consumption peaks, saving cost for utilities and building managers.

As buildings become increasingly networked, they play a crucial role in the development of energy-smart cities that unify the concepts of resource management and information technology on a municipal level.[19] A corporate campus like Microsoft's can serve as a test-bed for many technologies that will shape the sustainable cities of the future.

5
Conclusion

Aggregated data and powerful analytics that add "intelligence" to existing building infrastructure have the potential to transform the way in which companies manage energy across their real estate portfolio. In particular, building engineers can be empowered to take a more targeted, data-driven approach to their work while automation improves their productivity. This delivers substantial cost savings, while helping firms achieve carbon reduction targets with relatively low capital investments.

Microsoft's smart buildings pilot program shows that while various adoption barriers remain, these can be overcome by following a set of key design principles. Most importantly, the underlying technologies are now more widely available and easier to implement. By sharing its experience with the public, Microsoft hopes to contribute to the evolution of the technology and encourage other companies to implement programs of their own.

The potential for information technology to improve building energy efficiency is huge. The Global eSustainability Initiative (GeSI)[20], a consortium of leading high-tech companies, estimates that smart building technology has the potential to reduce carbon emissions in the US by 130-190 million tons of CO_2 – equivalent to the annual emissions of about 30 million passenger vehicles.[21] The related electricity cost savings amount to US$20-25 billion.[22] Quite simply, firms seeking to enhance their bottom line need look no further than the offices they're sitting in.

6
Appendix

About Microsoft

Founded in 1975, Microsoft is the worldwide leader in software, services, and solutions that help people and businesses realize their full potential. With 90,000 employees across its business divisions and global subsidiaries, the company generated revenues of US$ 69.9 billion for the fiscal year ended June 30, 2011. Its home page is www.microsoft.com.

Microsoft's Real Estate & Facilities organization is responsible for planning, delivery and operations of Microsoft's worldwide real estate portfolio, which comprises 33 million square feet (3.1 million m^2) and over 600 facilities across 110 countries.

About Accenture

Accenture is a global management consulting, technology services and outsourcing company, with approximately 236,000 people serving clients in more than 120 countries. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. The company generated net revenues of US$25.5 billion for the fiscal year ended Aug. 31, 2011. Its home page is www.accenture.com.

Accenture Smart Building Solutions (as part of Accenture Sustainability Services) enables commercial building owners to cost-effectively reduce energy usage and improve occupant comfort by managing and analyzing data to drive operational efficiency. The Accenture Real Estate Solutions practice helps organizations optimize their real estate portfolios and leverage their significant investment in space to support broader business goals and objectives.

About Lawrence Berkeley National Laboratory

Berkeley Lab is a U.S. Department of Energy (DOE) national laboratory that conducts a wide variety of unclassified scientific research for DOE's Office of Science. Located in Berkeley, California, Berkeley Lab is managed by the University of California, and the director is Dr. Paul Alivisatos. Berkeley Lab has a total of 4,200 employees, including 1,685 scientists and 475 postdoctoral fellows. Its budget for fiscal year 2011 is US$853 million.

Berkeley Lab's Environmental Energy Technologies Division performs research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. Researchers in the Division's Building Technologies Department work closely with industry to develop efficient technologies for buildings that increase energy efficiency, and improve the comfort, health and safety of building occupants.

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6. Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects, Mills and Mathew, June 2009.
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9. New workplace models constitute another strategy Microsoft employs to optimize its real estate footprint.
10. As of 2011, Microsoft's Sustainability Champions program included over 430 employees working in 73 different buildings across the main campus. Its objective is to reduce the company's environmental impact through employee engagement. Newsletters, events, training, "green bag" lunches and monthly building energy consumption reports by floor or wing are the key elements aimed at reducing employee-controlled electricity consumption.
11. For example, engineers collaborated with Siemens to convert data from the proprietary Apogee format.
12. Additional data elements include square footage, floors, types of rooms, location, and whether a building is owned or leased.
13. One of the three pilot software solutions is hosted on Microsoft's premises, whereas the other two are hosted off-site. The on-premise solution does not use Azure Connect as data is not transmitted outside Microsoft.
14. Including on-site vendor resources.
15. Virtual Private Network.
16. Research rock star: Efficiency star, Coloradobiz, 2011.
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19. The central role of cloud computing in making cities energy-smart, Microsoft, 2011.
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