CASE STUDY

Intel® IoT Gateway Technology
Intel® IoT Platform
Intelligent Systems

Intel Creates Smart Building Using IoT

Intel's smart building increases energy conservation, operational efficiency, and occupant comfort.

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In 2016, Intel created its first Internet of Things (IoT)-enabled smart building in Bangalore, India. The office building is a 10-story, 630,000 sq. ft. structure that was outfitted with approximately 9,000 sensors used to track and optimize temperature, lighting, energy consumption, and occupancy in the building. The sensors, of which 70 percent are located in the ceiling, provide 24/7 real-time data. Analytics is run on the data gathered from sensors to generate actionable insights for Intel's facilities team.

Challenges

- **Reduce resource usage.** Typical Intel office buildings use static building management systems (BMSs) that have limited capabilities to intelligently control energy- and water-related systems.
- **Improve operational efficiency.** Intel wanted to move to a mobile cubicle model to accommodate more employees.
- **Increase occupant comfort.** Oscillating temperatures in the building typically lead to many employee complaints about their zone being either too hot or too cold.

Solutions

- **Advanced building analytics.** Reduce energy and water usage by better controlling building systems using automation rules generated from sensor data.
- **Space optimization.** Increase cubicle utilization rates by employing occupancy sensor data to help employees find vacant cubicles.
- **Machine learning algorithm.** Maintain a constant temperature in all building zones by taking more environmental factors into account.

Impact

- **Energy/water savings.** The savings is forecasted to be $645,000 per year with a return on investment (ROI) payback period of less than four years.
- **Efficient office space.** Intel increased employee capacity by approximately 30 percent.
- **Productive workers.** Socially driven temperature control can increase worker satisfaction with workplace thermal comfort by 83 percent.[1]

Many buildings have a combination of proprietary systems that do not "talk" to each other.

Inflexible proprietary solutions

Many building and facilities managers are missing key information they need to make fact-based decisions. Although building systems are generating massive amounts of data, it is often not captured nor presented in an easy-to-understand fashion. A major reason is that buildings typically have large numbers of stand-alone and proprietary interfaces—this impedes the data sharing required to thoroughly analyze building performance.

By today's standards, many of these systems are inadequate, inflexible, and costly, partly because they are based on vendor-specific, proprietary technologies. Many vendor solutions are hardware-based, which generally makes it more complex to deploy new features and upgrades, compared to software-focused solutions. As a result, modifying a legacy BMS often requires customization by the manufacturer—a costly and time-consuming process. Smart buildings created using IoT technologies can overcome these flexibility and capability issues.

Other business drivers for smart buildings are both regulatory and operational in nature. With the focus on reducing CO_2 emissions in the 2016 Paris Climate Agreement, the need to decrease energy consumption within buildings is a high priority, and for good reason. In the European Union (EU), for example, buildings are responsible for 40 percent of the energy consumption and 36 percent of the CO_2 emissions.[2] Around 75 percent of Europe's building stock is energy inefficient.[3] By improving the energy efficiency of buildings, total EU energy consumption and CO_2 emissions could be reduced by about 5 percent.[2]

There is also the need to address the occupant experience. For instance, millennials entering the workforce expect more services from buildings than their predecessors, which could have a direct impact on employee satisfaction and retention.

Smart building solution

With the goal of increasing energy conservation, operational efficiency, and occupant comfort, Intel designed a smart building solution based on its IoT reference architecture. IoT technology greatly simplified the task of collecting and analyzing data from various building systems, including heating, ventilation, and air conditioning (HVAC); water; energy generation; occupant counters; and electrical. The building also has a Power over Ethernet (PoE)–based smart lighting system with sensors embedded in light fixtures to monitor occupancy, temperature, and other environmental factors.

Data collection

Figure 1 shows a basic illustration of this IoT architecture. Intel® processor-based IoT gateways act as the "central nervous system" of the building, securely connecting to a variety of smart sensors that monitor the building systems and ensure an uninterrupted flow of data between them. Essentially, the interoperability and data integration of the entire solution is facilitated by these IoT gateways. The gateways have built-in enterprise-grade security features, such as McAfee Embedded Control*, that provide end-to-end security protection for the network, building systems, and data.

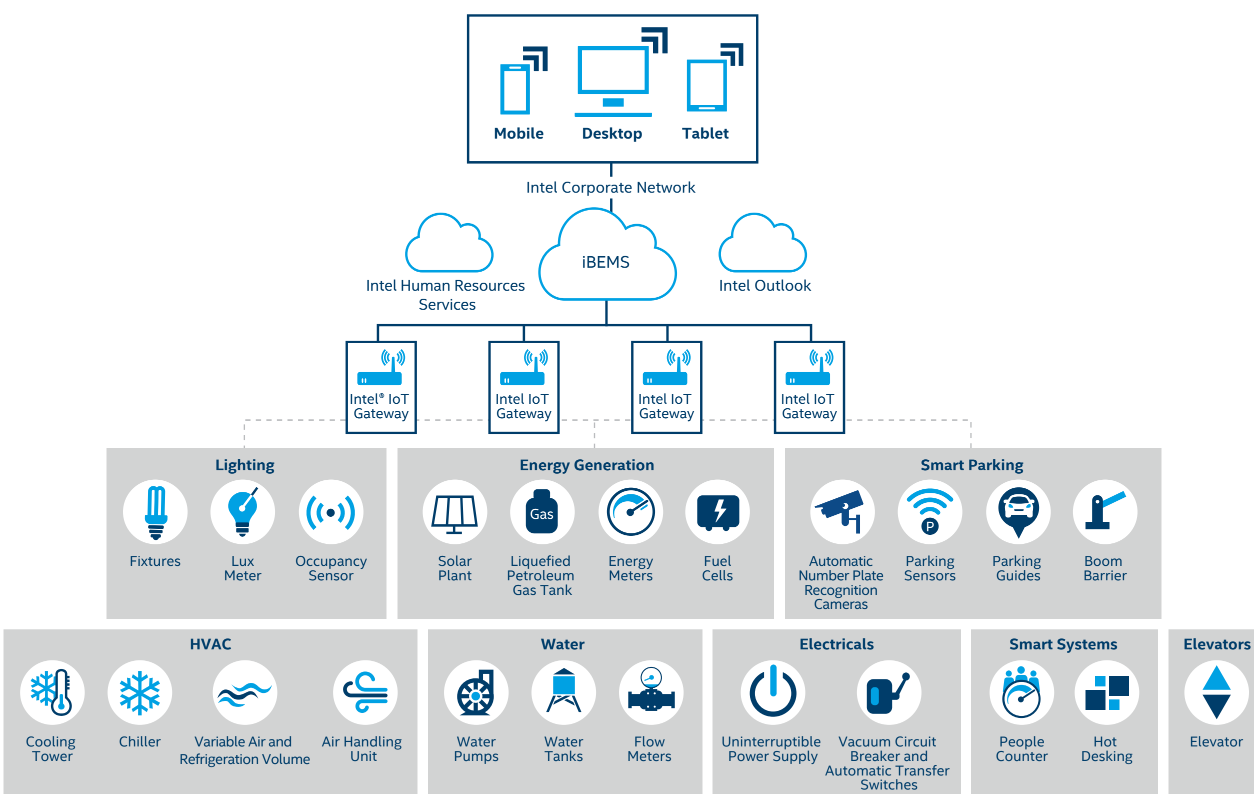

Figure 1. IoT architecture for smart buildings

Data analysis
The building was also equipped with an on-premises BMS that handles the usual building automation tasks for various subsystems (e.g., HVAC and lighting). Intel added advanced building analytics and rules capabilities via an integrated building energy management system, called iBEMS*, from L&T Technology Services. iBEMS software runs in a distributed computing environment, including the gateway software components shown in figure 2. On gateways, it executes rules on sensor data, and on a server connected to the Intel enterprise network, it analyzes filtered data from the gateway.

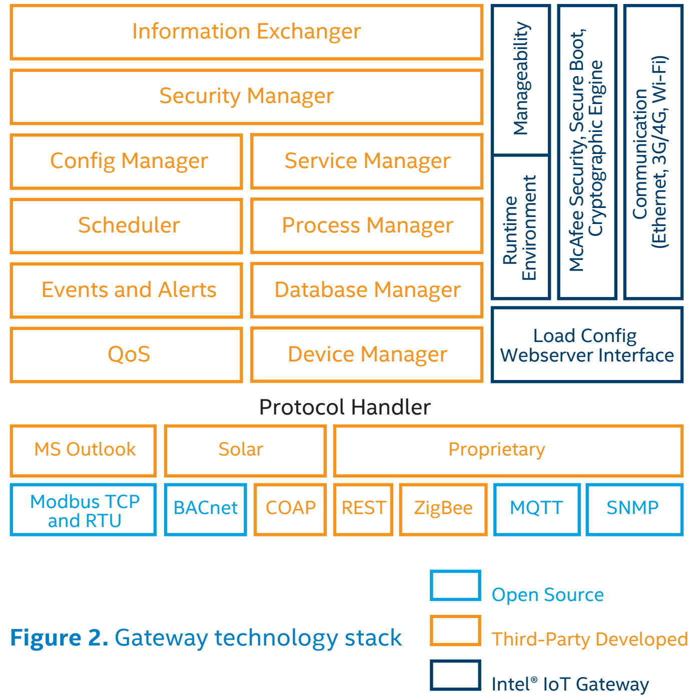

Figure 2. Gateway technology stack

Use case examples

To date, Intel's smart building enabled 40 different use cases. This section describes four use cases spanning energy conservation, operational efficiency, and occupant satisfaction. In figures 3 and 5, blue lines indicate inputs and red lines indicate actuation or outputs.

1. ENERGY CONSERVATION

Conference room HVAC control

In the Intel smart building, closed areas, such as conference rooms, represent approximately 18 percent of the total floor space.[4] These areas are good candidates for energy conservation because when they are vacant, the HVAC and lighting systems can often be powered down to save energy. However, many static BMSs maintain a constant temperature in closed rooms irrespective of whether they are occupied, booked, or vacant.

Solution
IT and IoT data is used to create the energy conservation solution shown in figure 3. The booking status of each conference room is collected from the IT corporate calendaring system, and room occupancy status is obtained from the previously mentioned, IoT-enabled PoE lighting fixtures in each room. These parameters are then integrated with the traditional input parameter of "return air temp" to more efficiently modulate the variable air volume (VAV) boxes in the conference rooms.

Impact
By running the VAV boxes more efficiently, Intel projects a savings of 4 percent of its total HVAC costs, allowing the solution payback period to be less than two years. In addition, lighting energy usage in watts per sq. ft. dropped from 1.08 (Intel baseline design) to 0.39 (actual) through the utilization of natural light, daylight sensors, and LEDs.

The benefits are not limited to energy conservation. This use case also visualizes other important data, such as conference room utilization rates, which gives building space planners the information they need to ensure the office configuration satisfies the needs of the occupants.

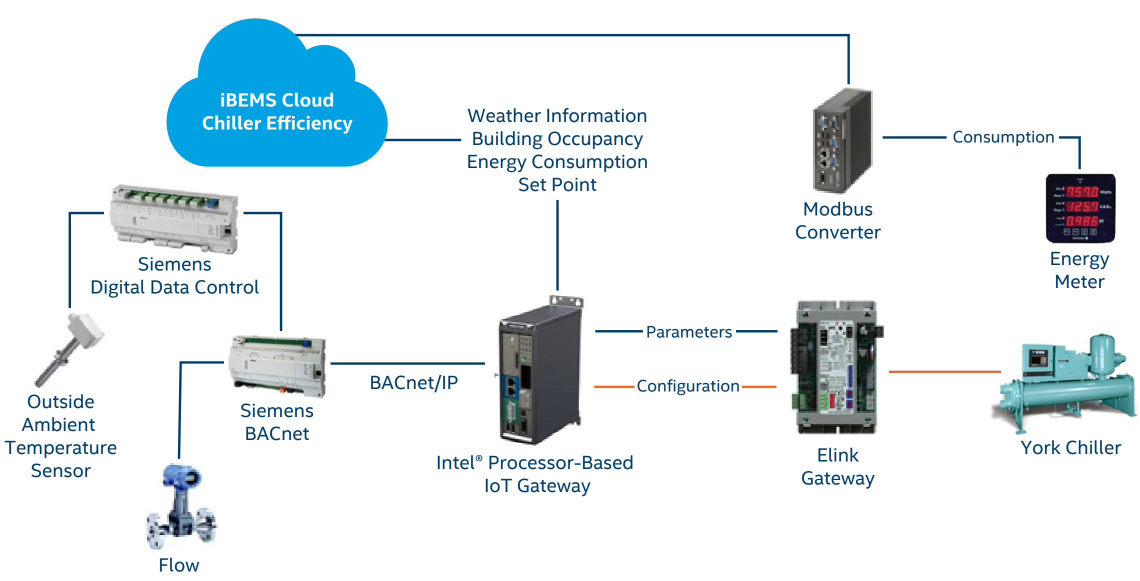

Figure 3. Solution for conference room HVAC control use case

2. OPERATIONAL EFFICIENCY
Automated demand response

In an effort to avoid involuntary service interruptions (i.e., blackouts), utilities implement demand response programs to entice their customers to lower energy usage during periods when overall demand may exceed capacity. Customers who participate are typically compensated through lower rates and credits.

Solution

Intel's smart building solution controls four energy sources: diesel generation, solar, fuel cells, and the grid. It enables the facilities team to remotely read energy meters connected to the different energy sources, and, with the touch of a button, change energy usage throughout the building. Both energy consumption and generation are monitored and controlled in order to meet an energy load profile that satisfies the utility's demand-response requirements. With this capability, Intel's smart building can take automated actions to reduce energy consumption when the 90 percent threshold of the permitted load is exceeded, as shown in the business logic illustrated in figure 4.

Impact

This use case promotes the efficient usage of renewable energy sources and avoids financial penalties for drawing more energy than the sanctioned load from the utility grid. The energy consumption of major building subsystems, such as lighting, HVAC, and fans, etc., is decreased, as needed, per their energy profiles. The facilities team can also ramp up fuel cell usage when demand increases or solar cell energy production dips on cloudy days.

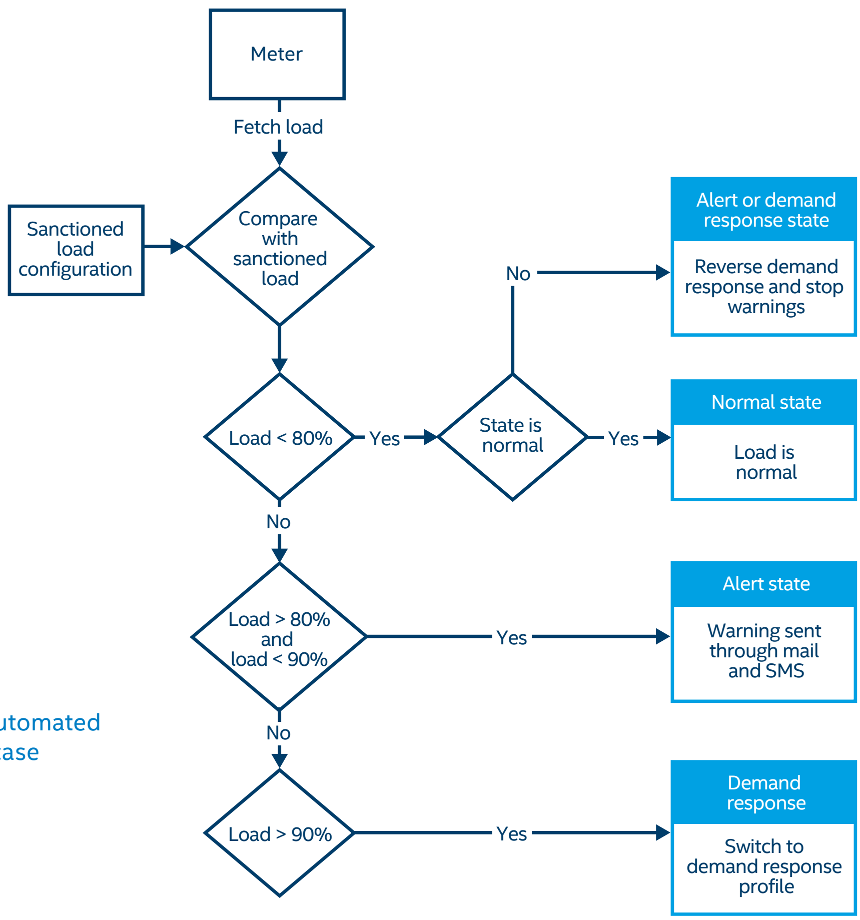

Figure 4.
Business logic for the automated demand response use case

3. OCCUPANT COMFORT
Constant temperature across building zones

Temperature variation through the day is a common complaint of building occupants.

Solution

To maintain a constant temperature across various building zones, Intel implemented a machine learning algorithm that predicts appropriate set points for the HVAC in the building. The algorithm not only factors in typical parameters (e.g., return air temperature), it takes into account many others, including occupancy and ambient temperature.

This algorithm runs every two minutes to keep set-point predictions current.

Impact

This use case improves both employee and facilities team efficiency. A study shows a socially driven HVAC at the Federal Building and U.S. Courthouse in Phoenix increased worker satisfaction with workplace thermal comfort by 83 percent,[1] which should translate into higher productivity and fewer tickets the facilities team needs to address related to occupants being too hot or too cold.

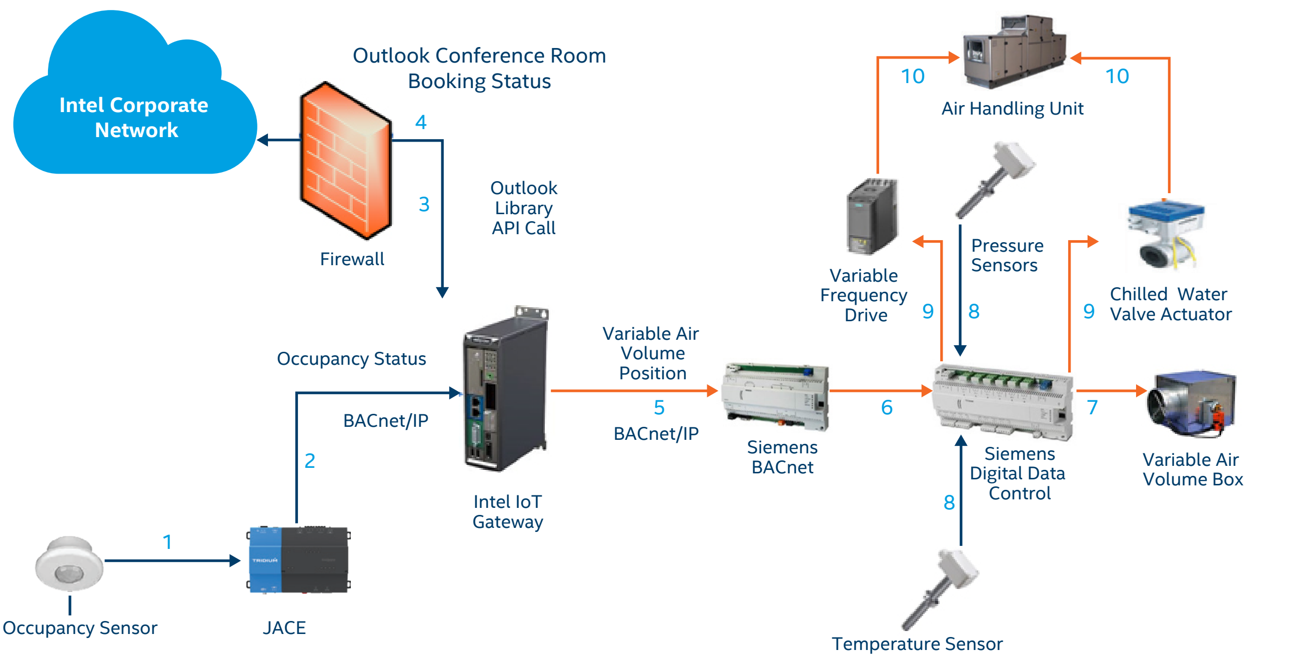

Figure 5. System interaction diagram for occupant comfort use case

4. OPERATIONAL EFFICIENCY
Mobile cubicle booking

A major concern of employees in other Intel office buildings is finding a mobile cubicle to work in because it can be difficult to identify which cubicles are unassigned and available for use.

Solution

Intel's smart building solution allows employees to view and reserve an available room for the day. The solution creates this view by combining data from occupancy sensors installed in each mobile cubicle (Figure 6) with data from the cubicle reservation system.

Impact

The mobile cubicle booking application allows Intel to maintain a mix of unassigned and assigned cubicles, with about 20 percent of the cubicles designated as mobile. As a result, Intel can accommodate approximately 30 percent more employees in this building than if every employee was assigned a permanent cubicle. This use case alone is expected to save several million dollars in operational expense each year. Moreover, employees have the ability to plan their seating arrangement for the day at the touch of a button.

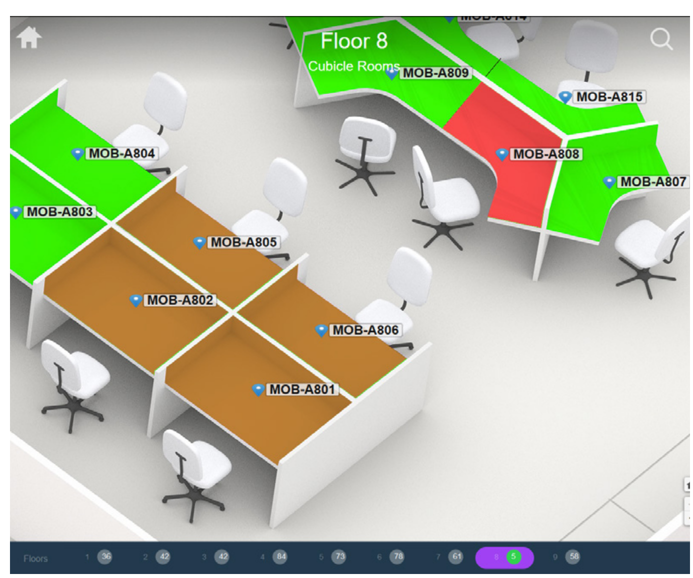

Figure 6. System-user interface for the mobile cubicle booking use case

IoT technology overview

The following sections provide more detail about the IoT technology employed by Intel's smart building solution. This includes additional information on communication protocols, rules, data integration, network and gateway security, and provisioning of the solution. These capabilities are relevant for any IoT-based solution for buildings.

Communication protocols, rules, and data integration
A challenge for building control is to bridge the different communications protocols used by the various building systems. This is one of the roles an Intel® processor-based IoT gateway can play, acting as a central coordinator with its ability to ingest messages on a variety of protocols such as Modbus* TCP/IP and BACnet-IP.

The gateway can also process messages based on a set of predefined rules (e.g., turn on VAV box when the lighting occupancy sensor detects a presence). Rules that are time sensitive and not compute intensive may run on the gateway, while more complex rules should run on a cloud server.

The Intel smart building solution has approximately 5,000 rules divided between gateways and two backend, redundant servers. Once the data is evaluated on the gateway, the portion that requires further processing is transmitted to the cloud in JSON format over the MQTT communication protocol. Approximately 50 GB of data is generated via the sensors on a daily basis, and this data set is distributed across 60 IoT gateways. About 40 percent of the sensor data is analyzed in the cloud. There is a backup and archiving mechanism for purging raw data in the cloud.

Network and gateway security
Intel employs a network topology and security policies specifically designed to protect against hackers trying to access the Intel corporate network via the sensor network. The topology physically isolates the sensor network from the corporate network using a gateway that bridges the two networks using separate interfaces for each. As for security policy, the iBEMS software running on a server in the corporate network is protected by a firewall. No Internet connections from outside the firewall to iBEMS are permitted.

To secure data transmissions, the gateway encrypts messages using OpenSSL and connects to clients over the secure socket layer (v2/v3) and transport layer security (TLS v1) network protocols. The gateway has a trusted platform module (TPM) chip to encrypt applications and secure their distribution.

That gateway itself is protected with secure boot and application whitelisting software. Secure boot verifies that the gateway's operating system is in a known good state and has not been tampered with. Application whitelisting ensures only a predefined specific set of applications and middleware are permitted to run on the gateway.

Provisioning
The gateway has preinstalled client software, permitting it to communicate with the iBEMS server. The server on the corporate network administers gateway software changes, including operating system, drivers, and application upgrades. The only required on-site configuration needed is to enter the server URL of the upgrade server, which also hosts the iBEMS application. On an ongoing basis, an agent on the gateway checks for hardware configuration changes stored on the server. Once a change is detected, the new software updates are pulled from the server and simultaneously installed on all gateways in the system. Typical time frames for pull, install, and restart are less than two minutes.

Summary

The Intel smart building in Bangalore implemented about 40 use cases, with approximately 55 percent focused on energy conservation and operational efficiency, and the rest on employee satisfaction. The relatively high number of employee satisfaction use cases is justified by numerous studies that indicate the associated increase in employee productivity can have a sizably larger impact on top-line growth than bottom-line improvements resulting from energy conservation and operational efficiency. In addition, smart buildings also create a positive image that can help companies attract the best job candidates.

Building owners need to move away from closed and proprietary BMS systems and toward open systems in order to reap benefits from the latest technologies. The Intel smart building is a step in this direction, treating the BMS as a service and gaining the flexibility to select from a large number of solution vendors.

Learn more

For more information about Intel's solutions for smart building, visit intel.com/IoT/smartbuilding.

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3. European Commission, "Accelerating clean energy in buildings." Pg. 2, November 30, 2016. https://ec.europa.eu/energy/sites/ener/files/documents/1_en_annexe_autre_acte_part1_v9.pdf
4. Intel calculation from building drawings.

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