FEMP
Federal Energy Management Program

Guide for Grid-Interactive Efficient Buildings for Federal Agencies

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Disclaimer

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List of Acronyms

ESCO	energy service company
ESPC	energy savings performance contract
FEMP	Federal Energy Management Program
GEB	grid-interactive efficient building
GSA	U.S. General Services Administration
HVAC	heating, ventilation, and air conditioning
UESC	utility energy service contract

Executive Summary

The U.S. Department of Energy's Federal Energy Management Program (FEMP) developed this guide as a resource for building owners, energy and building managers, and others interested in implementing grid-interactive efficient building (GEB) strategies and technologies through retrofits.

This guide provides an overview of GEB characteristics and benefits and how to analyze, identify, and implement GEB retrofit opportunities. It is important to understand the building's systems as well as what utility program offerings are available at the site (e.g., time-of-use, electricity rates, demand charges, demand response programs, etc.). It is also important to understand the key goals for the site (e.g., environmental, cost savings, energy savings, carbon reduction) and the current energy usage breakdown by equipment and load profile variability by day, month, and season.

This document also provides insights into key GEB stakeholders, identifying utility programs for GEBs, financing GEBs, and suggestions for potential no- and low-cost GEB upgrades. Additional GEB case studies, resources, and a full list of GEB technologies are provided at the end.

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1 Introduction

The U.S. Department of Energy's Federal Energy Management Program (FEMP) developed this guide as a resource for building owners, energy and building managers, and others interested in implementing grid-interactive efficient building (GEB) strategies and technologies through retrofits. This guide provides an overview of GEB characteristics and benefits and how to analyze, identify, and implement GEB retrofit opportunities. It is important to understand the building's systems as well as what utility program offerings are available at the site (e.g., time-of-use, electricity rates, demand charges, demand response programs, etc.). It is also important to understand the key goals for the site (e.g., environmental, cost savings, energy savings, carbon reduction) and the current energy usage breakdown by equipment and load profiles variability by day, month, and season.

This document also provides insights into key GEB stakeholders, identifying utility programs for GEBs, financing GEBs, and suggestions for potential no- and low-cost GEB upgrades. Additional GEB case studies, resources, and a full list of GEB technologies are provided at the end.

2 Characteristics of GEBs

Growing electricity demand and a push toward electrification in support of decarbonization are causing challenges for the electric grid and the associated infrastructure. A GEB is an energy-efficient building that uses smart technologies and on-site distributed energy resources to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.

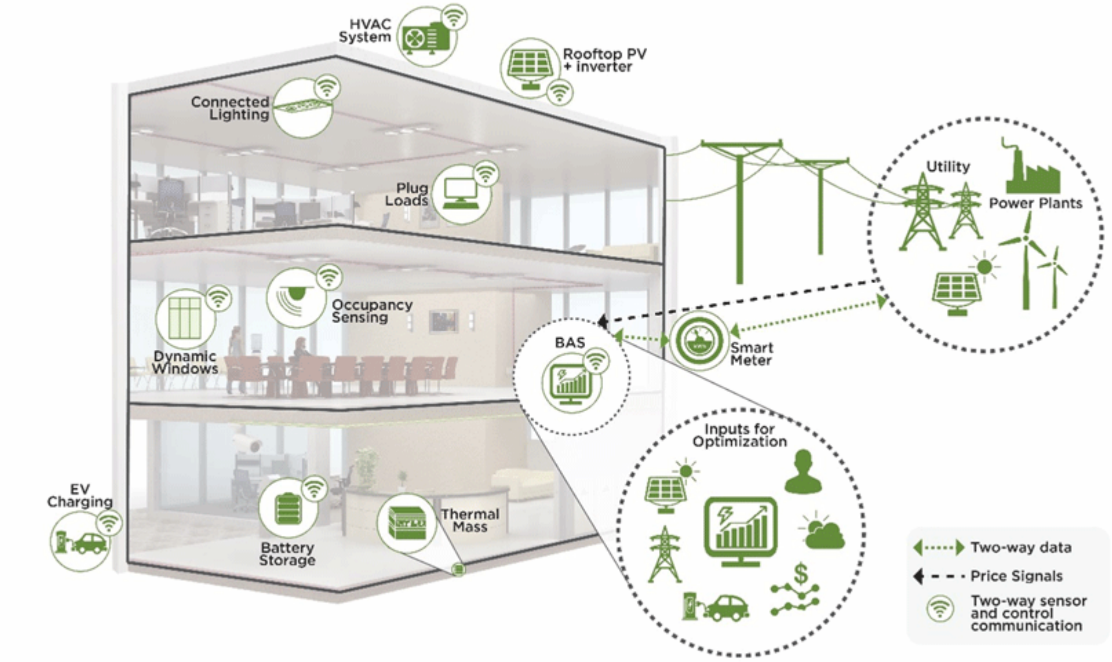

Figure 2-1. Components of a GEB

Illustration by Guidehouse Consulting

GEBs are characterized by four features: they are efficient, connected, smart, and flexible, and they help decarbonize the building stock. GEBs provide four key demand management strategies—efficiency, load shed, load shift, and modulate—which provide numerous benefits to the grid, including reduced capacity costs, reduced transmission and distribution costs, and increased system reliability (Neukomm, Nubbe, and Fares 2019).

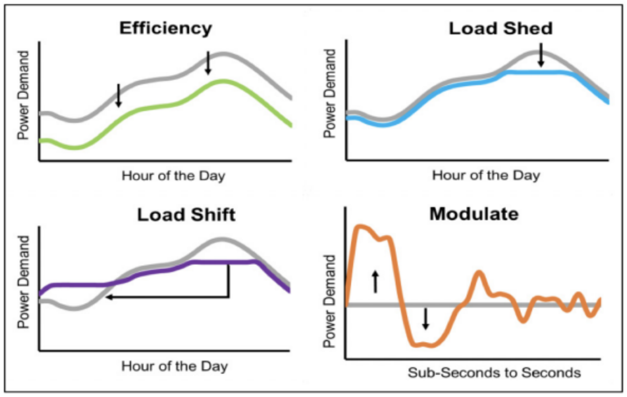

Figure 2-2. GEBs provide four key demand management strategies—efficiency, load shed, load shift, and modulate

Illustration by Guidehouse Consulting

Building owners may choose to deploy GEB technologies and strategies for a variety of benefits, including (Neukomm, Nubbe, and Fares 2019):

- Avoiding high utility demand charges and time-of-use peak period pricing
- Reducing utility bills, lowering rates, or receiving direct payments from utilities
- Increasing resilience to grid outages or disturbances
- Helping achieve decarbonization, electrification, and lower greenhouse gas emissions
- Enabling better energy system management and monitoring.

3 How To Analyze, Identify, and Implement GEB Retrofit Opportunities

Figure 3-1. GEB Retrofit Analysis Steps

3.1 Analyze Current Site Energy Systems and Energy Use

The first step in a GEB technology retrofit is to understand the current status of the site, including both the state of the building equipment and technologies that are installed and the energy usage at the site. It is important to understand the hourly, daily, and monthly load profiles of the facilities, as well as the seasonal variation. It is also important to understand your largest loads at your site that have the most potential for energy savings and load shifting, which are often heating, air conditioning, and ventilation loads.

3.2 Establish Energy Retrofit Goals

Next, it is crucial to establish what your energy goals are for the retrofit project, including energy savings, utility cost savings, decarbonization or emissions reductions, increased resiliency, etc. Goals should include a target reduction value and a timeline. You should also consider how you will track and measure progress toward these goals each year.

3.3 Understand Utility Rates, Program Offerings, and Incentives

In addition to energy usage analysis, it is important to conduct a utility bill analysis to understand your time-of-use rates, including differences between peak and off-peak periods, and the demand charges for your site. This will be crucial to developing demand management strategies for reducing utility bills. It is also important to research available utility program incentives and demand response programs available at the site.

3.4 Identify Potential GEB Technology Upgrades

Building off the facility's current installed technologies, current energy use by equipment, and energy retrofit goals, the next step is to develop an initial list of all potential GEB technologies and measures of interest for the site.

The FEMP GEB Workbook[1] is a helpful tool that provides guidance, recommendations, and prioritization of potential grid-interactive strategies, grid-interactive technologies, and electrification and controls upgrades in federal and commercial buildings. For an existing commercial or federal building considering a retrofit, users input key information about the building and are presented with a breakdown of less- to highly-applicable technologies and upgrades that could be implemented for the building. The workbook also highlights many different resources for the user to learn more information about the recommended technologies and strategies.

3.5 Identify GEB Demand Management Strategies for the Site

After identifying potential technologies, the next step is to analyze how you can reduce demand (energy efficiency) to use less energy overall and operate your existing equipment more efficiently. Next, based on the analysis and results from Sections 3.1-3.4 (energy usage, available demand response offerings, energy goals, GEB technologies list), you can identify which demand management strategies make sense for your facility, including load shifting, load shedding, peak management, load curtailment, etc. It is also beneficial to analyze how on-site energy generation can provide additional opportunities for demand management.

3.6 Develop a Retrofit Project Team With GEB Stakeholders

Once you have established the goals of the retrofit, an initial technology list, and identified demand management strategies, a key next step is to develop a retrofit project team with key stakeholders who can help with GEB technology implementation. These stakeholder and project roles are defined in Section 4.

3.7 Establish a Contract for Financing GEB Upgrades

Many GEB upgrade projects will need to be financed through a utility energy service contract (UESC) or an energy savings performance contract (ESPC). However, there are some GEB upgrades and controls strategies that can be implemented at low or no cost.

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[1] Federal Energy Management Program. n.d. "Grid-Interactive Efficient Building Strategies and Technologies Guidance Workbook." Accessed August 2024. https://www.energy.gov/femp/articles/grid-interactive-efficient-building-strategies-and-technologies-guidance-workbook.

4 Key GEB Stakeholders for Retrofits

The building owner, facility manager, utility representative, energy service company (ESCO), project facilitators, and GEB technology subject matter experts are key stakeholders that should be involved in a GEB retrofit project to ensure successful implementation. After completing the initial steps outlined in Sections 3.1–3.5 above, it is key to leverage the expertise of these different stakeholders to help decide on what technologies and strategies to implement to meet your energy goals while optimizing utility cost savings. The building owners and facility manager typically take a lead role as decision makers and project managers.

GEB retrofit projects benefit greatly by working closely with the site's utility representative(s). First, it is important to understand all utility offerings around demand response and incentives for GEB technology upgrades. In addition, many utilities offer additional benefits such as financing through UESCs and incentives for installing some connected equipment and controls. In some cases, building managers can negotiate different rates or direct payments in exchange for proving grid services.

The ESCO helps design the project and recommends technologies based on payback period in addition to arranging financing through ESPCs for projects that save energy. The ESCO will complete a preliminary site assessment and generally help ensure the retrofit project saves energy and reduces costs and can help with additional energy-related goals (FEMP n.d.[b]).

GEB technology subject matter experts encompass a wide range of individuals—from controls experts to design consultants—that can be pulled into the project to provide design help, recommendations, and other insights to help the building owner make informed decisions about the GEB upgrades and review recommendations from the ESCO.

For federal projects, a project facilitator is also a great asset who can assist with implementing ESPCs and UESC. Project facilitators are "experienced, unbiased advisors who guide the agency acquisition team through the project development and implementation process by providing technical and financial advice" (FEMP n.d.[c]).

5 Identifying Utility Programs for GEBs

Related utility offerings for demand response and variable utility pricing programs vary by utility, so it is important to research and understand how your GEB site could benefit from the available strategies and offerings. FEMP developed a list of demand response and variable utility pricing programs available for major utilities throughout the United States.[2] Some of the key utility programs and pricing relevant for deploying GEB technologies and strategies include:

- **Time-of-use pricing:** Utility rates vary based on the time of day, encouraging consumers to shift usage to off-peak hours.
- **Critical peak pricing:** Time-varying rate that charges you significantly more for electricity during select peak periods throughout the year.
- **Peak savings and rewards programs:** Utility offers bill credits or payments for reducing electricity use during certain "peak" energy events.
- **Direct load control or interruptible service:** Customers receive payments or credits for allowing the utility to reduce loads when requested or during specific hours.
- **Emergency load reduction:** Customers receive payments for reducing energy consumption or increasing electricity supply during periods of electrical grid emergencies.
- **Capacity market programs:** Payments or discounts for reducing loads to lower the capacity requirements during peak periods.

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[2] Federal Energy Management Program. n.d. "Demand Response and Time-Variable Pricing Programs." Accessed August 2024. https://www.energy.gov/femp/demand-response-and-time-variable-pricing-programs.

6 Financing GEBs Through UESCs and ESPCs

A UESC offers federal agencies an efficient way to engage local utilities for a wide array of energy conservation measures (FEMP n.d.[d]). In this arrangement, the utility partner evaluates possibilities and plans and executes energy conservation measures, spanning from lighting upgrades to renewable energy systems. They may also offer project financing. The agency has the flexibility to fund the project using a mix of savings from the energy conservation measures and financing. Many utilities offer UESCs as an option for financing retrofits, and building owners can work directly with their utility representative to learn more about them.

An ESPC involves a partnership between a building owner and an ESCO (FEMP n.d.[a]). The ESCO designs and implements energy efficiency improvements, and the owner pays for the services over time from the realized energy savings. Both UESCs and ESPCs share the common goal of reducing energy consumption and costs while promoting sustainability. The primary difference is that UESCs involve utilities, while ESPCs engage ESCOs. Despite this distinction, both contracts contribute to achieving energy efficiency objectives in a cost-effective manner.

7 Potential Low-Cost GEB Upgrades To Consider

There are many low and no-cost GEB measures that energy managers can implement to provide demand response and load flexibility at federal facilities. A 2021 report from Rocky Mountain Institute identified key measures and upgrades that can be done with little to no capital investment (<$50,000) and actionable steps that U.S. General Services Administration (GSA) building managers can take to implement these (Carmichael, Esau, and Taylor 2021). As a first step, it is important to analyze the existing building control system to understand the capabilities, including load-shifting equipment operation to off-peak times or to manage peak demand. Some of the key measures from the report are summarized in the following sections. For more detailed information, see the full report from RMI.[3]

7.1 Optimize HVAC Sequencing

High-load heating, ventilation, and air conditioning (HVAC) equipment can be programmed to run in sequential stages to minimize peak demand in the building. Change the temperature setpoints to lower the runtime of HVAC equipment. Adjust fan flow and supply air temperature settings to minimize energy use and maximize space function.

7.2 Optimize Building Operations to Occupancy Patterns

Modify temperature setpoints or HVAC settings to lower heating/cooling demand in lower occupancy areas or transitional areas during peak hours.

7.3 Optimize Thermal Mass

Core building spaces are able to store heat and resist heat transfer, so these spaces could potentially be preheated or precooled at off-peak times.

7.4 Maximize Use of Existing Storage

Examples of energy storage systems in buildings include ice storage, chilled water, hot water, phase change materials, and batteries. These storage systems could be used to shift energy loads to off-peak hours and to align with time-of-use pricing.

7.5 Automate Lighting Controls

Lighting controls can be used to dim or turn off lighting in spaces with daylight or spaces that are infrequently occupied.

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[3] Rocky Mountain Institute. "Grid-Interactive Efficient Buildings Made Easy: A GSA Building Manager's Guide to Low- and No-Cost GEB Measures." Accessed January 2024. https://rmi.org/insight/grid-interactive-efficient-buildings-made-easy/.

8 Federal GEB Case Studies

Though GEB technologies are still emerging, several U.S. federal facilities have successfully deployed GEB technologies and strategies as part of energy retrofit projects. Some example case studies are provided below, including information on the key project successes, challenges, lessons learned, and best practices.

The ***GSA Oklahoma City Federal Building: Smart Buildings Case Study***[4] demonstrated that GEB-ready strategies and technologies can be deployed across buildings with minimal investment. Key GEB measures installed at the site include a photovoltaic array, lighting controls, building automation system upgrades, battery energy storage system, and advanced power strips. The Oklahoma City Federal Building is a four-story building that occupies 178,342 square feet and houses several different federal agency offices.

The ***VA Carl T. Hayden Medical Center: Smart Building Case Study***[5] demonstrated a successful energy retrofit project that reduced energy consumption by 25% and used energy storage and on-site generation to shift loads to align with time-of-use pricing and reduce peaks to avoid demand charges. The Carl T. Hayden Medical Center is in Phoenix, Arizona—a 279-bed medical facility in a campus of 25 buildings and a total floor area of 850,000 square feet.

Grid-Interactive Efficient Building Case Studies in the Federal Portfolio[6] provides background information, GEB practices and technologies implemented, and lessons learned from nine different case studies of federal buildings in the United States.

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[4] FEMP. 2023. "GSA Oklahoma City Federal Building: Smart Buildings Case Study." https://www.energy.gov/femp/articles/gsa-oklahoma-city-federal-building-smart-buildings-case-study.

[5] FEMP. 2024. "Carl T. Hayden Veterans Affairs Medical Center: Smart Buildings Case Study." https://www.energy.gov/femp/articles/carl-t-hayden-veterans-affairs-medical-center-smart-buildings-case-study.

[6] GSA. 2021. *Grid-Interactive Efficient Building Case Studies in the Federal Portfolio*. https://sftool.gov/Content/attachments/GSA%20GEB%20Case%20Study%20Report%20Mar%202021.pdf.

9 Additional GEB Resources

Blueprint for Integrating Grid-Interactive Efficient Building Technologies into U.S. General Services Administration Performance Contracts[7] outlines a screening process that narrows down potential site characteristics that would make good GEB candidates and outlines challenges, solutions, and best practices.

Grid-Interactive Efficient Buildings Made Easy: A GSA Building Manager's Guide to Low- and No-Cost GEB Measures[8] provides an overview of GEBs and lays out actionable steps for GSA building managers to implement these no- and low-cost measures.

The Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis[9] details the core ways that the GSA could leverage its size, its leadership in the industry, and its relationships with utilities and regulators to pioneer GEB opportunities across its portfolio.

The **Grid-Interactive Efficient Buildings Technical Report Series**[10] evaluates state-of-the-art and emerging building technologies that have significant potential to provide grid services. The reports also identify major research challenges and gaps facing the technologies as well as opportunities for technology-specific R&D.

A National Roadmap for Grid-Interactive Efficient Buildings[11] identifies the most important barriers and outlines the key opportunities for full implementation of GEBs and associated demand flexibility.

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[7] National Renewable Energy Laboratory. 2021. *Blueprint for Integrating Grid-Interactive Efficient Building (GEB) Technologies into U.S. General Services Administration Performance Contracts*. https://www.nrel.gov/docs/fy21osti/78190.pdf.

[8] Rocky Mountain Institute. 2021. “Grid-Interactive Efficient Buildings Made Easy: A GSA Building Manager’s Guide to Low- and No-Cost GEB Measures.” https://rmi.org/insight/grid-interactive-efficient-buildings-made-easy/.

[9] Rocky Mountain Institute. 2019. “Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis.” https://rmi.org/insight/value-potential-for-grid-interactive-efficient-buildings-in-the-gsa-portfolio-a-cost-benefit-analysis/.

[10] Building Technologies Office. n.d. “GEB Technical Reports.” https://www.energy.gov/eere/buildings/geb-technical-reports.

[11] Building Technologies Office. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings*. https://gebroadmap.lbl.gov/A%20National%20Roadmap%20for%20GEBs%20-%20Final.pdf.

10 List of Key GEB Technologies

Some of the key GEB technologies are provided in the sections below. For more information on GEB technologies, see the ***Key Grid-Interactive Efficient Building Technologies for Federal and Commercial Facilities***[12] report.

10.1 Advanced Building Automation System/Energy Management Information System

An advanced building automation system is fully integrated into the building and able to automatically control and manage multiple energy systems within the building and allow for remote control and management; it is typically connected to a larger management network. An energy management information system is a general label for a software tool, information technology, or system that monitors, analyzes, and controls building energy use and system performance. They can also be networked within the building and can communicate/respond directly to grid signals from the utility/energy provider to provide real-time energy management.

10.2 Advanced Controls for Commercial Refrigeration

Advanced controls (embedded or external) that enable grid-friendly operation of commercial refrigeration equipment with limited impact on operations. Well suited to load shifting via scheduled precooling or emergency curtailment. Annual energy savings are achievable via smart control of the equipment.

10.3 Advanced HVAC Control

Controls and sequences of operation that allow for greater interaction and flexibility of the HVAC system, including air handler units, chillers, and rooftop unit controls. Strategies include adjusting temperature and pressure setpoints, utilizing variable frequency drive pumps, and changes to fan speed during peak periods.

10.4 Advanced Lighting Sensors and Controls

Connected lighting systems utilizing advanced controls and algorithms to automatically modulate lighting levels in response to external grid/pricing signals and building occupant needs.

10.5 Advanced/Smart Water Heater Controls

Advanced water heater controllers (embedded or external) that can provide multiple forms of value to the grid by leveraging the water heater's energy storage capabilities, depending on the algorithm that is implemented. Very valuable for predictable, scheduled peak load shifting via preheating (thermal storage) or for emergency (no preheating) curtailment.

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[12] FEMP. 2024. "Key Grid-Interactive Efficient Building Technologies for Federal and Commercial Facilities." https://www.energy.gov/node/4844854.

10.6 Automated Window Attachments

Automated window attachments include interior devices, such as blinds, shades, and drapes, and exterior devices, including awnings and shutters, that can be adjusted automatically to reduce solar heat gain. Can also be controlled to provide load shedding with coordinated HVAC controls, though effectiveness depends on attachment material and interior or exterior placement.

10.7 Basic Lighting Sensors and Controls

Typically includes occupancy sensors, scheduling, and/or daylighting controls. Provides efficiency benefits; scheduling can be used to provide basic demand response based on time-of-use pricing.

10.8 Battery Energy Storage System

A type of rechargeable battery with a relatively high charge density. Batteries (e.g., li-ion, lead acid, flow) can be used to store electrical energy during times of excess generation or off-peak periods and used during peak periods to reduce demand and reliance on the grid; typically installed with generation sources or to be used as a backup power source for increased resiliency to power outages.

10.9 Building-Scale Combined Heat and Power

Using natural gas or other fuel sources, combined heat and power systems capture wasted heat from the electricity generation system (e.g., engine, turbine, fuel cell) to satisfy space, water, and process heating loads.

10.10 Electric Vehicles and Chargers

A vehicle that runs on stored electricity and the associated charger that provides power to the battery. Electric vehicles with managed and bidirectional charging will charge according to the local utilities' operational priorities or a grid signal, rather than just charging the electric vehicle when it is plugged in. By using the battery to store energy from the grid, the battery enables load shed and shift.

10.11 Dynamic Glazing for Windows/Fenestration

Dynamic glazing includes a range of chromodynamic coatings applied to glazing that can switch between two or more states that block portions of the wavelengths that lead to solar heat gain in buildings. Reduces cooling load by controlling solar heat gain to provide efficiency and load shedding. Coordinated controls with HVAC calibrated to the building are needed to minimize response time and maximize response magnitude.

10.12 Management Controls for Continuous Operation Electronics/Computing

Controls to automatically reduce power draws, stage loads to avoid peaks, and transition to low-power modes or sleep/idle/off for continuous-operation electronics, including network equipment, set-top boxes, desktop personal computers, servers, and AV equipment.

10.13 Small Wind Turbines

Smaller-scale wind turbines that fundamentally function the same as large wind turbines by capturing kinetic energy from the wind and converting it to mechanical power.

10.14 Smart Power Strips

Advanced power strip that can shut off unused electronics through various means of sensing (e.g., current sensing, infrared, motion). Typically connected to electronics and computing equipment to control or schedule energy demand from these loads.

10.15 Smart Thermostats

Commonly used in residential homes for HVAC control but may be used in smaller commercial buildings without a building automation system. These are typically connected to the internet and allow for scheduling, programming, demand response, and automation.

10.16 Solar Photovoltaic Panels and Inverters

Panels used to capture solar energy and convert the generated DC current into AC current.

10.17 Submetering and Analytics

Circuit-level analytics and submetering platform technologies provide the ability to monitor individual circuits within an electrical panel in a building, providing detailed power and energy consumption data at a much more granular level than was previously achievable in a cost-effective manner. A circuit-level analytics and submetering platform allows for various innovative use cases, such as tenant billing, tenant engagement, measurement and verification, equipment-level benchmarking, automated fault detection and diagnostics, condition-based maintenance, identification of energy conservation measures, time-of-use management, and demand response.

10.18 Thermal Energy Storage

Thermal energy storage technologies heat or cool a storage medium and, when needed, deliver the stored thermal energy to meet heating or cooling needs. Thermal energy storage systems are often integrated with electric or absorption chillers to reduce peak electricity costs. Cool thermal energy storage technologies can be used with combined heat and power systems and absorption chillers to provide additional building space conditioning during high-demand periods when utility electricity tends to be most expensive. Hot water tanks are frequently used to store thermal energy generated from solar or combined heat and power installations.

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