Grid-Interactive Efficient Buildings Made Easy

A GSA Building Manager's Guide to Low- and No-Cost GEB Measures

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How to use this guide: This document provides an overview of grid-interactive efficient buildings (GEBs) and actionable steps for GSA building managers to implement low- and no-cost measures that result in utility cost savings and greenhouse gas (GHG) emissions reductions.

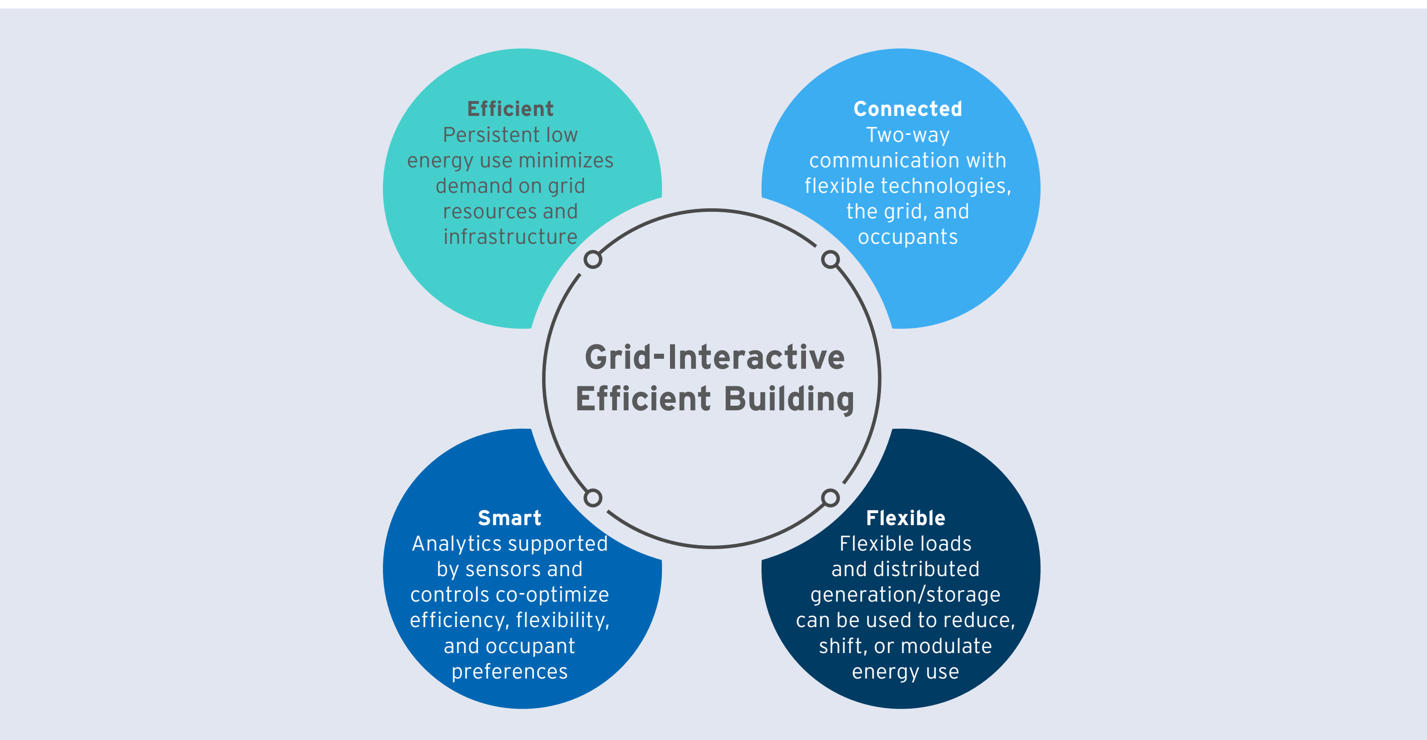
Introduction

What Are Grid-Interactive Efficient Buildings (GEBs)?

Grid-interactive efficient buildings (GEBs) are energy-efficient buildings that flex their energy load from one time to another based on the cost or carbon intensity of grid electricity. GEBs leverage energy efficiency, energy storage, renewable energy, and smart technology to provide load flexibility without compromising occupant needs (Exhibit 1). This creates a more dynamic building that optimizes capital investments, reduces operating costs, and provides access to new revenue.

GEBs build on demand response by responding to grid needs at a more granular and frequent rate. Where demand response events may only happen once or twice a year, GEBs are constantly responding to minute changes to grid price and carbon intensity,

Exhibit 1 **GEBs are efficient, connected, smart, and flexible**



Source: https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings resulting in more beneficial integration between buildings and the grid. Since buildings drive up to 80 percent of the peak demand on energy grids in the United States and energy grids are incorporating more variable renewable generation capacity, grid-interactivity has become more important and valuable than ever.[1] Enabling our buildings to shift load to align with renewable energy generation will help create a more resilient and reliable grid, which can reduce the overall cost of energy for all consumers.

Exhibit 2 illustrates three key differentiators between a grid-interactive efficient building and a building participating in traditional demand response.

Exhibit 2

Three differentiating factors of GEBs versus basic demand response capability

Key Differentiators of Grid-Interactive Efficient Buildings		
Attribute	**Optimized GEB Scenario**	**Demand Response Today**
Two-way communication between building and grid	Ability to receive utility signals (price or carbon) and to communicate load flex potential to grid	Manual, widget-based demand response programs
Interoperability and intelligence across building systems	Single, overarching integrator to monitor and control all loads, including plug and storage loads; ability to optimize for cost, carbon, resilience, etc.	Limited building automation system controls; isolated lighting, storage controls
Load flexibility and demand-focused building optimization	Building-level intelligence to track and map demand, and shift or shed rapidly based on inputs such as price, weather, carbon, peak grid demand, etc.	Isolated applications of thermal energy storage; battery storage

Why Are Grid-Interactive Efficient Buildings (GEBs) Valuable to Building Managers?

Many grid-interactive measures are within the purview of building managers and can be adopted as part of regular operations and maintenance routines without significant changes to building equipment or infusion of capital costs. Many of the strategies supporting GEBs are well-known and can largely be implemented with existing technologies. The innovation is around integration across multiple systems and interoperability with the grid.

A 2019 cost-benefit analysis by RMI, ***Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio***, estimates the savings potential and investment value of GEB measures across the GSA portfolio, including the benefits outlined in Exhibit 3 below.

The value for specific buildings will vary due to regional utility pricing structures, but typically include improved building operations, substantial utility cost savings, and futureproofing against utility rate changes.

How GEBs Help Meet Federal Climate Action Plans

The GSA provides continued leadership and support of federal climate action plans and directives. The United States' commitment to the Paris Climate Agreement and target to reduce 50% of GHG emissions by 2030 from a 2005 baseline means that buildings must:

- increase overall energy efficiency,
- phase out fossil fuel-burning equipment,
- avoid peak electricity demands to help reduce the carbon intensity of the grid, and
- support the integration of distributed renewables and storage into a smarter, more efficient grid.

As part of its commitment to making buildings more affordable, cleaner, and more resilient, the federal government has recently established programs and resources to support GEBs, including a new Federal Building Performance Standard, a national grid-interactive efficient buildings roadmap, and the GSA's blueprint to integrate GEB technologies into energy savings contracts.

Exhibit 3 Value potential of GEBs to the GSA, the grid, and society

Direct Benefits to GSA	Grid and Societal Value	Indirect Value to GSA
• $50M in annual cost savings • $206M in NPV • Project-level payback under four years • Futureproof: Accommodates future rate structure changes and helps manage costs	• Reduce grid-level T&D and generation costs up to $70MM/yr • These savings ultimately benefit the government and taxpayers • Future grid economic models will value savings (e.g., NWA's)	• Demonstrates federal and real estate industry leadership • Enables deeper savings in ESPCs and UESCs • Better building control can improve comfort, health, and productivity • CO_2 savings

Source: ***Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio*, RMI**

Low- and No-Cost Measures for Grid-Interactive Efficient Buildings

The measures provided in this guide are a subset of load flexibility measures that can be implemented with little or no capital investment. In some cases, these measures also improve the energy efficiency of a building but are not intended to be a comprehensive collection of efficiency measures.

The following is a definition of low-cost and no-cost as it applies to this report:

> **No-cost load flexibility measures** are building operational adjustments that fall under the purview of building managers from an operational perspective and require no capital costs.
>
> **Low-cost load flexibility measures** include measures that may require some capital costs but are within the procurement limit for building staff. The procurement limit for building staff varies from region to region. For this guide, we assumed a limit of $50,000.

Implementing Load Flexibility Measures for Grid-Interactive Efficient Buildings

Implementing the low- and no-cost measures below is relatively simple and can be deployed without impacting day-to-day operations. The process starts with three preliminary steps to gauge the impact of these measures in a building, including an evaluation of a building's utility rate structure, controls and automation capability, and daily energy use.

Step 1: Evaluate utility rate structure: Identify utility programs or rates that value the time in which electricity, and in some cases gas, is consumed. These rates can be time-of-use, real-time, or day-ahead pricing, and will have daily, weekly, monthly, or seasonal patterns. Even in situations where a building is not on a time-of-use rate structure, most utilities charge for energy demand and consumption. Utility bill cost savings can be captured from shifting or shedding a building's energy load to minimize premium demand charges. For utility pricing programs available in different regions across the United States, refer to the Federal Energy Management Program's **Demand Response and Time Variable Pricing Programs**.

Leverage the Recommissioning Process

An ideal time to implement the load flexibility measures listed in this guide is while other energy efficiency measures are being implemented during the recommissioning process. An energy audit is performed as part of GSA's recommissioning requirements and provides data that can be used to evaluate a building's load flexibility potential. This data can improve the implementation and efficacy of load flexibility measures.

The Future of Utility Rate Structures

An essential element of ideal grid integration is the ability to receive and respond to grid signals, whether they be cost or carbon. Real-time pricing is an example of this type of grid signal, which allows a building to engage with grid needs more so than other rate structures. Few real-time carbon signals exist today in the United States, but they will become more ubiquitous in the future as efforts to decarbonize grids increase. Buildings can respond to these signals based on a set schedule (as delineated by time-of-use rate structures), modifying sequence of operations, or—ideally—based on a signal integrated into the control system.

Step 2: Assess controls and automation capabilities: When it comes to easily dispatching the most cost-effective load flexibility, an energy management information system (EMIS) is an advanced control system with the highest capability of optimizing whole building energy use. Most GSA buildings are equipped with a building automation system (BAS) that primarily controls HVAC equipment. These systems are still capable of enabling load flexibility but require more manual operation from building staff compared with a fully automated EMIS.

In order to gauge the potential for implementing frequent load flexibility in a building, it is important to understand how well the control system can monitor and manage energy in the whole building. Exhibit 4 provides a reference for understanding the capability of your control system for implementing load flexibility.

Load flexibility is most effective in buildings with control systems on the right side of the spectrum in Exhibit 4. This level of control enables automation to handle the optimization of systems across the building, allowing building managers to "set it and forget it," and load flexibility to be evaluated and implemented at the whole building level. Prioritizing control upgrades in buildings with less advanced systems will maximize the benefits of load flexibility. This guide recognizes the spectrum of control systems in GSA buildings by indicating BAS control requirements necessary for each measure provided.

Exhibit 4 A spectrum for rating the level of advanced control of a building

Basic Control System

- Piecemeal monitoring and management of building systems through building automation system (BAS)
- Pneumatic or other non-digital control
- Monitoring points that are not energy related (e.g., fan status rather than electric draw in kWh)
- Little ability to optimize energy consumption
- Little visibility into how tenants are consuming energy

Advanced Control System

- Holistic management across all building energy end uses through energy management information system (EMIS)
- Direct digital control
- Monitoring that provides granular (hourly to 15 min) energy consumption data
- Two-way communication between building and the grid
- Tenant energy use submetering

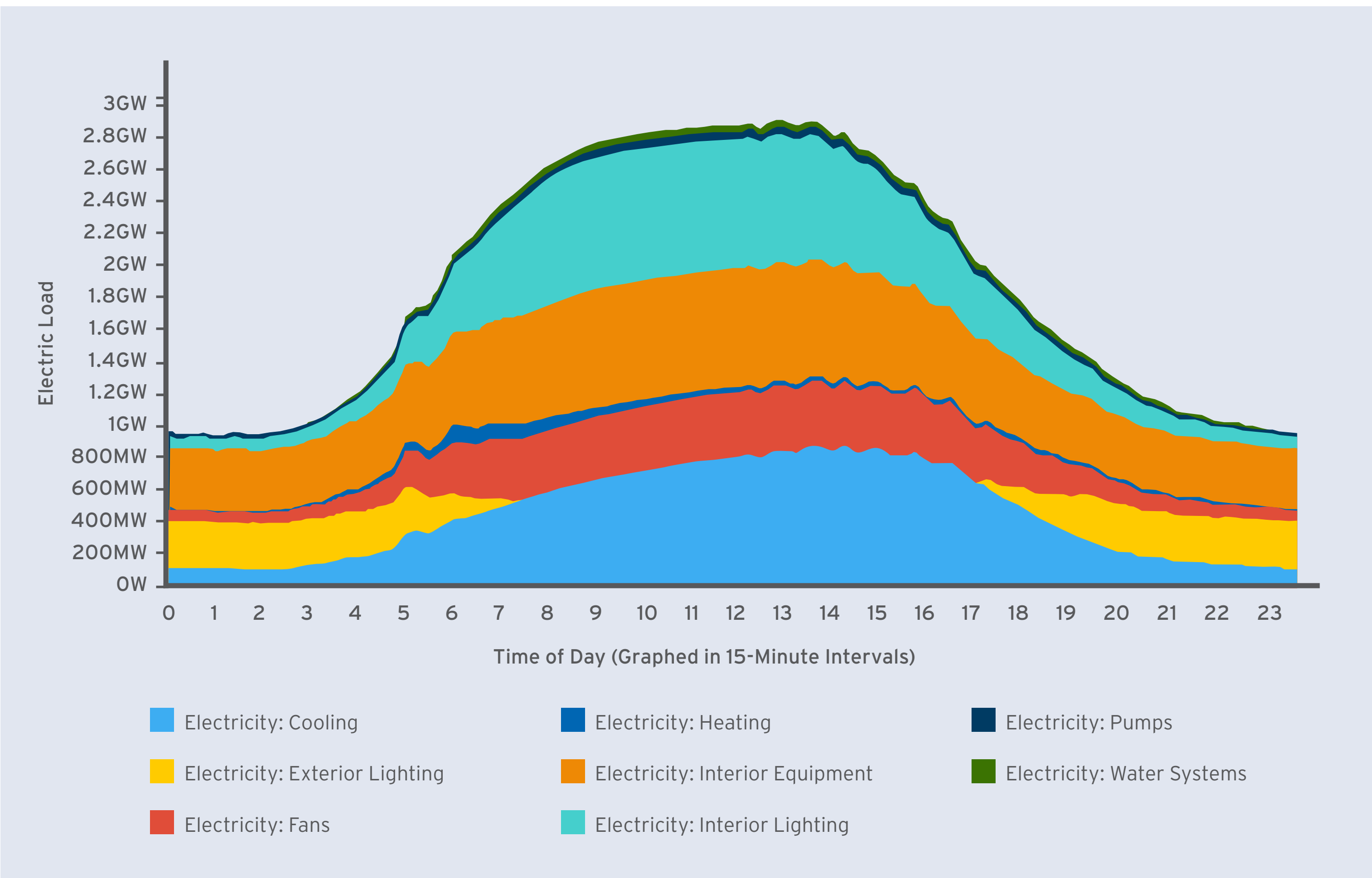
Buildings to the left of the spectrum should be targeted for controls upgrades and will require more manual control by a building manager to dispatch load flexibility.

Step 3: Review daily energy use: Evaluate the daily energy use profile of a building to help identify specific loads that can be shifted to different times. For example, a building's daily energy profile shows that cooling loads peak in the mid to late afternoon and could be made flexible by controlling setpoints during that time or by using thermal storage. Capturing a daily load profile requires the master-metering of the building's total electrical load. An example of a daily load profile can be seen in Exhibit 5.

For buildings with less advanced control systems, some of this analysis can be done manually. BAS data can be used in the place of power (kW, Btuh, etc.) meters, for instance, translating the fan status point (off/on) from the BAS for a constant volume fan to kW electric draw based on the fan's capacity. This effort can be minimized by targeting specific high demand days based on weather and grid peak rather than attempting to analyze every single day in a year. Since much of energy consumption is based on weather patterns (outdoor air temperature, cloud cover, solar radiation), weather is an important variable for choosing which days to evaluate your building's peak load.

Exhibit 5

Example of a daily building load profile broken down by end use



Source: ComStock National Dataset - V1 accessed via comstock.nrel.gov[2]

The following are best in class practices to advance load flexibility and can be adjusted to the unique needs of each building. Managers can sustain occupant comfort in conjunction with measures listed below.

HVAC (Heating, Ventilation, and Air Conditioning)

Optimize Building Operation to Occupancy Patterns

Buildings typically have ample opportunities to optimize operations based on how and when spaces are being used by occupants.

1. Review occupancy patterns in spaces with low traffic. Target spaces that have low occupancy or are transitional based on conversations with occupants and direct observation of use patterns. Bathrooms, large meeting rooms, or offices that are only used occasionally are examples of low occupancy spaces, whereas hallways or atriums are examples of transitional spaces.

2. Modify setpoints or zone-level HVAC settings in targeted spaces during peak hours. This can be done on the HVAC equipment side or by modifying the space thermostat settings. The goal is to reduce energy use in these low occupancy or transitional spaces during peak hours.

    - To modify thermostat settings, temperature setpoints can move up during cooling season and down during heating season. Exhibit 6 gives the P-100 new construction standards for temperature setpoints.

    - On the HVAC equipment, there can be opportunities to "rezone" by adjusting fan flow and decrease/increase supply air temperature settings (depending on heating or cooling season) to minimize energy use and maximize space function.

Exhibit 6 P-100 temperature guidelines for HVAC operation

Baseline	★ Tier 1 High Performance	★★ Tier 2 High Performance	★★★ Tier 3 High Performance
75±3°F cooling, 72±3°F heating Allowance for unoccupied setup and setback optimized with reoccupancy within a range of 55°F to 83°F	Baseline features and add passive control of surface radiant temperature to provide surface radiant temperatures ±7°F of the air temperature	Tier 1 High Performance features and add building automation system control to provide surface radiant temperature ±2°F of the air temperature	Tier 2 High Performance and individual occupant controlled surface radiant temperatures within optimized limits determined by a BAS and optimized air at 75–80°F cooling, 65–72°F heating

Note: For more information on the standards, see the P-100 documentation, section 5.2.1: Temperature: **https://www.gsa.gov/cdnstatic/2018%20P100%20Final%205-7-19_0.pdf**.

Source: PBS P-100 building standards for new construction[3]

BAS Control Requirement: thermostats and HVAC control (systems with temperature and airflow that can be easily adjusted) over targeted rooms, occupancy monitoring.

Optimize Thermal Mass to Building Operation

HVAC and thermostat settings can be managed based on a building's natural affinity for retaining heat or coolth, otherwise known as its thermal mass. Core spaces are good examples of thermal mass because they typically have a natural resistance to heat transfer, with numerous rooms, spaces, and walls between them and the outdoors. Because of their ability to store heat, these spaces could potentially meet most of their heating and cooling needs at off-peak times.

1. **Review the real-time temperature profiles of spaces from BAS data** (especially internal spaces). Areas with substantial thermal mass, such as interior core spaces, will see smaller changes in temperature over the course of the day.

2. **Modify HVAC settings in these targeted spaces during peak hours.** Take a targeted approach to adjusting space temperature setpoints during peak load events based on areas with temperature profiles that do not see significant changes over the course of the day. Flex the setpoints of specific spaces that can manage adjustments to decrease energy consumption. In heating season this would mean decreasing the setpoint. In cooling season, this would mean increasing the setpoint.

   Adjustments can be implemented through two strategies:

   - Stretching warm-up/cool-down timing. This could mean starting a warm-up process at 6 a.m. for the building to be warm at 8 a.m., rather than initiating the warm-up process at 7:30 a.m. The more gradual the warm-up, the less extreme the energy spike will be. Note: HVAC systems typically have optimal start functions that use algorithms to calculate the least energy-intensive warm-up/cool-down patterns.[4]
   - Identify spaces in the building that have temperature patterns that could be smoothed out. Extreme patterns in thermostat readings, such as frequent adjustments between high and low temperatures, are often associated with HVAC ramping up and down in an energy-intensive way. Minimizing this energy intensity during peak times supports grid integration.

BAS Control Requirement: HVAC zoning separated for perimeter and core spaces, thermostats, and HVAC temperature control in targeted spaces.

LEVERAGE GSA REGIONAL SPECIALISTS

GSA regional sustainability program specialists, regional energy program managers, and regional energy engineers are subject matter experts and equipment specialists that can provide detailed technical support on the implementation of GEB measures at the building level. Reach out to your contact for additional assistance.

Maximize Use of Existing Storage Capacity

Typical energy storage systems include: (1) thermal storage in the form of ice, chilled water, hot water, and phase change materials; or (2) battery electrical storage.

- **Use energy storage systems to shift load:** Take advantage of existing energy storage systems by shifting HVAC energy loads to off-peak hours and optimizing for utility rate structures. Double check thermal storage system schedules and sequence of operations to ensure they are operating as efficiently as possible and consider adjusting operations to account for utility rate structure or regional carbon emissions intensity.

Optimize Control System Algorithms and Sequence of Operations

Buildings that have a BAS can use targeted computer programming to manage demand based on rate structure, carbon intensity, and/or grid needs. The following are a few examples of actions that can be taken during peak hours to minimize building demand.

- **Stage HVAC equipment:** High-load equipment can be programmed to run in sequential stages, rather than all at once. The optimal application of this programming is to use it for minimizing peak demand in the building, rather than simply responding to a demand response event. RMI's GEB analysis of the GSA portfolio in 2019 found that HVAC staging is one of the most effective measures for managing peak demand on a regular basis. Examples of equipment that can be considered for staging include:

    1. Cooling and heating coils (e.g., central system/air handling unit (AHU) and terminal units)

    2. Cooling system compressors (e.g., dx coils, chillers)

    3. Fans (e.g., central system/AHU, cooling towers, and terminal units)

        Using fans as an example, here is an equipment staging process during a peak demand event:
        1. Coordinate ramping AHUs up so that the significant energy spike does not happen during a grid peak time. Allow them to turn on in sequential stages, rather than all at once.

        2. Leverage fan cycling sequences to meet space conditioning and ventilation needs without overworking one single bank.

- **Optimize air temperature and fan control.** These measures should be conducted within a holistic recommissioning effort since they can involve energy trade-offs.

    1. Decrease the supply air temperature setpoint. Depending on dehumidification requirements this could mean changing temperatures from 55°F–60°F to 50°F or below.

    2. Decrease fan speed so that space temperatures can maintain occupant thermal comfort. The optimization between fan speed and supply air temperature can occur within the algorithms and sequences of the EMIS control but might require some active management and thermostat observations from facility managers.

- **Bring in outside air prior to high demand times.** ASHRAE ventilation requirements are usually integrated into control systems based on occupancy, CO_2, or relative humidity sensors. Bringing in outside air is necessary for occupant health and comfort, but the timing of this ventilation can be adjusted to minimize outdoor air conditioning needs during peak times.

    1. Increase outside airflow by modifying the outdoor air intake damper position during off-peak times.

    2. Decrease outside airflow during times of peak energy costs, peak building energy demand, or peak grid carbon intensity.

BAS Control Requirements: AHU fan/coil control, occupancy/CO_2 monitoring, controllable outside air damper.

Lighting

Fully controllable LED fixtures can be programmed to shed or modulate load during peak hours and should be set to avoid impacting occupant comfort, productivity, and safety.

- **Automate controlled lighting:** Program lighting systems to automatically reduce lighting levels in spaces that have ample daylight, such as perimeter spaces, or do not require constant lighting, such as storage rooms or other infrequently occupied spaces. A 2014 study found that lighting in commercial buildings may be dimmed as much as 20% (and as much as 40% in areas with daylighting) without affecting occupant comfort, productivity, or safety.[5]

BAS Control Requirements: LED lighting with connectivity to daylight sensors and dimming ability.

Occupant Engagement and Education

As utility rate structures evolve, continue to educate and engage tenants on the impacts of their energy use. Plug and process loads, which are entirely under the tenant's control, represent 25% to 50% of electricity use in a typical building and are the fastest growing energy end use.[6] Plug loads and process equipment are a low-risk, high-yield opportunity to manage electricity consumption during peak hours. GSA building managers can help tenants reduce plug loads in their spaces by:

- Sharing energy use data with tenants so that they are aware of their energy consumption habits and installing dashboards that track energy consumption and carbon.
- Assisting the implementation of a plug load reduction strategy that includes energy-saver modes for multifunction printer devices during peak hours and staging banks of laptop charging during peak times so they are not all charging at once.

Conclusion

Beyond Low- and No-Cost

To realize the full value potential of grid-interactive efficient buildings, building managers should implement GEB measures that go beyond low- and no-cost. Buildings that are subject to time-of-use utility pricing, are all-electric or have future electrification planned, or have existing energy storage and renewable energy capabilities are most likely to receive the highest payback by implementing grid-interactivity adjustments. Upcoming renovations or equipment replacement projects present ideal opportunities to add GEB measures to the scope of work, particularly in energy savings performance contracts (ESPCs) or utility energy service contracts.

Furthermore, premium time-of-use and peak-demand utility rate structures are becoming commonplace. To reduce potential cost impacts and anticipate future grid decarbonization, building managers should consider "GEB-ready" measures, such as requiring smart controls on lighting, HVAC equipment, and other electric fixtures and equipment and integrating all new equipment into a central EMIS.

GEB Resources

The following resources provide information that can help building managers implement grid-interactive efficient building measures beyond low- and no-cost:

- For information on implementing GEB measures though ESPCs, refer to ***Blueprint for Integrating Grid-Interactive Efficient Buildings Technologies into U.S. General Services Administration Energy Performance Contracts***, NREL 2021
- For case studies on implementing GEB measures in GSA buildings, refer to ***Grid-Interactive Efficient Building Case Studies in the Federal Portfolio***, GSA 2020
- For information on the value potential of GEBs, refer to ***Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio***, RMI 2019
- For in-depth evaluations of GEB technologies spanning HVAC, water heating, refrigeration, lighting and electronics, building envelope, and controls, refer to the Department of Energy's **GEB Technical Report Series**
- For utility pricing programs available in different regions across the United States, refer to the Federal Energy Management Program's **Demand Response and Time Variable Pricing Programs**

Endnotes

1. *Grid-Interactive Efficient Buildings*, US Department of Energy, Office of Energy Efficiency and Renewable Energy, 2019, **https://www.energy.gov/sites/prod/files/2019/04/f62/bto-geb-factsheet-41119.pdf**.

2. Natalie Mims Frick, et al., *End-Use Load Profiles for the US Building Stock: Market Needs, Use Cases, and Data Gaps*, Lawrence Berkeley National Lab, 2019, **https://emp.lbl.gov/publications/end-use-load-profiles-us-building**.

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4. Rick Stehmeyer, *Building Energy Resilience Blog: Optimal Start/Stop and You're Done, Right?*, Cx Associates, 2018, **https://buildingenergy.cx-associates.com/optimal-start/stop-and-youre-done-right**.

5. Guy Newsham and Mary Ann Piette, *Demand-Responsive Commercial Buildings*, NRC Publications Archive, 2014, **https://nrc-publications.canada.ca/eng/view/ft/?id=c52b4228-e3e2-4b91-986d-dbba8ba72946**.

6. I. Metzger, et al., *Reducing Office Plug Loads through Simple and Inexpensive Advanced Power Strips*, National Renewable Energy Laboratory, 2014, **https://www.nrel.gov/docs/fy13osti/57730.pdf**.

Authors & Acknowledgments

Authors

Cara Carmichael
Rebecca Esau
Edie Taylor

Authors listed alphabetically. All authors from RMI unless otherwise noted.

Additional Contributors

Kinga Porst Hydras, US General Services Administration
Ken Sandler, US General Services Administration

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Robert Pajer, US General Services Administration
John Palmer, US General Services Administration
Kevin Powell, US General Services Administration
Sheldon Mendonca, RMI
Connor Usry, RMI

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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RMI Innovation Center
22830 Two Rivers Road
Basalt, CO 81621

www.rmi.org