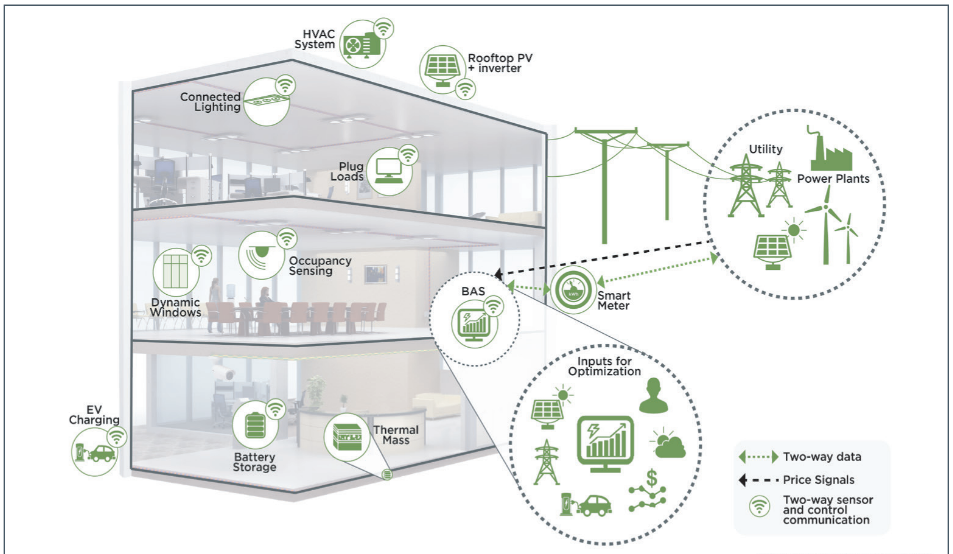
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# Grid-interactive Efficient Buildings

The U.S. Department of Energy's Building Technologies Office (BTO) envisions a future in which buildings operate dynamically with the grid to make electricity more affordable and integrate distributed energy resources while meeting the needs of building occupants.



Grid-interactive efficient building. *Image courtesy of Navigant Consulting.*

## Why are buildings important to grid modernization?

Growing peak electricity demand, transmission and distribution infrastructure constraints, and an increasing share of variable renewable electricity generation are challenging the electrical grid. As the grid becomes increasingly complex, demand flexibility can play an important role in helping maintain grid reliability, improving energy affordability, and integrating a variety of generation sources. Buildings can provide flexibility by reducing energy waste, helping balance energy use during times of peak demand and/or plentiful renewable generation, and reducing the risk of frequency deviations.

Buildings consume approximately 75% of U.S. electricity and drive as much as 80% of peak power demand in some regions.[1,2] Although buildings are the key driver of electricity demand, they can also be a part of the solution to peak demand issues. Electrical loads in many buildings are flexible and through advanced controls can be managed to operate at specific times and at different output levels. Estimated technical energy savings potential for sensors and controls is nearly 30% in the commercial sector alone.[3]

Advanced controls and communications enable buildings to adjust power consumption to meet grid needs through a variety of control strategies applied to existing equipment, such as lighting and heating, ventilating, and air conditioning (HVAC), along with on-site assets like solar photovoltaics (PV), electric vehicle (EV) charging, and electrical storage. These control strategies can change the way a building schedules energy use to avoid high peak load costs or to make building operations more resilient. Strategies may include reducing energy consumption, shifting energy to another time period, adjusting the power draw, or even increasing energy consumption to store for later use.

## What is a grid-interactive efficient building (GEB)?

Today, behind-the-meter distributed energy resources (DERs)—including energy efficiency, demand response, solar PV, EVs, and battery storage—are typically valued, scheduled, implemented, and managed separately.

The GEB vision is the integration and continuous optimization of DERs for the benefit of building owners and occupants, as well as the grid. As shown above, a GEB utilizes analytics and controls to optimize energy use for occupant patterns and preferences, utility price signals, weather forecasts, and available on-site generation and storage.

The graphic below outlines the key characteristics of a GEB. These buildings are *energy efficient*: High-quality walls and windows, high-performance appliances and equipment, and optimized building designs are used to reduce both net energy consumption and peak demand. Second, they are *connected*. The ability to send and receive signals is required to respond to grid needs that are time dependent. They are also *smart*. Analytics supported by sensors and controls are necessary to optimally manage multiple behind-the-meter DERs in ways that are beneficial to the grid, building owners, and occupants. Finally, they are *flexible*. The building energy loads can be dynamically shaped and optimized across behind the meter generation, EV, and energy storage.

### GEB Key Characteristics

| EFFICIENT | CONNECTED | SMART | FLEXIBLE |
|---|---|---|---|
| Persistent low energy use minimizes demand on grid resources and infrastructure | Two-way communication with flexible technologies, the grid, and occupants | Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences | Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use |

## What are the GEB benefits to building occupants and owners?

### A Continued Focus on Energy Savings

Energy efficiency has long been recognized by utilities as a cost-effective load management strategy. Efficient appliances, equipment, and whole building energy optimization reduce both overall energy consumption and peak demand. Energy efficiency measures combined with load flexibility, including demand response and storage, can further reduce utility bills by shifting peak load costs.

GEBs go beyond efficiency by harnessing the flexibility of their equipment and loads and deploy that flexibility as a new value stream and provide solutions to grid needs.

## Grid-interactive Efficient Building Research Focus Areas

In collaboration with key stakeholders in industry, academia, and research institutions, BTO's R&D is strategically addressing market barriers and technical challenges while also considering cybersecurity concerns arising from the increasing interconnectedness of buildings and the grid. These efforts are advancing key technologies and solutions to provide grid services that reduce the overall cost of electricity for all customers and will contribute to a future GEB strategy to advance the role buildings can play in energy system operation and planning.

| Focus Areas | Featured Projects (BTO) |
|---|---|
| **GEB value proposition:** Includes identification of inputs needed for determining the impact of flexibility on building load shapes, analysis on demand flexibility potential, and work related to GEB stakeholder value propositions. | **End Use Load Shapes** – this project will determine end-use load profiles on an hourly scale of the U.S. building stock. |
| **Building technologies for flexible loads:** Includes building technologies R&D activities focused on providing greater flexibility in building loads. | **Connected Lighting Systems** – this project will research ways to enable significant lighting energy savings and further systems integration. |
| **Optimization of building systems individually and across buildings:** Includes research in sensing, control, and modeling to enable individual building energy performance optimization, as well as optimization across a set of buildings. | **Responsive Residential Loads** – this project will research utilizing residential appliances (e.g., water heaters) for grid services, using control signals and interactions with the grid. |
| **Validation & verification of building performance for grid service:** Includes lab and field verification and validation of building technology performance and controls optimization. | **Connected Neighborhoods Research & Field Verification** – this project aims to validate a "smart," neighborhood-level, buildings-to-grid integration strategy. |

### Research in Action: Connected Neighborhoods Project

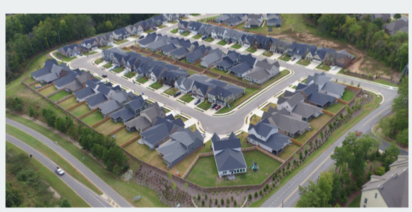


*Photo courtesy of Southern Company*

This Smart Neighborhood, located in Reynolds Landing at Ross Bridge in suburban Birmingham, Alabama, integrates high-performance homes, energy efficient systems and appliances, connected devices, and a microgrid on a community-wide scale for the first time in the Southeast. With 62 homes, it supports the community's energy needs by using leading-edge microgrid technology with solar panels, battery storage, and a backup natural gas generator. Alabama Power partnered with homebuilder Signature Homes, researchers at Southern Company, U.S. Department of Energy's Oak Ridge National Laboratory, the Electric Power Research Institute, and others on this project.

### Improved Functions: Resilience & Comfort

Smart devices connected to the Internet offer building occupants a new level of functionality and convenience. Some 200,000 smart devices are being connected worldwide every hour, and the U.S. market is growing at roughly 20% annually.[4] GEB homes and offices that include these connected and devices can produce new levels of comfort while providing building owners and operators added control and flexibility through room-level heating and cooling capabilities, tunable lighting, smart devices and appliances and automated building management. Additionally, buildings with advanced controls can integrate DERs and prioritize critical loads for resiliency while increasing comfort and minimizing energy waste. ■

### References


1 U.S. Energy Information Administration. 2018. Annual Energy Outlook 2018. Washington, DC: U.S. Department of Energy. eia.gov/outlooks/aeo/

2 Estimates based on internal BTO analysis.

3 PNNL. "Cut U.S. commercial building energy use 29% with widespread controls." Accessed March 2019. pnnl.gov/news/release.aspx?id=4422

4 U.S. Department of Energy. "Buildings and the Grid 101: Why Does it Matter for Energy Efficiency?" Accessed March 2019. energy.gov/eere/ buildings/articles/buildings-and-grid-101-why-does-it-matter-energy-efficiency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