Grid-Interactive Efficient Building Utility Programs: State of the Market

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Abstract

Grid-interactive efficient buildings (GEBs) are energy-efficient, grid-connected buildings that use distributed energy resources (DERs) and optimize energy use for grid services. Sometimes also called smart buildings, they feature information and communications technologies able to respond to signals from the grid to modify energy demand. GEBs can help utilities manage grid operations and lower system costs, and they deliver customer value in the form of reduced bills, improved worker productivity, and enhanced comfort. Energy savings from GEBs can also help meet state, municipal, and utility energy efficiency and emissions goals. This paper examines the current status of utility-run GEB programs in the United States. We describe early examples of pilots and programs, discuss barriers to further adoption, and conclude with recommendations to help utilities and program administrators take advantage of this new opportunity.

Introduction

The electric utility industry is undergoing a fundamental transformation due to advances in technology, changing customer preferences, and market developments. Now that LEDs are becoming the norm, utilities are looking for dramatic new energy-saving opportunities. Many states and municipalities want to drastically reduce emissions from power plants and on-site fuel combustion. The rapid growth of distributed energy resources (DERs) including renewable generation and energy storage is also helping to drive this transformation.[1]

As more renewable and other distributed resources become part of the supply and distribution systems, the grid requires greater flexibility so it can respond dynamically and reliably to meet customer demand at the lowest reasonable cost. An increasing number of jurisdictions are considering or already implementing building electrification requirements. Electric vehicles are also starting to gain substantial market share. Such trends will add new loads to utility grids, which can strain existing transmission and distribution systems.

The fact that buildings are becoming smarter and more connected may also help address this need for higher energy savings levels and increased flexibility in energy demand. Smart building market research estimates that between 2017 and 2022 more than five billion new Internet of things (IoT) devices (such as connected thermostats, smart lighting controls, and smart security systems) will be connected in residential and commercial buildings worldwide (Memoori 2018). These devices enable smart energy management by giving occupants greater insights into and control over their energy consumption.

Retrofitting commercial buildings with smart connected equipment can reduce total energy consumption by 8–18% (Perry 2017).[2] Some analyses estimate even greater energy savings in newly constructed buildings. Smart connected equipment can also help manage *when* a building uses energy and how much it uses. Buildings with efficient energy consumption and demand flexibility are called grid-interactive efficient buildings (GEBs). Although the popular press also uses the term *smart buildings,* as we explain later, a GEB is more than just a standard smart building.

GEBs can reduce energy demand and utility costs and increase customer energy bill savings. They have great potential as a demand resource and as a tool for more-efficient management of the utility grid. They can help mitigate grid stresses, for example by shifting loads to avoid steep ramps and high demand peaks. GEBs can also assist with curtailing renewable energy during times when it is overproduced. From a distribution perspective, GEBs function as a nonwires alternative that helps utilities avoid or defer grid upgrades.

The US Department of Energy (DOE) Buildings Technology Office has put forth a vision for GEBs. In this vision, buildings take advantage of energy-efficient materials and equipment to help minimize energy use. In addition, they contain other DERs, such as energy storage,

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[1] Demand response encompasses various customer actions taken to reduce or shift electric load in response to signals or requests from a utility or system operator, usually to provide load relief at a time of high system demand. Energy efficiency signifies measures and technologies implemented by customers that reduce the amount of energy used whenever the device is operated.

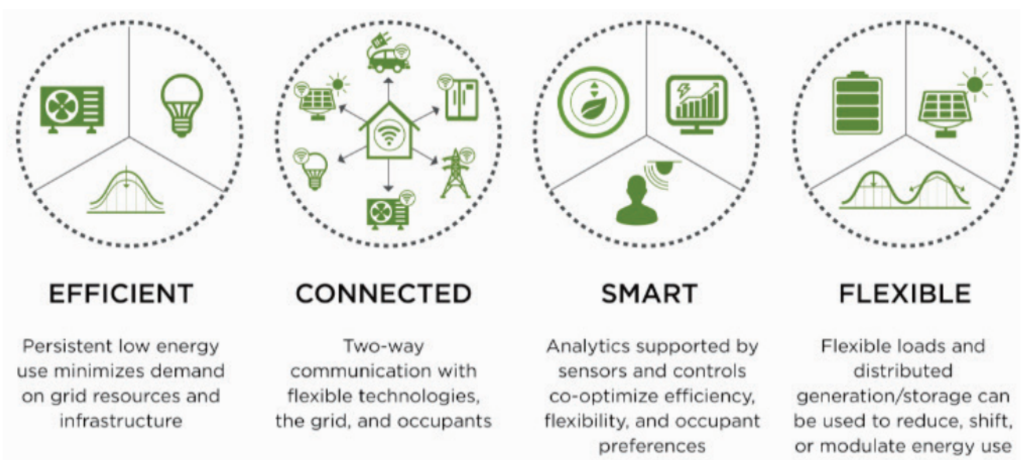
[2] Sectors considered in the analysis include office, retail, hotel, and hospital.

rooftop solar photovoltaics (PVs), and grid-connected water heaters.[3] These end uses will be "dynamically managed to help meet grid needs and minimize electricity system costs," while also meeting building occupants' expectations for experience and comfort (Neukomm, Nubbe, and Fares 2019). These end uses will be managed through hardware such as sensors, actuators, and controllers as well as through software algorithms that allow equipment to exchange data and interact with other equipment and systems.

GEBs can be a key piece of a utility's solution to increase energy savings and emissions reductions, manage grid operations, and lower system costs, while also delivering customer value in the form of reduced bills, improved productivity, and greater comfort. Despite this potential, few utility-sector energy efficiency programs integrate energy efficiency and connected, interactive measures (York, Relf, and Waters 2019). This brief presents early examples and recommendations to help utilities and program administrators develop programs that focus on GEBs and their benefits.

Features of a Grid-Interactive Efficient Building (GEB)

GEBs can be viewed from two perspectives: that of the individual building system, and that of the building as part of the grid system. From a building systems perspective, GEBs are first and foremost energy efficient. They are well insulated, have energy-efficient windows, and use highly efficient mechanical and lighting systems. These buildings use smart equipment, sensors, and controls to optimize energy use based on occupancy, weather, and other factors. In the commercial sector, such controls could include an energy management and information system (EMIS), submeters, advanced power strips, electronic window solar film, and smart lighting controls. In the residential sector, only a subset of these controls may be used, sometimes in combination with other DERs such as solar PVs, energy storage, and electric vehicles. Figure 1 shows the four main GEB characteristics according to DOE.



[3] We define DERs as "resources sited close to customers that can provide all or some of their immediate electric and power needs and can also be used by the system to either reduce demand (as with energy efficiency) or provide supply to satisfy the energy, capacity, or ancillary service needs of the distribution grid" (Baatz, Relf, and Nowak 2018). Energy efficiency is considered a DER because it acts as a resource for the grid by reducing overall energy demand. However, since utility programs typically separate energy efficiency and demand response/flexibility, we generally refer to efficiency separately from other DERs in this paper.

Figure 1. Characteristics of grid-interactive efficient buildings. *Source:* DOE 2019.

Since the building is already energy efficient, it will have a lower overall energy demand during peak times than similar buildings, which is valuable to the grid. The GEB's unique feature as compared to an efficient smart building is its ability to connect and interact with the local grid system. The two-way flow of information between the grid and a GEB enables the building to act as a flexible resource for grid managers. For instance, the building can draw on energy storage when the grid is at peak use, thereby shifting its load. It can also reduce load during peak times, such as through dimming lights or reducing HVAC energy consumption. Figure 2 shows the elements commonly found in a commercial GEB.

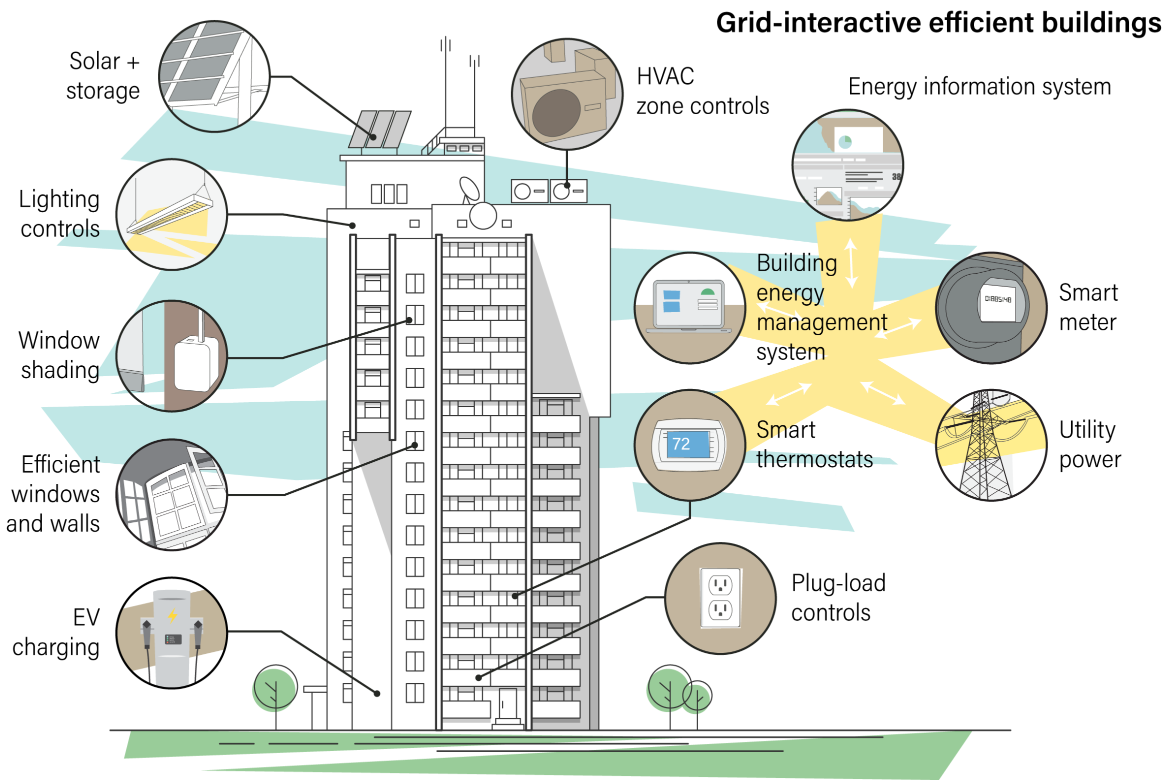


Figure 2. Example of a commercial GEB

The Value of GEBs for Utilities and Their Customers

GEBs can provide many benefits and opportunities for utilities and their customers. Through surveys and interactions with utilities in a GEB working group,[4] we learned that the most important benefits to utilities and program administrators are customer bill savings, flexible demand, system efficiency, and grid reliability. Other forms of potential value that were less commonly cited include increased understanding of customer loads and strengthened customer relationships.

[4] More information on ACEEE's GEB Utilities Working Group can be found at aceee.org/grid-interactive-efficient-buildings-gebs.

Customer Energy and Bill Savings

GEB technologies can allow utilities to deliver multiple energy savings opportunities to their customers. At the most basic level, grid-interactive technologies can deliver energy savings. ENERGY STAR-certified connected thermostats, for example, are estimated to offer at least 8% energy savings over traditional thermostats (EPA 2019). Grid-interactive technologies also deliver savings by enabling greater system control and smart energy management. For example, large commercial buildings with an EMIS can analyze data from smart devices and sensors to identify energy-saving opportunities such as reducing heating in unoccupied areas and diagnosing inefficiently operating equipment. Lawrence Berkeley Laboratory estimates that, when using best practices, EMIS technologies can offer 10–20% energy savings by enabling better energy management and control (Singla and Granderson 2017).

In addition to saving overall energy, GEBs can deliver further customer bill savings when rates or bill credits closely reflect system costs at different times of day. For example, GEB technologies that are qualified to participate in demand-response programs enable customers to receive compensation for reducing or shifting their energy consumption during demand-response events.

GEB technologies can deliver additional cost savings in service territories that offer time-varying rates because customers can shift their demand to low-cost periods and reduce it when costs increase. GEBs can also deliver sustainable customer cost savings in areas with high-demand charges, where large commercial and industrial customers are charged a monthly fee based on their facility's individual peak demand from that month. In some areas, these fees can account for as much as 70% of a customer’s energy bill (McLaren et al. 2017).

Working together, energy efficiency, smart energy management, demand response, and load shifting can lead to substantial customer savings. For example, Rocky Mountain Institute (RMI) evaluated the potential value from GEB buildings in the Government Services Administration (GSA) building portfolio and found that GEBs could achieve $50 million in annual cost savings, which equates to about 20% of the GSA’s annual energy costs (Carmichael et al. 2019). The analysis revealed that the buildings with the greatest cost savings potential from GEB technologies were those in areas with high-demand charges, moderate-to-high electricity consumption charges, and time-of-use rate structures.

Load Flexibility and Demand Response

GEBs provide flexible demand to the grid. While energy efficiency and customer self-generation, such as from PV systems, can reduce and offset customer energy demand, they can also strain the grid depending on when they save or generate energy. For example, solar PV can reduce energy loads during the day but may also require steep supply ramping when the sun goes down and other types of supply or storage resources are needed to meet residential loads. Grid-interactive technologies can help smooth these peaks by shifting demand from times of peak demand to times of high peak supply. Figure 3 shows the value of flexible demand combined with energy efficiency.

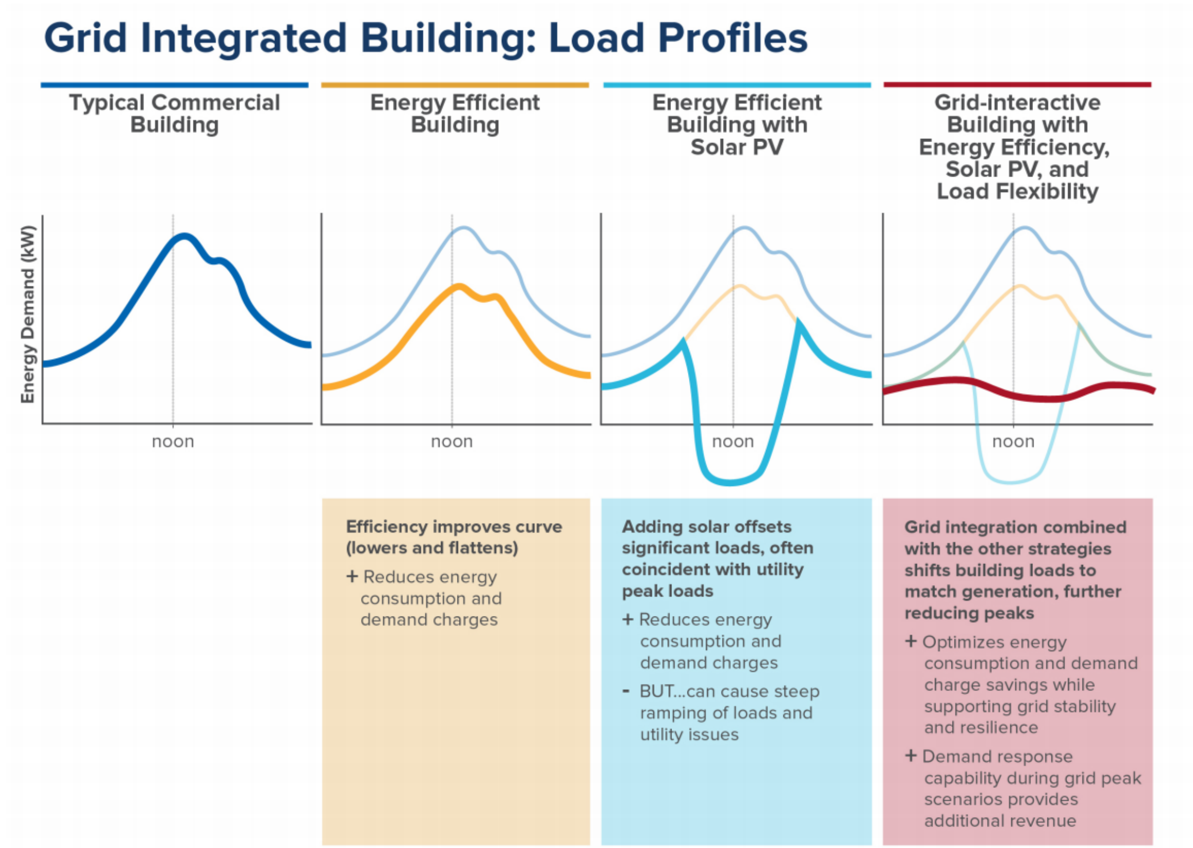


Figure 3. Flexible demand. *Source:* Carmichael et al. 2019.

Load flexibility builds on the foundations established by load management and demand-response programs as early as the 1970s. Such programs and associated technologies enable utilities to signal customers to take actions to reduce or shift load at specific times. In some cases, the utility can remotely initiate such changes, such as by cycling central air conditioners off for short periods to reduce power demand. Demand-response approaches are more dynamic than early load-management programs and typically involve some price signal from grid operators to encourage customer actions to reduce load.

In some cases, the role of controlling connected DERs based on grid signals may fall to third-party aggregators. For residential buildings, aggregators may form partnerships with DER equipment manufacturers—such as NEST, Tesla, and Honeywell—to gain the ability to control their units. However, for commercial buildings, aggregators typically still use methods that rely on customers' manual demand responses, which may be based on day-ahead signals. Thus, instead of controlling connected DERs in real time based on grid signals, the aggregator typically sends a message to the building and the building operator, who then responds by manually reducing lighting or HVAC (depending on that building's demand-response protocols).

Grid Efficiency

GEBs can increase system efficiency and grid reliability. Grid operators can use dynamic building loads to smooth out both supply and demand peaks, increasing the electricity system's efficient operation. For example, connected thermostats and HVAC controls can be used to precool spaces during times of peak energy supply and thus reduce cooling loads during times of peak demand. Relieving strain on the grid reduces the likelihood of power outages and brownouts, improves power quality and grid reliability, and can moderate wholesale electricity markets by avoiding the high price spikes that can occur during peak demand periods. Reducing congestion can provide other ancillary grid benefits such as frequency regulation and distribution voltage support (Carmichael et al. 2019).

Grid Infrastructure Modernization

Traditionally, utilities have had to invest in expensive generation, transmission, and distribution infrastructure to meet growing peak demand and balance variable loads. More recently, a growing number of utilities have begun exploring and investing in nonwires solutions such as energy efficiency and DERs to meet future capacity needs. For example, ConEd's Brooklyn-Queens Demand Management (BQDM) project is a nonwires solution to meeting forecasted overloaded capacity in the Brooklyn and Queens service areas. Instead of pursuing a new substation, the BQDM project combines many smaller generation and efficiency projects to relieve 52 megawatts of energy demand in the area.[5] By summer 2018, the company achieved over 35 MW customer-side load reductions; the anticipated savings will grow past 41 MW by 2021. Some of the project's nonwires solutions included a residential direct-install lighting program, a free audit and direct-install program for commercial buildings, and a demand-response auction (Reilly 2019). GEBs present another asset to include in future nonwires solution projects.

Greenhouse Gas Emissions

GEBs reduce greenhouse gas (GHG) emissions in several ways. Efficient and smart buildings use less energy and therefore require less energy generation, which in turn leads to fewer GHG emissions. Flexible demand from GEBs can also reduce the reliance on carbon-intensive energy supply to balance variable renewables. As an example, an RMI model estimates that a portfolio that relies on demand flexibility rather than natural gas generation to balance loads produces 20% fewer CO_2 emission each year (Goldenberg, Dyson, and Masters 2018).

In a similar fashion, reducing peak electricity demand can lead to emissions reductions by avoiding the need to power up inefficient sources of generation. Some states, such as California and New York, are starting to reevaluate their reliance on inefficient and often older "peaker plants" to meet their peak electricity needs. New York's Department of Environmental Conservation estimates that its peaker plants emit at least 30 times the level of NOx as newer power plants (Walton 2019).

Scaling Up to GEB Programs

Our research concluded that no existing programs or pilots qualify as a full-fledged holistic GEB program. However we observed a number of utility programs and pilots that promote aspects of the GEB vision for programs. These tend to fall into one of two categories: programs that primarily focus on energy efficiency, or programs that focus on grid

[5] They planned to use utility-scale projects and traditional infrastructure projects to meet the remaining demand.

interactivity. While some programs may promote both, they often clearly prioritize one over the other, and thus miss opportunities for greater customer and grid benefits. See Appendix A for the published sources of the program information in this section.

Program types can be arranged on a scale that stretches up to integrated GEB programs. On one end, programs deliver either basic demand response for the grid or energy savings for customers. Moving up the scale, programs use an increasing number of connected and integrated technologies to provide smart energy efficiency and load-flexibility benefits. Figure 4 shows this scale.

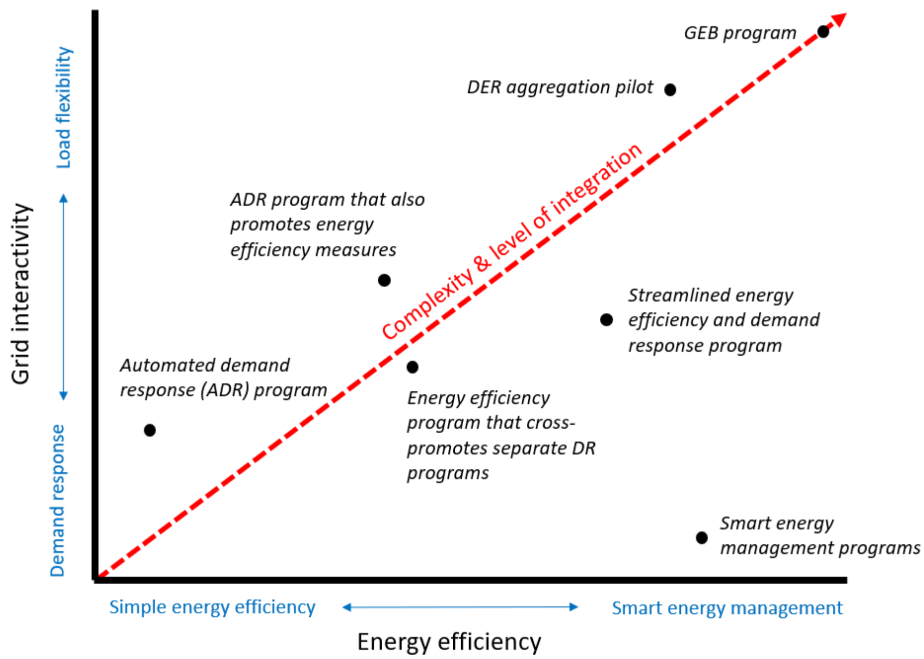


Figure 4. Scaling up to GEB programs

Energy Efficiency–Focused Programs

Energy efficiency programs that promote smart energy management can be precursors to future GEB programs because they encourage building owners to adopt the technologies and services necessary to control and optimize energy loads. Currently, these programs encourage optimizing loads to efficiently meet occupant needs; in the future, such programs may also encourage load optimization to provide benefits to the grid.

For residential and small commercial buildings, smart energy management programs typically promote and incentivize individual smart devices such as connected thermostats and smart plugs. Programs for large commercial buildings typically require more complex offerings such as integrated EMIS with advanced sensors and controls. For example, NYSERDA's Real Time Energy Management (RTEM) program provides incentives to large commercial and multifamily customers that purchase EMIS from qualified vendors. To qualify, vendor products must include several smart control features such as energy consumption tracking, energy performance analysis, equipment-level data collection, interval data collection (at least every 15 minutes), and recommended or implemented energy-saving actions based on data analysis.

Increasingly, efficiency programs are finding ways to integrate with demand-response programs. At the most basic level, some efficiency programs include smart devices and cross-promote separate demand-response programs. For example, many home performance programs now include connected thermostats as an incentivized measure and help customers enroll their devices in demand-response programs.

A few utilities provide a single streamlined program that simultaneously promotes energy efficiency and demand-response offerings. For example, NV Energy's Business Solutions Center program provides a one-stop shop that helps commercial customers identify and install energy efficiency measures and smart thermostats that enable greater energy management; it also auto-enrolls qualifying devices into demand-response programs. Utility marketplaces are another common type of streamlined program. Some utility marketplaces offer both efficiency and demand-response rebates for qualifying devices. For example, Fort Collins Utilities marketplace offers streamlined rebates for connected thermostats and water heaters and automatically applies them at checkout.

Some utilities offer smart home and business programs that include various smart devices and auto-enroll qualified devices in demand-response programs. For example, AEP Ohio's It's Your Power program provides customers a home energy management device, called The Energy Bridge, that connects their home to a smart energy meter and displays real-time energy use data through a phone app. The program markets smart devices that can connect to The Energy Bridge; these devices include connected light bulbs, door sensors, motion sensors, and smart thermostats. The program also lets customers participate in demand response. Through the app, the utility will inform customers of demand-response events and show them how to reduce their energy consumption if they choose to participate. This type of program is well aligned with the GEB vision because it promotes smart, efficient energy management as well as offers a basic level of grid interactivity.

Grid Interactivity–Focused Programs

For the most part, utilities promote grid interactivity to customers through demand-response programs and pricing. These programs can vary in the level of control and load flexibility they offer to the grid. A simple program may just inform participants of a demand-response event and provide behavioral nudges or incentives to adjust their energy use. Pricing signals can also encourage buildings to adjust loads. More advanced programs allow utilities or third-party aggregators to directly control devices to reduce energy consumption without customer interaction.

Automated demand-response (ADR) programs are a common program type that enables end users to provide demand-flexibility services. ADR programs incentivize customers to install advanced communication equipment so that the utility can then send signals that tell connected equipment to shed energy use in predetermined ways. While ADR programs promote technologies (such as real-time energy data analytics and greater systems control) that enable smart energy management, energy efficiency is usually a latent program benefit.

Duke Energy Carolina's EnergyWise Business program is one such ADR program. The utility provides free smart thermostats and Wi-Fi switches for HVAC equipment and covers the costs for professional installation. Customers can then opt in to different participation levels for demand-response events; in return, they receive a commensurate annual bill credit.

In the Pacific Northwest, a collaborative pilot program offered by Bonneville Power Administration (BPA), Portland General Electric (PGE), and the Northwest Energy Efficiency Alliance (NEEA) quantified the peak load reduction and energy-shifting benefits of grid-connected water heaters. Because nearly 70% of the connected water heaters in the program were high-efficiency heat pump water heaters, energy efficiency was a latent benefit and energy savings were not quantified.

Some utilities go to greater effort to promote energy efficiency measures through their ADR programs. For example, Pacific Gas and Electric's (PG&E's) ADR program offers additional incentives to participants that install energy efficiency measures at the same sites that participate in demand-response events. It also requires participating facilities to receive an on-site audit that identifies both demand-response and energy-saving opportunities. Similarly, Dominion's Smart Thermostat program primarily encourages customers to purchase smart thermostats and participate in demand-response events, but it also sends participants individualized information about their energy consumption and recommends behavior changes to save more energy.

Beyond demand response, no utilities offer programs where grid-interactive technology provides real-time demand flexibility to the grid, optimized to match generation. Some utilities such as Sacramento Municipal Utility District (SMUD) and Southern Company are implementing pilots to explore how they can aggregate a fleet of DERs to provide greater load-shifting control and flexibility. Fleets can include a variety of DERs such as residential and commercial rooftop solar, hot-water heater controllers, and electric vehicles; the ability to simultaneously manage these different resources allows for additional grid-flexible options. Aggregation pilots can support future GEB programs by providing key insights into how utilities and third-party aggregators can integrate and manage multiple DERs, as well as identify the remaining barriers to maximize benefits from integrating grid-interactive technologies.

Table 1 summarizes our findings on programs focused on energy efficiency and grid interactivity.

Table 1. Programs with GEB elements

	Program type	Description	Example programs and pilots*
Energy efficiency–focused programs	Energy efficiency programs that cross-promote separate demand-response programs	Programs that offer a range of smart devices such as energy management hubs, connected thermostats, and smart lighting. The utility cross-promotes demand-response programs for eligible devices.	National Grid New York's Electric C&I Retrofit program (C&I), United Illuminating's Home Energy Solutions Income Eligible (R), National Grid New York's Home Energy Solutions program (R), Entergy Arkansas's Home Energy Solutions program, BGE's Quick

Program type	Description	Example programs and pilots*
		Home Energy Check-up (R)
Streamlined energy efficiency and demand-response programs	Programs designed to promote energy efficiency and demand response simultaneously in a single streamlined program	AEP Ohio's It's Your Power program (R), NV Energy's Power Shift Commercial Energy Services program (C&I), NYSEG's Smart Solutions (R), Austin Energy's Power Partner Thermostats (R), Fort Collins Utilities' Peak Partners program (R), Ameren Missouri's Peak Time Savings program (R)
Smart energy management programs	Programs that promote smart technologies and services that enable smart energy use	NYSERDA's RTEM program (C), BC Hydro's Continuous Optimization program (C), Efficiency Nova Scotia's EMIS program (C&I)

	Program type	Description	Example programs and pilots*
Grid interactive–focused programs	Automated demand-response (ADR) programs	The utility provides incentives and installs communication equipment at customer facilities. The utility can then send signals to equipment to conduct load-curtailment strategies. Energy efficiency is not included in these programs.	Duke Energy's EnergyWise Business program (C&I), Austin Energy's Load Co-op pilot (C&I), BPA Smart Water Heater Pilot (R)
	ADR programs that also promote energy efficiency measures	Programs that promote energy efficiency measures and offerings to ADR program participants. Programs may provide additional rebates or incentives for energy efficiency measures installed at the same site. If the program requires a facility audit, the utility recommends an efficiency measures audit report. It can also provide energy-saving behavioral tips and feedback to participants.	PG&E's ADR program (C&I), Dominion's Smart Thermostat program (R, C)
	DER aggregation pilots	Utility pilots that integrate multiple separate DERs into fleets for greater demand flexibility.	Southern Company's Smart Neighborhood pilot (R), MECO's Jumpsmart Maui pilot (R), SMUD's 2500 R Street pilot (R), PGE's Smart Grid Test Bed pilot (R)

* R = residential, C = commercial, I = industrial. See Appendix A for links to program information.

Full-Fledged GEB Programs

GEB programs accurately value and incentivize the energy efficiency and load-flexibility benefits of buildings and their connected technologies.[6] They deliver customer energy efficiency bill savings and provide a variety of grid services through demand flexibility back to the system. Rather than skew toward either energy efficiency or grid flexibility, they instead take a holistic approach to value both simultaneously. Although no existing

[6] ACEEE recently reviewed integrated energy efficiency/demand-response programs across the United States (York, Relf, and Waters 2019). Such integrated programs can be the foundation of holistic GEB programs. However GEB programs would take fuller advantage of grid-responsive capabilities of building systems and use improved methods to value and compensate for GEB benefits.

programs currently represent a full-fledged GEB program, current programs can take steps now to begin working toward it.

GEB programs promote the installation of technologies in buildings that can provide energy efficiency and demand flexibility. Using smart connected systems, GEBs respond to grid needs by optimizing building loads, including other DERs including solar PV, electric vehicles (EVs), and energy storage. In addition to incentivizing technologies, these programs may also incorporate market signals and time-varying pricing to influence and shape customer loads for grid objectives. Utilities can use third-party aggregators to consolidate and manage responses and transactions with wholesale energy markets, as individual customers generally consume too little energy to participate in these markets.

Water heaters exemplify the often-conflicting objectives of grid flexibility and energy efficiency in GEB programs. Two main types of water heaters can be used to store thermal energy for grid use: electric resistance water heaters and heat pump water heaters. Energy efficiency program teams tend to advocate for programs that feature heat pump water heaters because they can reduce energy consumption by more than 50% compared to electric resistance water heaters (Shapiro and Puttagunta 2016). However demand-flexibility program teams are more inclined to prefer electric resistance water heaters that use more energy and thus represent a larger source of energy storage that can be used to benefit the grid. A GEB program will be able balance these conflicting objectives by assigning appropriate value to energy efficiency and grid benefits.

When thinking about the future of GEB programs, one approach to consider is PG&E's model of technology-agnostic programs. For instance, its Excess Supply Demand Response Program (XSP) sets demand-response targets, and rather than specifying which technology should meet them, it lets customers (and aggregators) choose. Examples of technologies that have been used in this program include solar PV, energy storage, thermal storage, and electric vehicles. Similarly, many utilities implement bring-your-own-device (BYOD) programs that allow customers to enroll their own demand-responsive devices into the program rather than specify a certain set of products. Future GEB programs could model themselves after such approaches and include both energy demand (kW) and energy consumption (kWh) targets and allow their customers to select the best GEB technologies.

Barriers and Opportunities for GEB Programs

Program administrators will need to overcome barriers to develop fully integrated programs. We have identified barriers and opportunities in four categories: technology, administration, policy, and metrics for valuation.

Technology

Much of the technology that is needed to enable GEBs already exists, from advanced metering infrastructure to connected HVAC, lighting, and water heating to DERs such as solar PV and energy storage. However connecting these technologies together and managing them from a central system that can interact with the grid is the primary technological challenge.

In its 2018 study on DER aggregation, the National Renewable Energy Laboratory (NREL) cited utility case studies in which communication failed between the DER and the aggregator, and then the utility. The authors recommended that utilities develop "data-communication requirements for DERs" when determining how to compensate customers for their grid services (Cook et al. 2018). Similarly, many of the existing load control switches on equipment allow for only one-way communication, which is adequate for traditional demand-response programs. However demand-flexibility programs require switches that allow for the two-way flow of information between the utility and the customer (Trabish 2019). Researchers at the Smart Electric Power Alliance (SEPA) envision that infrequent demand response—in which demand-response events occur seven to nine times per year on average—will evolve into continuous and flexible demand response, which can respond to micro-demand-response events that can happen in as little as five-minute intervals (McCormick and Bronski 2019). This is a seismic shift for managing the flow of energy on a grid, akin to jumping from rotary phones to smart phones.

Commercial buildings contain much more complicated building systems than residential, which adds complexity when trying to connect them together. In residential buildings, the utility can dispatch signals—for example through a smart thermostat—to directly manage and control DERs. However this is not commonly done in medium and larger commercial buildings, which typically contain a central EMIS; currently no universal standards exist for a utility or aggregator to connect to the building through an EMIS to control DERs. The many EMIS manufacturers, including Siemens, Johnson Controls, and Schneider Electric, and the different vintages of these systems present a substantial challenge for interconnecting commercial buildings with the grid. "These buildings remain black boxes," says Benjamin Hertz-Shargel of aggregator EnergyHub (vice president, Analytics, pers. comm., September 6, 2019).

Within a single building, separate systems such as lighting and HVAC can be connected and controlled through an EMIS. However, when a utility attempts to manage loads from multiple buildings (and other grid resources), it does so through a distributed energy resource management system (DERMS). Presently, DERMS are in their infancy. Most utilities are just starting to investigate DERMS feasibility; questions includes whether they will need to build brand new systems or can instead modify existing grid management and demand-response systems.

The Austin-based research organization, Zpryme, offers utilities five steps for adopting DERMS technology:

- Conduct an internal assessment of utility and customer needs for the next three to five years.
- Develop a roadmap and strategic plan.
- Identify internal and external partnerships that will be needed.
- Focus on customers and how best to optimize their energy flows.
- Use DERMS to integrate and optimize DERs into the grid (Zpryme 2018).

We suggest that, for GEB programs, many utilities should consider replacing Step 5 with "Conduct a targeted pilot study." The study's objective should be to identify barriers to scaling up, which the utility can then use to develop recommendations to modify the program's design to address these barriers. There are still many outstanding research questions about monitoring and managing GEBs, and this list will vary for different utilities and programs. DOE identified a list of 15 areas for future research in its overview report on GEBs; among these areas is quantifying "the impacts of different modes of demand flexibility on energy efficiency" (Neukomm, Nubbe, and Fares 2019). Questions like this are important to answer up front, since what is most beneficial from an efficiency perspective is not always the most beneficial for demand flexibility. Through pilot studies, utilities can help answer some of these questions for their programs with a goal of scaling up. In addition, sharing research findings among utilities through research reports, presentations, and working groups can help spread knowledge and speed the adoption of GEB technologies.

Administration

Traditionally, the groups responsible for creating energy efficiency programs have a different set of values, metrics, and priorities than the groups responsible for demand response and other grid services. As a result, these groups remain siloed within their own organizations, have different goals, and rarely interact with each other. Although this was an acceptable setup for separate programs, utilities and program administrators looking to take advantage of the combined efficiency and load-flexibility value stack often must overcome internal organizational barriers. One member of our working group, for example, noted a problem with traditional methods of combining energy efficiency and demand-response program, when "one team has a project that is aligned with its goals and then tries to shoehorn the other team in although the project doesn't benefit them."

Some utilities have restructured in order to enable better coordination among siloed teams. In 2016, ConEd made the decision to bring its demand management team together with its energy efficiency department, resulting in better coordination between the groups for long-term project planning. Some of ConEd's projects, such as the Smart Homes Rate project, provide both load flexibility and energy efficiency benefits; however, like most utilities, it is still working to understand how to best value these multiple value streams (Z. Sussman, senior specialist of energy efficiency and demand management's emerging technologies, ConEd, pers. comm., August 19, 2019).

Using a somewhat different approach, the SMUD Value for What You Pay initiative took an existing DER delivery team and broke it down into three groups: residential, commercial, and planning. Each of the groups takes a holistic look at DER components, including energy efficiency, electric vehicles, and energy storage (Changus and Cope 2018).

Taking a longer-term perspective, utilities face a larger question about the role they should play in a future of GEBs and DERs. With flexible resources such as water heaters, energy storage, and solar PV connecting to the grid, utilities will have to determine if they will be responsible for controlling connected DERs or if they will just play the role of platform and focus on monitoring and managing the grid, while third parties (e.g., aggregators) lead customer acquisition and operations for these flexible resources.

Either way, the future of utilities will place a greater emphasis on information technology (IT) departments than in the past. For instance, advanced metering infrastructure, a GEB-enabling technology, provides a massive quantity of information that utilities will need to monitor, maintain, and manage in order to understand the best ways to respond to fluctuating grid needs from the demand side. Additionally, a strong IT department can help safeguard against cybersecurity threats—an inherent risk with any connected technology.

Policy

An informal survey of utilities and program administrators suggests that top-down policy mandates, such as those from state and local governments and regulators, could help support utilities in their development of GEB programs. For instance, the majority of states require utilities to file integrated resource plans (IRPs) with their state public utility commissions. These IRPs act as a roadmap for how utilities will meet forecasted demand in an energy-efficient and cost-effective way (Girouard 2015). Making GEBs a required component of an IRP would be an effective way to help utilities justify further investigating them.

In addition, collaboration between utilities and their regulators could help remove roadblocks from utility investment in GEB technologies and programs. Nick Wagner, current president of the National Association of Regulatory Utility Commissioners, says that engaging "in collaborative discussions is critical in creating a modern, efficient and reliable grid that we can provide to consumers—which is the end goal for both utilities and regulators" (Berst 2014). Although his quote was aimed at enabling smart grid capability, the same message applies to GEBs, which provide more-efficient buildings and a more stable grid for consumers and thus address common goals for utilities and their regulators.

For states and cities that implement electrification policies, creating complementary GEB policies will be paramount. Electrification policies require the addition of load on the electric grid, primarily from end uses such as electric vehicles, heat pumps, and heat pump water heaters. Unmanaged, these loads strain the grid; managed, they can act as DERs to benefit the grid. For example, electric vehicles can charge during the middle of the day in areas with high solar PV production, grid-connected heat pumps can shave load during peak demand, and smart heat pump water heaters can function as energy storage. However this can happen only if the right pricing, procurement, policies, and programs are in place.

Regulations can also impact the emissions reduction potential from GEBs. A European Union study estimated the potential carbon impacts from smart grid technologies in six countries by 2020. The study analyzed three scenarios: no smart grid technologies are introduced; smart technologies are introduced but no regulatory changes are made; and both technologies and supporting legislation are introduced. Compared to the no-action scenario, the study found that countries' carbon emissions decreased 1–6% in the technology-only scenario and by 4–13% in the technology and legislation scenario. The findings showed the greatest carbon-saving potential for all countries was from zero-carbon generation and using load shifting and demand reduction to use fossil fuel generation more efficiently (McKenna and Darby 2017). While promoting GEB technologies can reduce carbon emissions to some extent, regulation will be necessary to maximize this capability.

A combination of policies and standards will be needed to foster GEBs and GEB programs. This includes policies and standards around interoperability, cybersecurity, and workforce training. For DERs, which are a key component of GEBs, the Smart Electric Power Alliance (SEPA) advocates for a plug-and-play standard. With this type of standard in place, as soon as consumers plug in a DER, such as a smart water heater or battery storage device, it would immediately begin a two-way communication with the grid (Lanyi 2017). Organizations such as SEPA, the Pacific Northwest National Laboratory, and GridWise Alliance are all actively exploring such standards to improve communication between connected DERs and the grid.

Metrics for Valuation

Inherently tied to organizational, technology, and policy barriers is the barrier of developing metrics to fairly value GEBs. Energy efficiency is typically valued by kilowatt-hour (kWh) energy savings, while grid services (typically in the form of demand response) uses a kilowatt (kW) savings metric to measure capacity. However valuing demand-flexibility benefits, such as peak demand, negative peak, ramp rates, congestion, and demand variability, provides a unique challenge for utilities.

This is compounded by the fact that there is no one-size-fits-all model since different utilities have vastly different grid needs, such as different mixes of energy generation. For instance, because California and Vermont are two of the highest solar PV adoption states, they are more concerned about negative peak during the middle of the day during peak sun than other states. The Midwest has a much higher penetration of wind energy, which typically generates energy more uniformly than solar, although it tends to peak at night, so states there may be more concerned with evening oversupply.

Different policy priorities and local economics also play into how a utility values grid services. Some utilities are starting to consider carbon reductions in addition to energy, and this will change how they value grid services as compared to utilities that solely value energy. Avoiding increasing (or reducing) peak energy on a grid can help a utility defer the costs of building new generation equipment and upgrading the transmission and distribution system. However the costs of these upgrades will change depending on the economics of the region.

The New Buildings Institute (NBI) is collaborating with utilities as part of its GridOptimal Buildings Initiative to develop a framework for valuing these types of grid services. By incorporating utility preferences, such as cities or jurisdictions that prioritize GHG emission reductions, NBI works with utilities to develop their own thresholds for valuing grid services based on the metrics that are most important to their organizations.

Some utilities, such as Salt River Project (SRP), have ongoing research projects to answer questions about the value of GEB technologies to better inform how they create GEB-type programs. SRP is using its own 50,000-square-foot office as a test bed for smart and connected technologies. The utility is installing a smart system as an overlay on its existing building management system, which includes artificial intelligence learning capabilities and OpenADR connectivity. Automation, sensors, and cameras on the site will be used for occupancy detection. Ultimately, SRP plans to use its own facility to pilot smart and connected technologies to potentially offer to its commercial and industrial customers (J. Dudley, senior planning analyst, SRP, pers. comm., July 1, 2019).

One reality of grid valuation for GEBs is that even within a utility, these values will not remain static. As new DERs enter the grid, the composition of that grid changes and the value of grid services will follow suit. To properly value services, the infrastructure will have to be in place at a utility to effectively catalogue and monitor connected DERs in real time (or at least on a somewhat regular basis). Within utilities, IT expertise will be required to evaluate how connected DERs impact the grid and adjust values as needed. Nonetheless, utilities can develop their frameworks for valuing these services even as they work to update their organizational structures, technology expertise, and GEB-enabling policies to prepare for a future of dynamic valuation of the benefits produced by GEBs.

Conclusions and Recommendations

In the ideal future scenario, GEBs will be the norm. They will help cities and jurisdictions meet their energy and climate goals, help maintain the security and stability of the grid, and help customers save money on their energy bills. Top-down policies will make grid-interactive buildings part of state, city, and jurisdiction plans. Regulators will collaborate with utilities and program administrators to design programs that make it easy and affordable to install GEB technologies and connect them to the grid. Utilities will have the infrastructure in place to coordinate with aggregators and provide customers with an accurate valuation of their grid services; they will also provide a platform with easy-to-access means of delivering that value. A robust market of contractors and aggregators will support utilities and customers in delivering these services. Customers will install plug-and-play equipment and readily allow it to be connected to the grid, understanding that doing so both reduces their energy bills and benefits society.

However this is not the current reality. Few policies encourage GEBs. Smart and connected technologies exist, but there is no standardized method for them to connect and interact with each other. No standardized method currently exists for valuing grid benefits, and even if it did, many utilities lack the infrastructure and IT expertise to benefit from the most valuable services. Within utilities, silos between the energy efficiency and demand-response teams means that these programs typically have their own goals and their own methods of developing programs.

A future in which buildings act as a resource for the grid is something utilities and program administrators can work toward. The first step for utilities is to inventory where they are organizationally and technologically. If a utility or program administrator offers only energy efficiency programs, it can consider trying a demand-response pilot or program (and vice versa). Expanding programs to include smart and connected technologies such as advanced metering infrastructure and smart thermostats can help lay the groundwork for future GEB programs.

If a utility has both energy efficiency and demand-response programs, it can create cross-functional teams to integrate program features and optimize for customer and grid value. It can also consider reorganizing departments to position energy efficiency and grid services together or at least begin the process of integrating the two groups so that in the future it will be easier to develop programs that can align their efforts toward common objectives. Most utilities will need to upgrade their IT departments and internal data and energy management systems to prepare to properly track and manage a much larger flow of data, as well as the flow of electrons.

In addition, energy efficiency programs will benefit from moving toward structures that subsidize services, not just technologies. Traditionally, energy efficiency programs focus on incentivizing hardware; however the smart and connected equipment in GEBs may be implemented as part of a service contract that more directly monetizes the value of these investments. Ultimately, utilities will also need to explore the question of valuation of demand flexibility, as well as how to integrate it into rate and market structures to align financial incentives with value to the grid.

Utilities and program administrators should also keep an eye on current research and policy changes to enable grid-integrated buildings. To overcome interoperability challenges, researchers at New York University are investigating how to create a connection between a commercial building's EMIS and a distributed energy resource management system (Ergan 2019). This would allow aggregators to manage commercial buildings, based on price signals from utilities. As far as cutting-edge policies, California recently passed Senate Bill 49, aimed at helping to improve California's flexible demand by prioritizing grid-interactive building appliances and equipment (California Senate 2019).

Using the framework we have laid out in this report, utilities and program administrators can begin developing programs that fall somewhere along the path to full-fledged GEB offerings. If they already have a strong demand-response program, they can find ways to also incentivize customer energy efficiency savings. Alternatively, if they have a strong efficiency program, they can tie in demand-response value and controls. Utilities with somewhat integrated programs can scale them up to reach more customers. They can also attempt a more complex DER aggregation-type pilot to help reveal the challenges and best ways forward to incentivize GEBs. For states that require utilities to do integrated resource or distribution system planning, making GEBs a required component of these efforts may help utilities justify further investigating them. These are just some of the ways that utilities can start laying the groundwork to make GEB programs a widespread reality.

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Appendix A. Sources of Program Information

Table A1. Program sources

Program administrator	Program name	URL
AEP OH	It's Your Power	www.itsyourpowerohio.com
Ameren Missouri	Peak Time Savings	www.amerenmissourisavings.com/peaktime
Austin Energy	Load Co-op pilot	savings.austinenergy.com/rebates/commercial/offerings/load-management/load-co-op
Austin Energy	Power Partner Thermostats	savings.austinenergy.com/rebates/residential/offerings/cooling-and-heating/pp-thermostat
BC Hydro	Continuous Optimization Program	www.bchydro.com/powersmart/business/programs/continuous-optimization.html
BGE	Quick Home Energy Check-up	bgesmartenergy.com/residential/quick-home-energy-check
BPA	Smart Water Heater Pilot	www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Field-Tests/Pages/Smart-Water-Heater-Pilot.aspx
Dominion Energy	Smart Thermostat Program	www.scc.virginia.gov/docketsearch/DOCS/3l3501!.PDF
Duke Carolinas and Duke Progress	EnergyWise Business	www.duke-energy.com/business/products/energywise-business
Efficiency Nova Scotia	Energy Management and Information System Program	www.efficiencyns.ca/efficiency-nova-scotia-services-at-a-glance
Entergy Arkansas	Home Energy Solutions	www.entergy-arkansas.com/your_home/save_money/ee/home-energy-solutions
Fort Collins Utilities	Peak Partners	www.fcgov.com/utilities/residential/conserve/energy-efficiency/peak-partners
MECO	Jumpsmart Maui pilot	evohana.com
National Grid New York	Electric C&I Retrofit Program	www.nyrevconnect.com/utility-profiles/national-grid
National Grid New York	Home Energy Solutions program	www.nationalgridus.com/NY-Home/Energy-Saving-Programs
NV Energy	NV Energy PowerShift Commercial Energy Services—Integrated Energy Efficiency and Demand Response (EE/DR)	www.nvenergy.com/save-with-powershift
NYSEG	Smart Solutions	www.nysegsmartsolutions.com

Program administrator	Program name	URL
NYSERDA	Real Time Energy Management	www.nyserda.ny.gov/All-Programs/Programs/Real-Time-Energy-Management
PG&E	Automated Demand Response program	www.pge.com/en_US/large-business/save-energy-and-money/energy-management-programs/demand-response-programs/automated-demand-response-incentives/automated-demand-response-incentives.page
PG&E	Smart Grid Test Bed pilot	www.portlandgeneral.com/our-company/energy-strategy/smart-grid/smart-grid-test-bed
SMUD	2500 R Street pilot	www.smud.org/-/media/Documents/Corporate/About-Us/Energy-Research-and-Development/research-2500-R-Street-entegrated-energy-evaluation.ashx
Southern Company	Smart Neighborhood pilot	www.southerncompany.com/newsroom/2019/may-2019/smart-neighborhoods-are-transforming-the-smart-home-industry.html
United Illuminating	Home Energy Solutions Income Eligible	www.energizect.com/home-energy-solutions%E2%84%A2-income-eligible-program-offers-free-services-those-fixed-or-limited-income