GRID-INTERACTIVE EFFICIENT BUILDINGS

PROGRAM GUIDEBOOK FOR UTILITIES

WPPI ENERGY

CONTENTS

GLOSSARY

Building automation system (BAS) Building Automation Systems (BAS) or commercial Energy Management Control Systems (EMCS) are computerized control systems that regulate the energy consumption of a building by controlling the operation of end-uses, such as the heating, ventilation and air conditioning (HVAC), lighting, and water heating systems. This creates numerous opportunities for more efficient operations, control during demand response events, and response to time-based rates.[1]

Energy efficiency (EE): Energy efficiency is the persistent and maintained reduction in energy and/or demand, as compared to baseline consumption, to provide the same or an improved level of service.[2]

Distributed energy resources (DERs): DERs are physical and virtual assets that are deployed across the distribution grid, typically close to load, and often behind the meter (BTM), which can be used individually or in aggregate to provide value to the grid, individual customers, or both. DERs discussed in this guidebook include technologies such as solar, energy storage, electric vehicles, and load flexibility / demand response.[3]

Demand response: The active reduction, increase, shift, or modulation of energy and/or demand on a limited time basis, as compared to baseline consumption, in response to a price/incentive payment or command signal, which may result in a lower level of service.[4]

Demand-side management (DSM): The modification of energy demand by customers through strategies including energy efficiency, demand response, distributed generation, storage, electric vehicles, and/or time-of-use pricing structures.[5]

Demand flexibility: The technical capability, associated with a building, to actively lower, increase, shift, or modulate energy usage, compared to a baseline scenario reflecting the passive state of operation, and in response to utility grid needs.[6]

Demand response management system: Management software that allows utilities to monitor, control, schedule, and manage a portfolio of DR programs and DERs, primarily load altering DERs such as water heaters, smart thermostats, and HVAC switches.[7]

Distributed energy resource management system: A software application platform designed to manage device information, monitor and enable optimization and control of distributed energy resources (DERs) and demand response (DR). Distributed energy resource management software must be able to aggregate, simplify, optimize, and translate DER and DR functionalities. The distributed energy resource management software enables the implementation of system services to the grid.[8]

Grid-interactive efficient buildings (GEBs): An energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences in a continuous and integrated way.[9]

Grid services: Technologies and controls help system managers ensure that the grid provides value and services, such as power capacity, reliability, resiliency, peak load reduction, outage recovery, and voltage support, among others. These support the short- and long-term ability of the grid's generation, transmission, and distribution of electricity by providing value through avoided electricity system costs.

1 Potter, J., Stuart, E., & Cappers, P. (2018). Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study. Prepared by Berkeley Lab. Washington, DC: DOE.

2 Satchwell, A., Cappers, P., Deason, J., Forrester, S., Frick, N., Gerke, B., & Piette, M. (2020). A Conceptual Framework to Describe Energy Efficiency and Demand Response Interactions. Prepared by Berkeley Lab. Washington, DC: DOE.

3 SEPA. (2019). Integrated Distribution Planning: A Framework for the Future.

4 Satchwell, A. et al. (2020).

5 Ibid.

6 Ibid.

7 SEPA. (2023). Encyclopedia of DERMS Functionalities.

8 Ibid.

9 Neukomm, M., Nubbe, V., & Fares, R. (2019). Grid-interactive Efficient Buildings: Overview. U.S. Department of Energy.

EXECUTIVE SUMMARY

Grid-interactive efficient buildings (GEBs) are energy-efficient buildings that use smart technologies and onsite distributed energy resources (DERs) to provide demand flexibility while also reducing energy cost, offering grid services, and meeting occupant needs in a continuous and integrated way.[10] The U.S. Department of Energy's Building Technologies Office estimates that services and other benefits from GEBs have the potential to save up to $18 billion in power system costs and 80 million tons of carbon emissions annually.[11]

GEBs are a relatively new concept in utility customer programs. Why now? Technological advances in the past 20 years enabled utilities to promote energy efficient electric equipment to help customers save energy. Advances in load control switches also enabled utilities to control some of this equipment for demand response. Over time, equipment has become increasingly efficient, and control capabilities more sophisticated.

With the growth in internet and software capabilities, it is now possible for utilities to leverage a variety of customer equipment for WiFi-controlled peak demand management, such as smart thermostat demand response programs. This, in turn, has laid the groundwork for GEBs — an even more advanced approach. In the GEBs approach, utilities use buildings as grid assets by integrating controls across systems and managing them in real-time for additional grid service. Utilities see benefits of cost savings, increased visibility to the grid, and customer engagement.

Getting to GEBs is a journey that will take time, and most utilities are just getting started. **This guidebook outlines how utilities can begin the process of combining the basic building blocks of GEBs to prepare for the future.**

What can a utility do to advance GEBs?	

Promote Multiple GEB Technologies and Behaviors
• Energy efficiency upgrades
• Sensors, building controls, smart thermostats
• Other behind-the-meter DERs
  ◦ Electric vehicles (EVs)
  ◦ Solar photovoltaic (PV)
  ◦ Batteries
• Active demand response (DR)
• Demand flexibility & DER management
• Time-of-use retail rates
• Behavioral engagement
	Complete the Groundwork for Successful GEBs Program
	• Group offerings in a coordinated portfolio
	• Invest in controls software (demand response management software, etc.)
	• Promote the utility as the customer's energy services partner — managing costs, offering control
	• Educate customers on tools and benefits
	• Develop tools to capture full value of coordinated services

Figure 1. How can utilities advance GEBs?

10 The GEBs concept was introduced by the U.S. Department of Energy's Building Technologies Office (BTO). See: Neukomm et al. (2019).; also see SEPA. (2022). Accelerating Coordinated Utility Programs for GridInteractive Efficient Buildings: Practitioners' Perspectives.

11 Satchwell, A. et al. (2021). A National Roadmap for Grid-Interactive Efficient Buildings. United States.

Utility staff should keep the following themes in mind when considering GEB program development:

1. GEBs are a new approach. Utilities and federal agencies are piloting the "first generation" of GEB programs and projects. While early adopters continue gathering experience, program managers can rely on the best-practices from simpler forms of integrated programs, such as coupled energy efficiency and demand response programs.[12] The U.S. Department of Energy Connected Communities program website is a good resource to stay up to date on GEB programs and techniques.[13]

2. Strategic planning is critical to GEB program development. GEB programs should be built in stages; strategic planning is needed to guide the process. Experienced utilities emphasize that it is valuable to dedicate time to go through a goal-setting process, create a financial and customer service case for GEBs, and craft and share a compelling story to secure internal buy-in.

3. Utilities interested in GEBs long-term can take manageable steps today. Meaningful first steps towards GEBs get the utility's staff and customers "GEB-ready" while providing operational efficiencies and cost-savings.

a. Consider combining teams and processes to integrate and streamline delivery of existing programs.[14]

b. Explore ways to use time-based retail rates to encourage energy use in line with grid needs.

c. Explore and pilot demand response management software or distributed energy resource management software to control and coordinate customer devices. These types of software are the technological backbone of GEBs.[15]

4. For electric utilities just starting, pilot proven technologies and solutions to get customers — and their buildings — "GEB-ready." The major building systems for GEBs are the building shell, HVAC, water heating, and lighting. Other major behind-the-meter loads to consider are electric vehicles, renewables, and battery storage. Use market research or other customer insights to determine which systems provide opportunity and value in your service territory. **A key finding of this guidebook is that smart thermostats are a valuable starting point for many utilities, based on their high market penetration and demand reduction potential.** Additionally, other demand response programs may be an alternate entry point to customer demand management where market penetration of relevant equipment is already high or is expected to grow quickly.

Note: Appendix A contains detailed insights on the researched peak kilowatt (kW) reduction potential of several technologies (smart thermostats, heat pumps, heat pump water heaters, thermal energy storage in refrigeration, and energy management systems) as well as opportunities to combine technologies in a GEB approach.

5. Providing a good experience for program participants is especially important for GEBs enrollment and success. GEBs introduce customers to new technology and new approaches to managing energy and buildings. Financial incentives for participants should both reflect the value of grid services provided and reflect an understanding of the potential impact on participants. For example, small businesses may be able to participate in a demand response program using the same smart thermostat as a residential customer, but different outreach approaches are needed to engage and recruit them, and higher incentives are needed to offset any perceived greater risks of participating.

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12 For case study examples of how to integrate energy efficiency and demand response programs, see: SEPA. (2022). Accelerating Coordinated Utility Programs for GEBs: Case Study: Internal Utility Silos, p. 36-37.

13 US Department of Energy Connected Communities Program.

14 For case study examples of how to overcome internal organization silos, see: SEPA. (2022). Accelerating Coordinated Utility Programs for GEBs: Case Study: Internal Utility Silos, p. 35-36.

15 See SEPA. (2023). Encyclopedia of DERMS Functionalities, and SEPA. (2023). DERMS: State of the Industry 2023 Gaps & Opportunities.

HOW YOU CAN USE THIS GUIDEBOOK

This Guidebook shares steps to explore and pursue customer programs that promote grid-interactive efficient buildings (GEBs). The Guidebook serves as a resource for utilities to:

Learn what GEBs are:	**Section 1:** What is a GEB?
Assess the opportunity for GEBs:	**Section 2:** Why develop a GEB program?
Identify key steps to develop a GEBs program:	**Section 3:** How to develop a GEB program
Learn how to develop a GEB program from existing programs:	**Section 4:** GEBs Pathway to Combine Systems, Programs, and Services
Key findings to coordinate benefits to customers, the utility, and the grid:	**Section 5:** Conclusion — Key Project Findings
Find out where to learn more:	**Appendices** A: Data Analysis: What Building Technologies Help Manage Peak Demand in a GEBs Setting?

PROJECT BACKGROUND

The Smart Electric Power Alliance (SEPA) developed this guidebook as part of a project for WPPI Energy, a joint action agency with 51 small to medium-sized utility members in Wisconsin, Michigan, and Iowa. The funding for this work came from the American Public Power Association (APPA) Demonstration of Energy & Efficiency Developments (DEED) program.

SEPA developed this guidebook based on insights from a web survey and interviews with 25 utilities offering GEB programs and their predecessors. Additionally, SEPA conducted two focus groups with WPPI Energy departments involved in planning power supply, customer services, and marketing. Secondary research on GEB technology impacts also informed this guidebook.

Our research aimed to highlight the perspectives and needs of public power utilities, particularly smaller utilities and those serving rural communities and small towns. We also included larger and metropolitan utilities with experience integrating retail programs and services with wholesale markets.

Smart Electric Power Alliance

DEED PUBLIC POWER RESEARCH & DEVELOPMENT
American Public Power Association

WHAT IS A GRID-INTERACTIVE EFFICIENT BUILDING?

The grid-interactive efficient buildings (GEBs) approach is all about coordinating multiple building energy uses — and optimizing them to benefit both the grid and occupants.

GEB DEFINITION

Grid-interactive efficient buildings (GEBs) are energy-efficient buildings that use smart technologies and on-site distributed energy resources (DERs) to provide demand flexibility while reducing energy cost, offering grid services, and meeting occupant needs in a continuous and integrated way.[16] *Figure 2* illustrates key characteristics of GEBs.

Efficient

Persistent low energy use minimizes demand on grid resources and infrastructure.

Connected

Two-way communication with flexible technologies, the grid and occupants.

Smart

Analytics supported by sensors and controls co-optimize efficiency, flexibility and occupant preferences.

Flexible

Flexible loads and distributed generation/storage can be used to reduce, shift or modulate energy use.

Figure 2: Key characteristics of GEBs

Source: [U.S. Department of Energy. (2024). Connected Communities: Resources: General Information.]

WHAT DOES A GEB LOOK LIKE?

Figures 3 and *4* show examples of a residential single family GEB and a large commercial office GEB, including building technologies and grid systems. In both building types, buildings:

- Save energy through efficient appliances and equipment with smart or integrated controls where possible,
- Exchange information with the grid through smart meters, building automation systems, or smart appliances and equipment, and
- Schedule and control systems within the building through building-level automation or "smart home" control centers.

The major building systems shown in the two GEB examples below are the building shell, HVAC, electric vehicles, water heating, lighting, and behind-the-meter renewables and batteries. GEBs can apply to other sectors, including smaller commercial spaces, commercial spaces with refrigeration, municipal buildings like government facilities or schools, as well as multi-family residential properties.

16 Neukomm et al., (2019). GEBs: *Overview*.

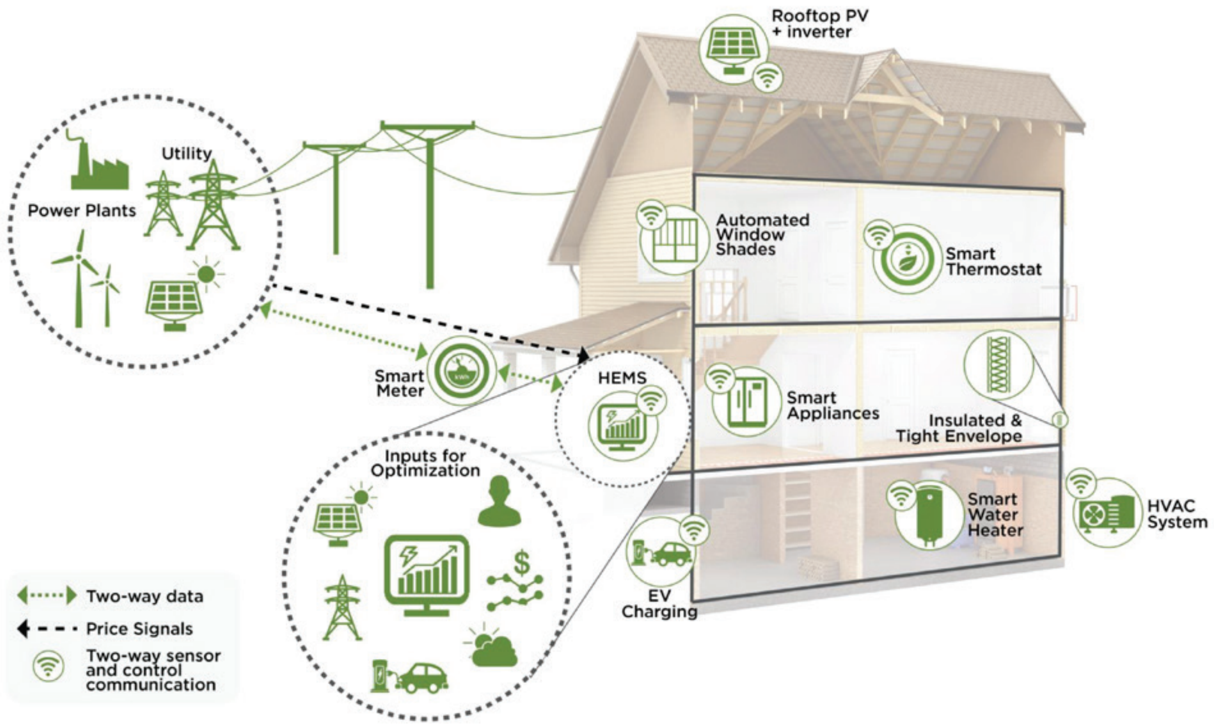


Figure 3: Example residential single-family GEB

Source: [Navigant Consulting, as published by U.S. Department of Energy](). HEMS = home energy management system.

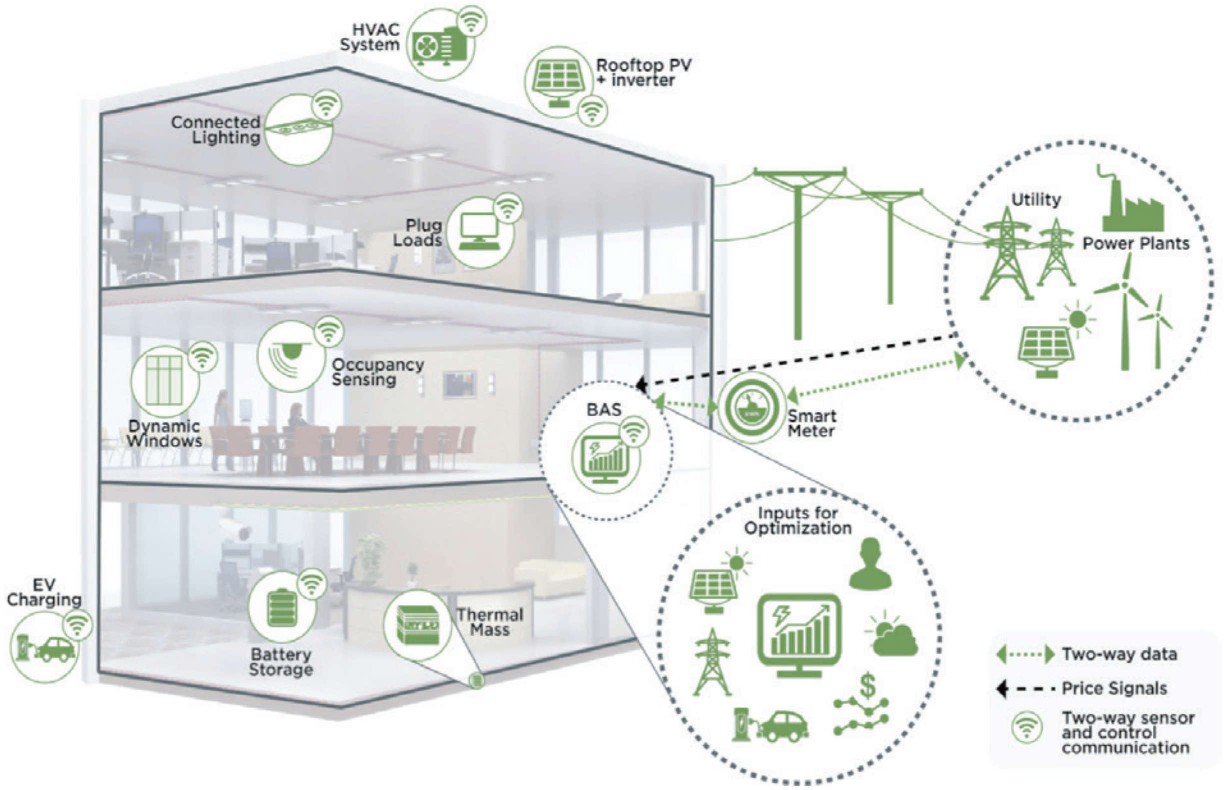


Figure 4: Example commercial office building GEB

Source: [Navigant Consulting, as published by U.S. Department of Energy](). BAS= building automation system.

HOW DO GEB TECHNOLOGIES WORK WITH THE GRID?

Utilities and customers depend on the electric grid for safe, reliable, and affordable service. System managers have a variety of tools and technologies to maintain the grid's operations, including both centralized and distributed resources. "Grid services" is a term to capture the various ways in which these resources help maintain grid operations.[17] Example grid services include providing power capacity, supporting reliability and resiliency, enabling peak load reduction, facilitating outage recovery, and offering voltage support, among others. GEBs provide a variety of grid services, shown in *Figure 5* below. The figure includes GEB elements (efficiency, load shed, load shift, demand modulation, and generation) and examples of the benefits they can provide when adopted in the aggregate.

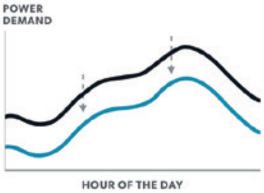
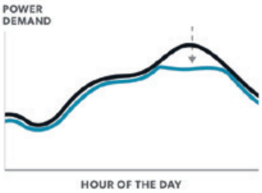
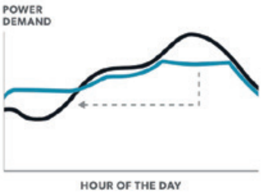
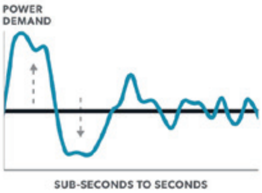
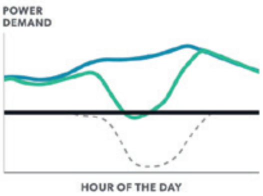
	LOAD IMPACT	EXAMPLE MEASURE	EXAMPLE BENEFIT
Efficiency		Building has an insulated, tight envelope and an efficient HVAC system to reduce heating/cooling energy needs	Reduced costs of burning fuel to satisfy energy demand, and reduced emissions associated with lower fuel use
Shed Load		Building dims lighting system by a preset amount in response to grid signals while maintaining occupant visual comfort levels	Reduced investment in generation and transmission capacity due to lower peak demand
Shift Load		Connected water heaters pre-heat water during off-peak periods in response to grid signals	Reduced energy costs due to shifting consumption to cheaper hours of the day; avoided curtailment of renewables during off-peak periods
Modulate		Batteries and inverters autonomously modulate power draw to help maintain grid frequency or control system voltage	Reduced ancillary services costs, improved integration of variable generation resources (e.g., wind, solar)
Generate		Rooftop solar PV exports electricity to the grid	Reduced T&D losses due to on-site consumption; avoided need for grid-scale generation

Figure 5. Ways in which GEBs can provide value to the grid

Source: Satchwell, A. et al. (2021). A National Roadmap for Grid-Interactive Efficient Buildings. T&D = Transmission and Distribution.

17 Liu, J. et al. (2022). State of Common Grid Services Definitions. Lawrence Berkeley National Laboratory for U.S. Department of Energy's Grid Modernization Laboratory Consortium.

WHY DEVELOP A GEB PROGRAM?

The U.S. Department of Energy estimates that the services and other benefits from GEBs have the potential to save up to $18 billion in power system costs and 80 million tons of carbon emissions annually.[18] The potential utility benefits include operational and power supply cost savings and increased ability to foresee and proactively adapt to the changing grid.

Until recently, utilities have often promoted energy-saving solutions individually, such as energy efficiency (EE), demand response, renewable energy, vehicle electrification, energy storage, and smart controls. Each solution offers its own benefits; however, by combining programs and technologies in a GEBs approach, additional benefits can be achieved, such as:

- Cost reduction and efficiencies of scale across once-siloed programs,
- Better ability to manage related grid challenges (e.g., peak demand reliability under high-electrification or high-renewables scenarios),
- New opportunities to reduce carbon emissions and environmental impacts, and
- Opportunities to leverage current customer programs and deepen customer engagement.

In developing this guidebook, we asked diverse utilities about their main reasons for developing GEB programs and what benefits they are hoping to achieve. *Figure 6* summarizes responding utilities' top motivations for coordinating their commercial or residential energy programs. Reducing costs, managing capacity, improving existing programs, and increasing customer engagement and satisfaction were leading reasons to coordinate and combine programs.

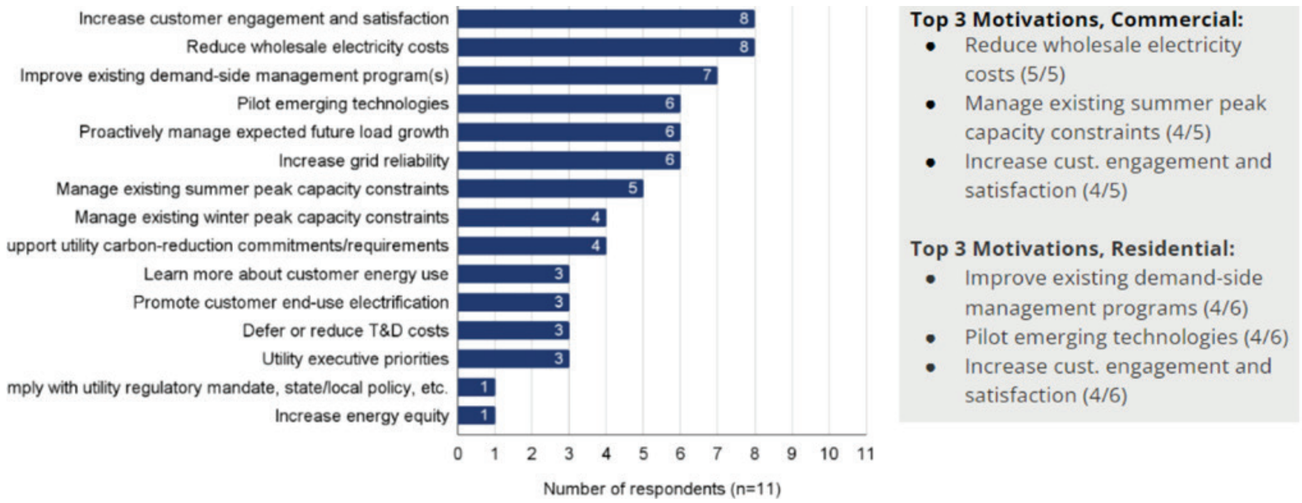


Figure 6. Common drivers for GEB program development among utilities with coordinated programs that support GEBs

Source: Study results as developed by SEPA, 2024.

18 Satchwell, A. et al. (2021).; [DOE Invests $61 Million for Smart Buildings that Accelerate Renewable Energy Adoption and Grid Resilience]

HOW TO DEVELOP A GRID-INTERACTIVE EFFICIENT BUILDING PROGRAM

Utilities can implement the vision for GEBs in a variety of ways. Some GEB programs are focused on new construction, retrofits, building management, or a combination of these factors. Some GEB programs are focused narrowly (such as using tactics that adjust individual building systems), while others are focused broadly (such as on engaging full communities). No matter the path taken, a GEB program should promote several core features, and utilities can build up to full implementation in stages.

Figure 7 details the path to develop a GEBs program. Options on the path move from the simpler and lower-cost actions you may already take, to more complex and higher-cost actions with the potential to provide a wider range of value.

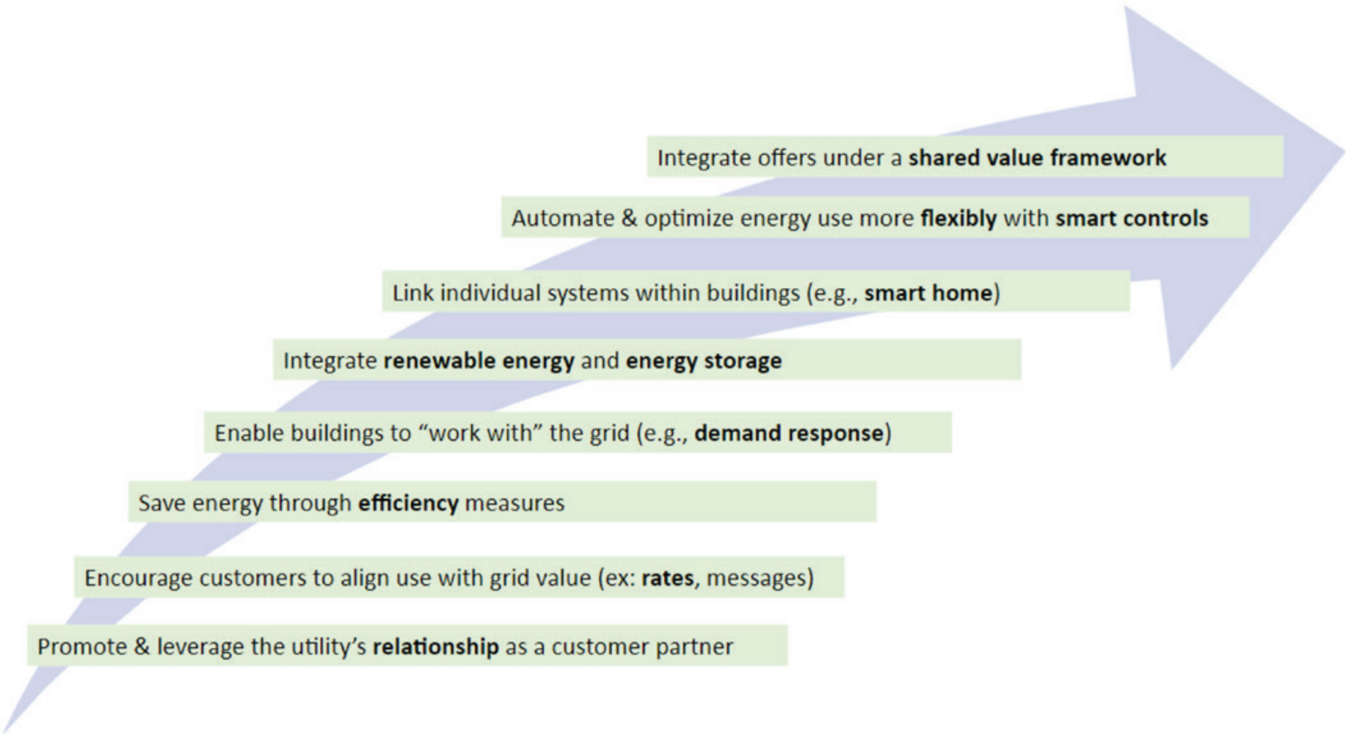


Figure 7: Path to GEBs

Source: SEPA, 2024.

Many stages of GEB program development require significant technical, administrative, and customer investment. Strategic planning is critical to manage this investment and deliver the desired value to both utilities and customers. Experienced utilities emphasize that it is valuable to dedicate upfront time to go through a goal-setting process, create a financial and customer service case for GEBs, and craft and share a compelling story to secure internal buy-in.

Key steps include:

1. Identify Organizational GEB Program Goals. Identify what goals and objectives the utility wants to achieve with GEBs (ex. increased power supply capacity, meeting customer expectations, carbon reduction).

2. Solicit Internal Stakeholder Feedback to Develop GEB Business Case. Bring together groups of internal stakeholders across customer service, member (utility) service, power supply, information technology, and marketing/communications to provide key feedback on the GEBs business case.

3. Develop Organizational Business & Customer Case for GEBs. Develop an organizational financial and customer service case for GEBs, outlining important utility and customer needs or gaps, how GEBs would help, and what benefits can be expected. This information can be used to build leadership understanding of the economic value to the utility and customers, and build support for the potential technical approach and investment.

Box 1. Key internal questions for GEB program development

Questions to pose to help identify and align internal stakeholders on GEB program goals, organizational value, and key development steps can include:

1. What factors are driving utility interest in GEB program offerings (e.g., building electrification, EVs, solar penetration, energy market opportunities, state policy, technology advances)?
2. Which of the grid services that GEBs provide are most valuable to utilities and customers (e.g., demand reduction, load shedding or shifting, grid frequency, voltage control)?
3. Are there any anticipated capacity constraints over the next 5+ years?
   How would this impact the need for demand response/demand flexibility?
4. How does the utility currently model / financially value demand response and DERs?
5. What level of certainty would you require to count on cost savings from demand response?
6. What challenges do you foresee in deploying GEB program offerings?
7. What current programs or partnerships can be leveraged? Are there successes to replicate?
8. What new technologies or services would need to be procured to deliver GEBs, which involve more grid interaction and building automation than typical customer energy programs?
9. Which customer segments can most benefit from GEBs?
   What types of outreach, education, and incentives would be needed to engage them?
10. How do you envision utility customer program offerings evolving in the next few years?
    How would your customer service approach need to change?

The experiences of utilities that have developed GEB programs shine a light on which steps need the most upfront attention *(Figure 8)*. When asked to rate the importance of various tasks for successful program integration, responding utilities most often cited defining common metrics for progress/success, selecting the right software platform, and linking funds or responsibilities. Where applicable, working closely with regulators was also seen as an important step.

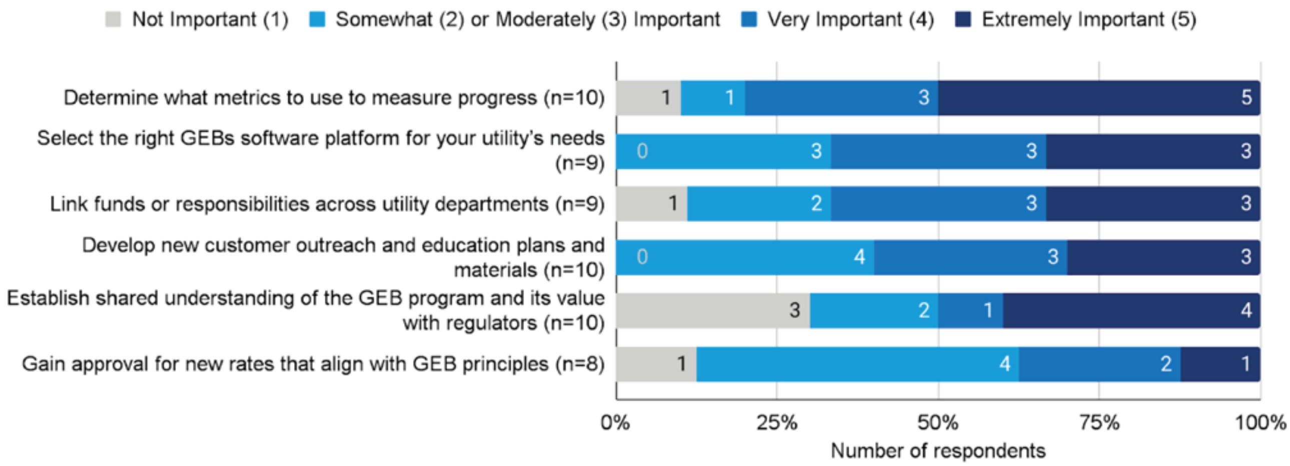


Figure 8: Evaluation of key GEB program development steps

Source: Study results as developed by SEPA, 2024.

HOW CAN UTILITIES ADVANCE GEBS?

Conceptually, in a GEBs program, a utility offers customers program options that provide integrated occupant, utility, and grid benefits. To prepare, utilities must promote additional GEB technologies/behaviors to customers and complete the groundwork for a new program *(Figure 9)*. This could include grouping program offerings in a coordinated portfolio or delivering them to customers as a pre-packaged set.

What can a utility do to advance GEBs?

Promote Multiple GEB Technologies and Behaviors

- Energy efficiency upgrades
- Sensors, building controls, smart thermostats
- Other behind-the-meter DERs
  - Electric vehicles (EVs)
  - Solar photovoltaic (PV)
  - Batteries
- Active demand response (DR)
- Demand flexibility & DER management
- Time-of-use retail rates
- Behavioral engagement

Complete the Groundwork for Successful GEBs Program

- Group offerings in a coordinated portfolio
- Invest in controls software (demand response management software, etc.)
- Promote the utility as the customer's energy services partner — managing costs, offering control
- Educate customers on tools and benefits
- Develop tools to capture full value of coordinated services

Figure 9. How can utilities advance GEBs?

STEPS TO A GRID-INTERACTIVE EFFICIENT BUILDING PROGRAM

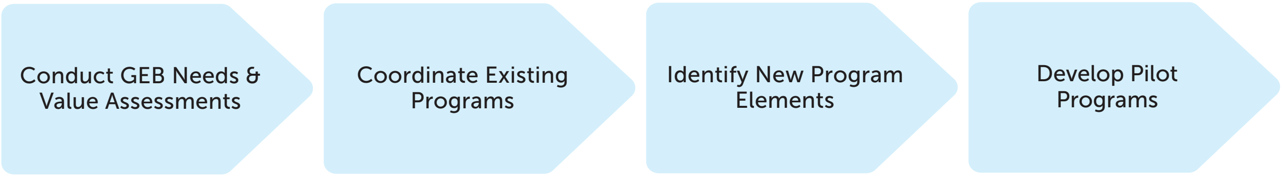


Figure 10. Steps to GEB programs

1. Conduct GEB Needs & Value Assessment. Once you determine the potential value of GEBs to your utility, inventory existing customer programs. How might each program contribute to the goals of your GEBs program? What is missing? And how can you fill those gaps? See *Box 2* for specific opportunities to consider.

2. Coordinate Existing Programs. Identify and map the steps your utility and a customer would need to take to bundle existing programs to provide GEB services. How can you make the customer's journey easier and more familiar? Can you channel customers, bundle product offers, or automate cross-marketing between energy efficiency and demand response programs? Are new customer relationship management (CRM) tools needed to coordinate engagement across programs? Could the utility partner with trusted entities that help customers with internet-enabled services to promote GEBs options (ex. libraries, community groups, etc.)?

3. Identify New Program Elements. A more advanced GEBs program will require new elements. How will the utility manage grid-interactive control of multiple appliances, coordinate building energy use, and tap into behind-the-meter resources like EVs, batteries, or solar? Consider options to evaluate and pilot, including utility-scale software or vendors. Software costs can be significant if a utility is new to grid-edge or distributed digital controls.

4. Develop Pilot Programs. Develop pilot programs that simplify the customer journey toward digitally-connected, holistic energy management. If a new offering demonstrates cost-effective value, consider integrating it into your portfolio. Over the long term, you may discover that a partial adoption of a few GEBs services effectively meets your needs — or alternatively, that there is an opportunity to offer an end-to-end GEBs initiative.

Box 2. Opportunities for existing programs to drive GEBs

Some of the more-accessible tools available to begin upgrading efficient buildings to grid-interactive efficient buildings are sensors, controls, energy management systems, and time-based rates– but they are not always offered in standard customer energy programs.

- If you or a regional partner offer energy efficiency discounts or rebates, look at whether they provide opportunities for customers to install occupancy sensors, smart home controls, or building energy management systems alongside the efficient products.
- Assess whether the energy efficiency program includes products with connected controls.
- Explore steps to integrate connected products into a demand response program or create a new one. For example, water heaters with smart connected controls.
- Assess time-based rates and how well they encourage customers to shift usage away from the peak.
- Assess which GEB technologies have high potential for demand flexibility, but which may not be otherwise promoted in programs focused on energy and peak demand response (e.g., automated window shades).

PATHWAY TO GEBS AS A SMALLER UTILITY WITH EXISTING PROGRAMS

Considering the potential scope and scale of GEBs, a utility's near-term objective should include comprehensive planning, stakeholder engagement, and technology assessment.

Figure 11 outlines a potential roadmap to illustrate a high-level GEBs transition timeline for a utility with standard customer energy efficiency and / or demand response programs. It also shows how their course of action might evolve and expand over the medium and long term.

Element	Short Term	Medium Term	Long Term
Planning & Valuation	• Determine the value of GEBs to your organization. • Agree on GEBs vision and tools to achieve goals. • Gain leadership buy-in to invest in GEBs pilots for risk management and innovation.	• Use learnings to update or refine the value proposition to utility and customers. • As demand response elements reach scale, explore opportunities to gain added value from wholesale markets.	• Continue to review progress and adjust strategy as markets evolve and early-adopter insights emerge.
Program Operations	• Link easy-to-combine programs and administrative systems (EE, demand response, DERs). • Study existing overlap and gaps in programs and customer participation across them.	• Revisit harder-to-combine programs and systems. What is now possible, and valuable? What resources are available? • Continue shifting demand response program operations to digital and automated solutions: e.g., Demand Response Management System	• Explore whether new and potentially higher-investment technologies are now needed, such as DERMS, supervisory controls, or others.
Customer Focus	• Cross-promote programs (e.g., promote demand response programs when and where customers are purchasing EE products). • Build customer awareness of basic GEB equipment. • Streamline becoming "GEB ready" — it should be simple for customers to find new programs and participate again.	• Make options available to help customers manage the upfront costs of new technologies. • Build customer awareness of technology that will enable more-advanced GEBs including sensors and controls.	• Ensure benefits are reaching all customer segments and that programs continue to meet needs.

Element	Short Term	Medium Term	Long Term
Customer Experience & Benefits	• Customers are aware of and understand new equipment; feel it is easy and beneficial to adopt for their home or business. • Customers adopting EE, demand response, or DERs experience benefits–such as lower electricity bills, increased comfort and productivity, resilience, etc.	• Customers see utilities as their partner in managing the community's energy future. • Customers are accepting of utility digital controls. • Customers see ongoing benefits, plus system reliability and emissions reduction.	• Customers are aware of energy management as a holistic system — they become interested in additional ways they can shift energy use to provide grid services.
Technology Mix	• Use available technologies with proven models to build experience and acceptance; for example, smart thermostats, connected water heaters, EV rates or EV managed charging, smart lighting, building automation systems (BAS) with real-time energy management capabilities (for larger businesses or real estate portfolios).	• Explore technology that will enable more-advanced GEBs, including sensors and controls. • Monitor emergence of new technologies & new data on impact / cost-effectiveness. • Monitor ongoing customer adoption (e.g., EVs, BTM solar, BTM storage) and leverage for demand response/GEBs. • Pilot additional technologies to increase share of building energy use managed.	• Find ways to add new technologies and reach new sectors, such as: thermal energy storage for refrigeration, advanced analytics and advanced building automation (including "lite" versions of BAS and real-time energy management solutions that are cost-effective for small businesses), and emerging virtual power plant (VPP) model.

Figure 11. Pathway to GEBs as a smaller utility with existing programs

Source: SEPA, 2024. Based on secondary research and original interviews with 15 investor-owned, public power, and cooperative utilities. Not all linkages may be possible in policy environments that limit mixing of energy efficiency, demand response, and DER program funds.

ILLUSTRATIVE GEB PORTFOLIO CONCEPT AND REAL-WORLD EXAMPLES

As shown in *Figure 7* above, you can work in stages to develop GEBs. This section includes several resources to help you visualize an "end state" GEBs program with linked and coordinated programs.

Some of the more advanced actions involve installing software or hardware to coordinate multiple building systems, and integrating customer offers under a shared value framework.[19] *Figure 12* depicts a hypothetical GEB portfolio. In it, a hypothetical utility first brought together existing programs and services (blue) and then layered in new control methodologies and cross-cutting program coordination (orange). Throughout the process, utility staff (or departments) collaborate to create a shared plan and understanding of value, while customers are engaged to provide feedback on program design and share their satisfaction and experience. To manage risk and investment, new elements (orange) can be piloted before they are launched at full-scale. Technologies for GEBs continue to evolve. Monitoring today's early-stage or high-cost solutions for potential maturity and cost reduction can enable adoption in the future.

19 Advanced actions also involve blending programs and leveraging customer assets for new grid services; a related step is to incorporate these new costs and benefits into any economic tests used to determine customer and utility cost-effectiveness.

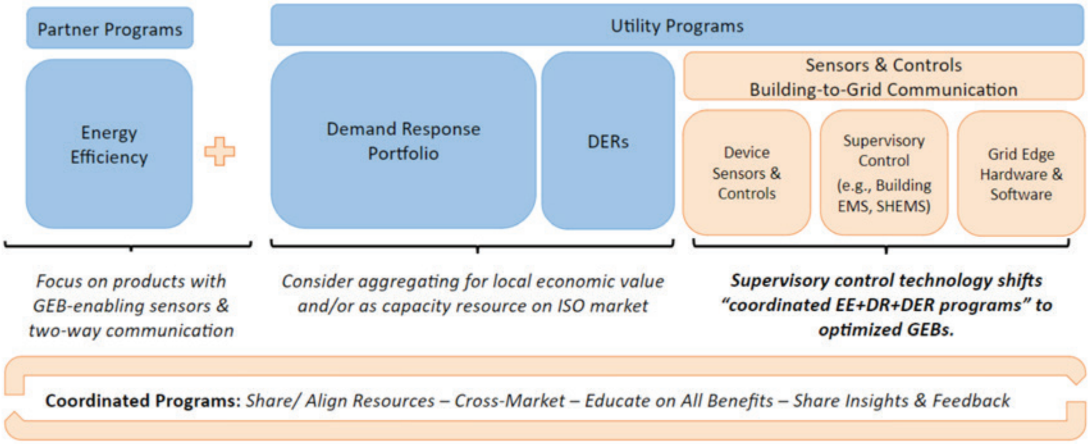


Figure 12. Illustrative GEB portfolio concept leveraging existing programs

Source: SEPA, 2024. Note: Grid edge refers to hardware and software that is in proximity to the end-use customer. Supervisory controls are building-level systems that manage the controls placed on individual devices and appliances. Supervisory control is needed to monitor the building system as a whole. Other functions include executing integrated controls, predicting loads, measuring impacts, and enabling the analysis to optimize systems in a continuous way. Examples of supervisory controls include commercial building energy management systems, smart home energy management systems, or model predictive control (Satchwell, A. et al. (2021)).

Figure 13 includes examples of utility programs that promote core GEBs technologies and features. Programs are shown on a spectrum of least to greatest complexity and potential to provide grid services. More-advanced programs can be developed in stages to increase the level of dispatchable grid services and to advance GEBs.

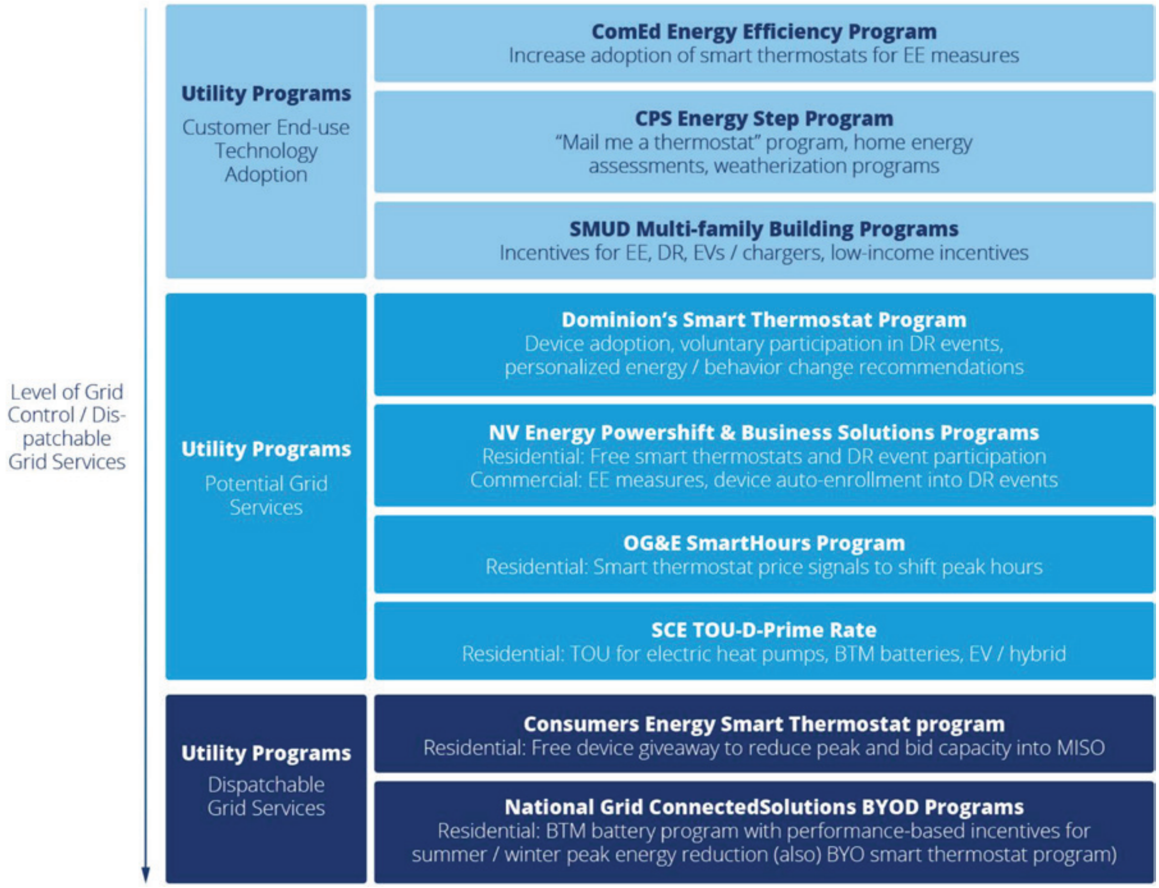


Figure 13: Utility program examples that promote GEB technologies

STRATEGIES TO MANAGE THE INVESTMENT AND EFFORT

Small-to-midsize utilities tend to have fewer staff than larger utilities, and staff wear many hats. Anticipating the administrative aspects of GEB program development can help staff plan ahead for resourcing and focus their time most appropriately. Again, referencing experiences of utilities that have integrated energy efficiency, demand response, and/or DER customer programs, *Figure 14* below reports ten utilities' reflection on which administrative steps are the most time-intensive. They observed that educating customers and participants, resolving interoperability problems,[20] and calculating full program value were leading key elements.

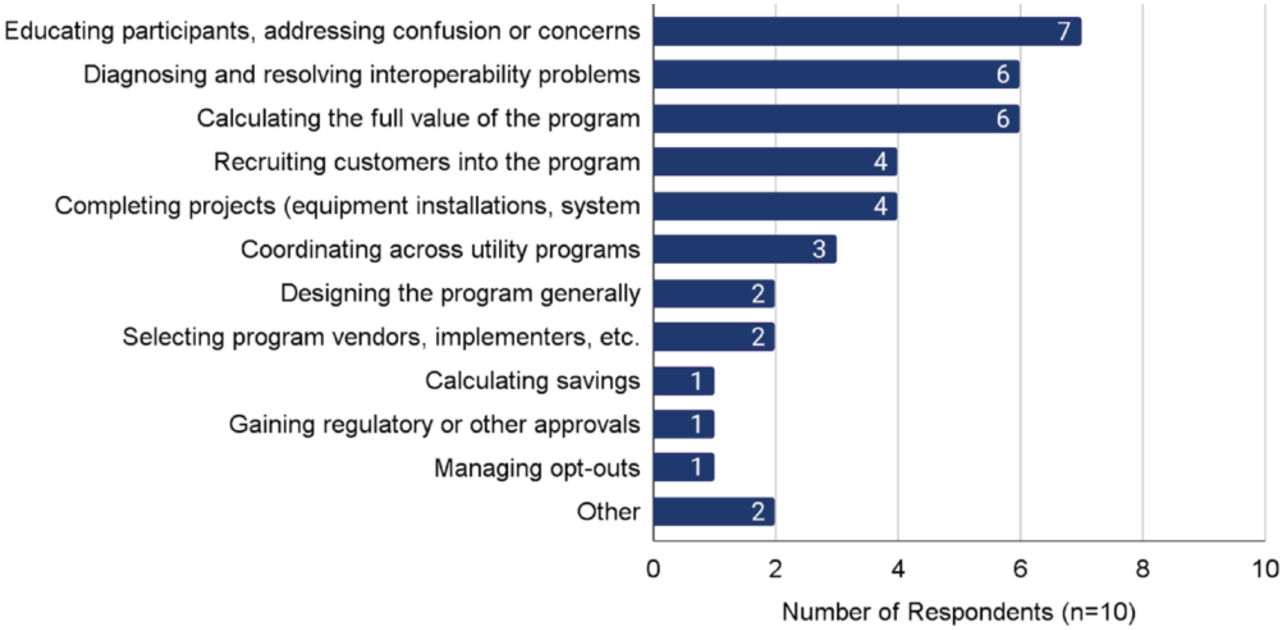


Figure 14: Evaluation of time and resource-intensive GEB program development steps

Source: Study results as developed by SEPA, 2024. Interoperability is the ability of technologies such as DERs or smart home devices to communicate and integrate with each other, and to understand and interpret data and commands. For additional information, see SEPA (2020). Plug & Play DER Challenge.

Based on project utility interviews and research, *Figure 15* summarizes additional strategies to manage the cost and effort of getting started, and best practices for balancing customer and grid needs while running the program.

Area to Manage	Strategies to Manage the Cost or Effort
Utility Commitment	• Coordinate all departments and entities that interface with the same customers early in program development. • Assess the full value proposition by looking at utility and customer costs and benefits across the multiple resources, time scales, and grid elements targeted (ex. wholesale, retail, transmission & distribution system, carbon reduction, etc.).

20 Interoperability is the ability of technologies (DERs, smart home devices), apps, or other grid components to communicate and integrate with each other, and to understand and interpret data and commands. Interoperability is important for GEBs because of the information exchanges required to link equipment to/from other equipment, equipment to/from energy management software, and device or meter data to/from the utility.

Area to Manage	Strategies to Manage the Cost or Effort
Software Cost	• Solicit and procure software tools and controls such as Demand Response Management System or DERMs and decide on an administrative approach (utility staff time vs. vendor). • Get multiple bids to align software capabilities with business cases and utility needs to "right-size" your software tools. Consider how software needs may evolve, and refine / revisit the business case as needed. • If you're part of a joint action agency (JAA), explore ways to coordinate or centralize the software elements of your program to bring costs down for projects serving small- to medium-sized service areas.
Administration and Implementation	• If multiple staff and/or systems are used to manage distinct customer programs, look for ways to integrate them and share knowledge across them. • Offer time-based retail rates to encourage shifting consumption along with technology-based measures. • Develop integrated marketing, education, and outreach material to provide information about more than one service/technology.
Customer Experience	• Map how each program supports grid needs, occupant/customer participation/satisfaction, the value of demand response opportunities, and customer incentives. • Managing participant fatigue and satisfaction for demand response programs can be a challenge. Which customers and/or demand response opportunities are suited for frequent minor adjustment? Which are suited for less-frequent and more substantial curtailment? • Many utilities target the small-medium business (SMB) market segment via traditional residential program offerings; however, SMB often have different financial incentives and overall motivations, requiring tailored offerings and engagement strategies. Ensure customer compensation aligns with their perceived impact and burden. Small businesses may be able to use the same smart thermostat as residential, but will require higher compensation given perceived risks to their customers' comfort. • Position all offerings to engage customers and build/maintain customer trust in the utility.
Policy and Oversight	• Testing new technologies and approaches will present both opportunities and (managed) risks. Work to increase understanding and acceptance of these risks. • Review any internal or external requirements to provide demand-side management programs, such as energy efficiency or demand response. Depending on who is responsible for providing them (a utility, a third-party administrator, the state), it may be possible to leverage them for GEBs. Have conversations with any potential partners or allies early to assess their ability to support your GEBs vision.

CONCLUSION: KEY PROJECT FINDINGS

Key project findings for utility staff to keep in mind as part of GEB program development include:

1. GEBs are a new approach. Utilities and federal agencies are piloting the "first generation" of GEB programs and projects. While early adopters continue gathering experience, program managers can rely on the best-practices from simpler forms of integrated programs, such as coupled energy efficiency and demand response programs.[21] The U.S. Department of Energy Connected Communities program website is a good resource to stay up to date on GEB programs and techniques.[22]

2. Strategic planning is critical to GEB program development. GEB programs should be built in stages; strategic planning is needed to guide the process. Experienced utilities emphasize that it is valuable to dedicate time to go through a goal-setting process, create a financial and customer service case for GEBs, and craft and share a compelling story to secure internal buy-in.

3. Utilities interested in GEBs long-term can take manageable steps today. Meaningful first steps towards GEBs get the utility's staff and customers "GEB-ready" while providing operational efficiencies and cost-savings.

- ***a.*** Consider combining teams and processes to integrate and streamline delivery of existing programs.[23]
- ***b.*** Explore ways to use time-based retail rates to encourage energy use in line with grid needs.
- ***c.*** Explore and pilot demand response management software or distributed energy resource management software to control and coordinate customer devices. These types of software are the technological backbone of GEBs.[24]

4. **For electric utilities just starting, pilot proven technologies and solutions to get customers — and their buildings — "GEB-ready."** The major building systems for GEBs are the building shell, HVAC, water heating, and lighting. Other major behind-the-meter loads to consider are electric vehicles, renewables, and battery storage. Use market research or other customer insights to determine which systems provide opportunity and value in your service territory. A key finding of this guidebook is that smart thermostats are a valuable starting point for many utilities, based on their high market penetration and demand reduction potential. Additionally, other demand response programs may be an alternate entry-point to customer demand management where market penetration of relevant equipment is already high or is expected to grow quickly. Appendix A contains detailed insights on the researched peak kilowatt (kW) reduction potential of several technologies (smart thermostats, heat pumps, heat pump water heaters, thermal energy storage in refrigeration, and Energy Management Systems) as well as opportunities to combine technologies in a GEB approach.

5. Providing a good experience for program participants is especially important for GEBs enrollment and success. GEBs introduce customers to new technology and new approaches to managing energy and buildings. Financial incentives for participants should both reflect the value of grid services provided and reflect an understanding of the potential impact on participants. For example, small businesses may be able to participate in a demand response program using the same smart thermostat as a residential customer, but different outreach approaches are needed to engage and recruit them, and higher incentives are needed to offset any perceived greater risks of participating.

21 For case study examples of how to integrate energy efficiency and demand response programs, see: SEPA. (2022). Accelerating Coordinated Utility Programs for GEBs: Case Study: Internal Utility Silos, p. 36-37.

22 US Department of Energy Connected Communities Program.

23 For case study examples of how to overcome internal organization silos, see: SEPA. (2022). Accelerating Coordinated Utility Programs for GEBs: Case Study: Internal Utility Silos, p. 35-36.

24 See SEPA. (2023). Encyclopedia of DERMS Functionalities, and SEPA. (2023). DERMS: State of the Industry 2023 Gaps & Opportunities.

APPENDIX A: DATA ANALYSIS: WHAT BUILDING TECHNOLOGIES HELP MANAGE PEAK DEMAND IN A GRID-INTERACTIVE EFFICIENT BUILDINGS SETTING?

Various commercially-available technologies exist to manage building loads for grid services. *Figure 16* provides an overview of the market maturity of several technologies and control systems applicable to major building systems. It is important to note that this figure does not include solutions for electric vehicles (e.g., EV managed charging), behind-the-meter batteries, and renewables (e.g., rooftop solar integration and analytics). These additional solutions are in the commercial availability and pilot availability phases and should be reviewed for building-vehicle-grid integration.

In the near to medium term, emerging technologies' commercial availability may increase and costs may decrease, potentially making them more attractive and accessible to small- to medium-sized utilities looking for GEB solutions for their larger customers.

Emerging technology may also benefit small to medium business demand response. Today, many utilities are grappling with the challenge of effectively serving this segment. On one hand, building energy management systems (EMS) are perceived as too complex and expensive for small businesses.

On the other hand, utilities have often had a difficult time recruiting and retaining small businesses in simpler smart thermostat demand response programs. This is reportedly due to a mix of factors, including challenges in determining an incentive level that effectively compensates the participant for their perceived risks, while being cost-effective for the utility.

Additionally, new pilots and demonstrations are emerging for thermal energy storage, multi-building control, predictive control and automation for building managers, with additional insights on the effectiveness of these technologies.

To summarize the impact of demand response in a GEBs setting, we reviewed the evaluated savings generated by several commercially-available technologies controlled to provide peak demand reduction in residential and small commercial settings. Our analysis included publicly-available studies evaluating the effectiveness of each technology in reducing or shifting electricity demand through digitally automated demand response; *Figure 17* provides a summary.

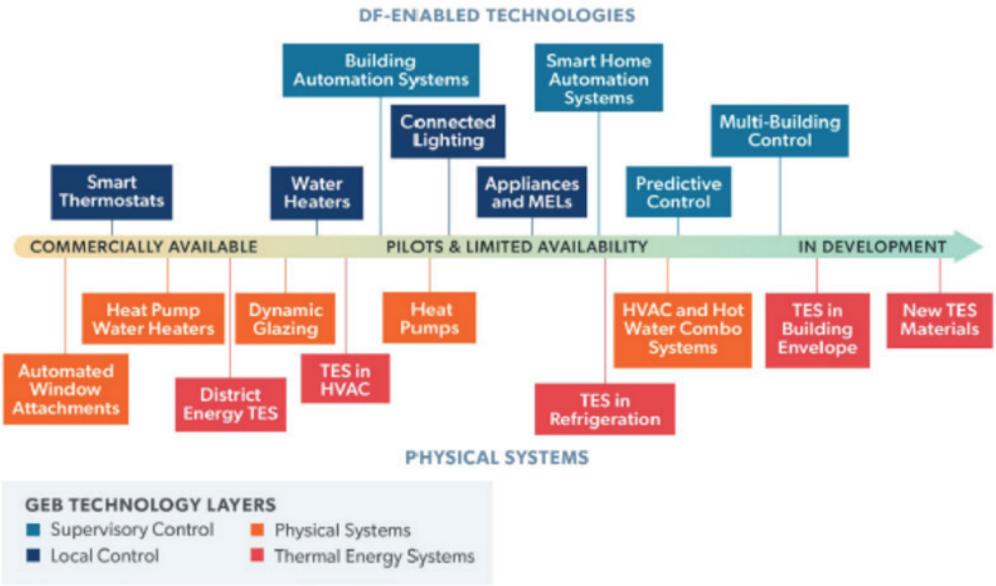


Figure 16. Technology pipeline for GEB technologies in the buildings sector

Source: Satchwell, A. et al. (2021). A National Roadmap for Grid-Interactive Efficient Buildings. TES=thermal energy storage. MEL=miscellaneous electric loads.

Technology	Definition* and Findings
Smart Thermostat	**Definition:** Smart thermostats sense the temperature conditions inside a building and control the attached HVAC equipment to maintain the target conditions necessary for thermal comfort. **Findings:** There are numerous programs and significant evaluation evidence on peak kW reduction. Some residential programs allow small business participation, with limited enrollment from that sector, due in part to limited marketing to small businesses. *Range of savings — Residential 0.2 kW – 1.13 kW; Commercial: 0.44 1.13 kW*
Heat Pump	**Definition:** Heat pumps use electricity to move heat from a cool space to a warm space, making the cool space cooler and the warm space warmer. During the heating season, heat pumps move heat from the cool outdoors into the building. During the cooling season, heat pumps move heat from inside the building to the outdoors. **Findings:** Demand response is an emerging use of heat pumps and early studies suggest limited savings in the residential sector and no completed public evaluation reports in the small commercial setting. In a study of summer demand response that adjusted ductless mini-split heat pump setpoints or cycling strategy via factory-installed WiFi demand response controls, evaluators found limited savings as a demand response asset. The technology was still viewed favorably as an EE resource. *Range of savings — Residential: 0.12 kW; Commercial: No studies found***
Heat Pump Water Heater	**Definition:** A heat pump water heater (HPWH) uses electricity to take the heat from surrounding air and transfer it to water in an enclosed tank. They are more energy-efficient than conventional electric resistance water heaters. During periods of high hot water demand, HPWHs switch to standard electric resistance heat automatically. HPWHs come with control panels that allow the selection of different operating modes. **Findings:** Demand response is an emerging use of HPWH. Studies suggest limited savings due to high energy efficiency and load profile with low overlap with the summer peak. No evidence of commercial applications at this time. HPWH are viewed favorably as an EE resource despite limited savings as a demand response asset. *Range of savings — Residential: 0 kW – 0.18 kW Commercial: None found***

Thermal Energy Storage (TES) in Refrigeration	**Definition:** The TES medium can be regenerated during non-peak hours, stored, and then discharged at any point throughout the day for daily load shedding. With appropriate controls, TES can be used more strategically in other behavioral, price-driven demand flexibility scenarios, or for emergency/economic demand response. Integrating thermal storage with frozen and refrigerated food can enable demand flexibility in refrigeration systems. **Findings:** TES is an emerging technology for commercial spaces. The few identified kW impact studies are from demonstrations and manufacturer reports (vs large-scale programs). Refrigeration-based thermal storage has proven effective in industrial cold storage and warehouse facilities (as opposed to grocery stores which have a lower temperature gradient between refrigeration and the outside environment). *Range of savings — identified resources reported average on-bill peak demand reduction of 16.4 kW per facility; estimated a 75 percent reduction in consumption during the program period; and estimated a 25% reduction in peak energy use, with future reductions projected at 42%.*
Energy Management Systems (EMS)	**Definition:** Energy management systems are the collection of products and methods to communicate with devices in a home or business, like an air conditioner or a water heater. There are fewer systems on the market to integrate end-use systems and DERs. Commercial EMS may be integrated with lighting controls and other DERs, but many only control HVAC. Some automation and control systems can receive grid signals with the installation of an OpenADR gateway. In other cases, the system may have grid communication capabilities such as OpenADR available as a native element of the control system. **Findings:** It is difficult to isolate the kW impacts of EMS at small business based on the reviewed studies of commercial demand response programs. EMS and real time energy management are viewed favorably as an EE resource, especially for commercial real estate portfolios which can achieve value at scale (e.g., across multiple buildings). *Range of savings — Varied savings exist for programs that offer EMS as one of several available C&I auto demand response control strategies, but we could not isolate savings from EMS specifically.* NYSERDA's RTEM program provides information about how to use EMS for demand management.

Figure 17. Summary[25] of per-technology savings in utility program evaluation reports

Notes
*: Definitions are from Satchwell, A. et al. (2021). A National Roadmap for Grid-Interactive Efficient Buildings.
**: No dedicated commercial or SMB demand response/demand flexibility programs were identified for these heat pump technologies. Residential programs exist but based on document review it is not clear whether small commercial customers participated.

25 Based on studies available in 2023, we reviewed single-product programs. Single-technology savings are a good way to approximate impacts but have limitations for planning fully integrated GEBs programs. Higher or lower impacts could occur if the technologies are interacting with other GEB systems. The U.S. DOE's Connected Communities pilots, which were approaching launch at the time of this guidebook, are expected to provide useful data on whole-building savings in a fully integrated GEB environment. Additionally, results reflect utilities with rigorous program evaluation, measurement and verification standards–generally, investor-owned utilities with a policy requirement to provide customer demand-side management and paying for an external evaluation consultant.

Additional study findings offered insight on how a utility could use these technologies as part of a bundled program promoting integrated energy efficiency, demand response, demand flexibility, and DER programs. Some of the opportunities include:

1. Enroll any **residential smart thermostats provided as an energy efficiency upgrade in demand response programs.** Pursue cost-effective paths to ensure demand response participants have also received any relevant building shell upgrades. This provides year-round energy savings and indoor temperature stability, thereby helping to maintain customer comfort during demand response events. For income eligible residential customers, there may be opportunities to partner with local weatherization agencies to support these building envelope improvements.

2. Water heater demand response. Conventional electric water heaters may need add-on internet connectivity, but small and rural utilities have included them as part of their electrification/demand management strategy for years. Some models may have integrated controls or require add-on controls. Heat pump water heaters are an emerging energy efficiency measure and have been tested as a demand response resource. Early pilots reviewed for this study suggest that demand response savings may be a challenge due to the equipment's high efficiency and low coincidence with today's peak periods. The measure could be monitored for potential aggregate demand reduction value in the future as program models continue to develop.

There are numerous GEB-enabling technologies and concepts that were not covered in-depth in this study. Several to point out for future monitoring and potential adoption include:

3. Smart efficient lighting. These may offer an approachable way to begin raising awareness and educating customers on the concept of smart energy management. Note that the cost of smart lighting compared to conventional LEDs may make these difficult to justify based on energy efficiency cost-effectiveness alone.

4. Electric vehicle managed charging for residential customers and f**leet electrification** support for commercial and municipal customers. EV managed charging is an opportunity for utilities to balance the benefits of vehicle electrification with peak demand management and grid services. Managed charging remains an emerging opportunity for utilities in areas where few customers have yet to adopt EVs. SEPA resources on vehicle-to-grid and managed charging provide added context on opportunities.[26]

5. Residential energy storage (batteries): While rare in the mass-market today and primarily purchased by customers for resiliency purposes, behind-the-meter battery storage has the potential to help integrate renewables and provide grid services.

6. Last, while not a building technology, we recommend exploring valuation frameworks for capturing the full benefit-cost analysis that multi-benefit technologies provide to utilities, ratepayers, and society. Technologies that are not cost-effective for a single energy service (e.g., energy efficiency) may become so if they are evaluated in terms of multiple GEB benefits (e.g., demand flexibility, and others). Resources include the *National Standard Practice Manual for Benefit-Cost Analysis of DERs (2020).*[27]

26 For additional information on transportation electrification, see: SEPA. (2023). The State of Bidirectional Charging in 2023, and SEPA. (2023). Preparing for Customer Fleet Electrification: A Utility Framework.

27 National Energy Screening Project (NESP). (2020). National Standard Practice Manual for Benefit-Cost Analysis of DERs. NESP coordinated by E4TheFuture.

APPENDIX B. RESOURCES: WHERE CAN I LEARN MORE?

Pilot Programs

Many utilities use a pilot approach to try new tools on a smaller scale or with a lower investment. The goal is to gain hands-on experience with new technologies, evaluate their performance in specific conditions, identify crucial factors contributing to their success, and determine what is needed to successfully bring the effort to full scale. Conducting pilots and demonstrations provides the experience and data to better assess the feasibility and benefits of future plans. *Box 3* lists aspects of pilots to consider.

Box 3. Program pilots and demonstrations – from early steps to increasing integration

- Demonstrate and validate new approaches and technologies (physical, digital)
- Collect real-world data on technical performance
- Experiment with new or altered policy, administrative, or regulatory approaches in a "sandbox" environment
- Develop utility staff experience
- Gather insight into financial and economic performance in a lower-risk setting
- Assess customer experience, areas of confusion, and wants/needs
- Validate the business case for moving from a small-scale test to integrated deployment

GEB Program Planning Resources

- AMP/VEIC. (2021). Grid-Connected Heat Pump Water Heater (HPWH) Guidebook. Prepared for APPA (available to DEED program members).
- Guidehouse. (2021). Incentive Mechanisms for Leveraging Demand Flexibility as a Grid Asset An Implementation Guide for Utilities and Policymakers.
- National Association of State Energy Offices. (2019). Considerations for Grid-interactive Efficient Buildings (GEB) Pilot Projects.
- PNNL. (2022). Pilot Considerations for Grid-Interactive Efficient Buildings in Hawaii.
- PNNL. (2021). Pilot Considerations for Grid-Interactive Efficient Buildings in Washington.
- Tennessee Valley Authority. (2022). Grid-interactive Efficient Buildings Implementation Guide.

National Strategy for GEBs and Federally-Funded GEB Pilot Programs

- Olgyay, V. et al. (2020). Connected Communities: A Multi-Building Energy Management Approach. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75528.
- Satchwell et. al. (2022). A National Roadmap for Grid-Interactive Efficient Buildings. U.S. DOE.
- SEPA. (2022). Accelerating Coordinated Utility Programs for Grid-Interactive Efficient Buildings: Practitioners' Perspectives.

Other Resources

- National Energy Screening Project. (2020). National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources.
- PLMA. (2018). The Future of Utility "Bring Your Own Thermostat" Programs: A Compendium of Industry Viewpoints.
- SEPA. (2023). Encyclopedia of DERMS Functionalities.
- SEPA. (2023). DERMS: State of the Industry 2023 Gaps & Opportunities.

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