# Pilot Considerations for Grid-Interactive Efficient Buildings in Washington

**November 2021**

Christine Holland, Pacific Northwest National Laboratory
Juliet Homer, Pacific Northwest National Laboratory

PNNL-32353

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# Abstract

This technical brief supports the research, design, and creation of grid-interactive efficient building (GEB) pilots. GEBs integrate energy efficiency and demand flexibility with smart technologies and communications to improve affordability, comfort, and productivity. GEBs can also support grid reliability and renewable resources integration. GEB pilots can help identify the costs and benefits of GEBs to building owners and operators, utilities, and grid managers. For building owners and operators, GEB pilots can measure the impact of different GEB components on occupant comfort, productivity, and cost savings. For grid or utility managers, GEB pilots can provide information on how GEBs can provide cost-effective flexibility and reliability to the grid. This guide provides state policymakers, regulatory staff, utilities, and other energy stakeholders with information to support GEB pilot design, including a summary of the potential value of GEBs, technology requirements and communication protocols, and cost-effectiveness considerations. This brief also lays out illustrative examples, metrics for gauging pilot success, and considerations for public utility commissions and pilot designers.

# Acknowledgments

This work was funded by the Building Technologies Office of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, under the guidance of Monica Neukomm. This work is being conducted through the Department of Energy's Grid Modernization Laboratory Consortium and supported by the National Association of State Energy Offices and the National Association of Regulatory Utility Commissioners through a designated Grid-interactive Efficient Buildings Working Group. The authors also would like to acknowledge project support by Natalie Mims Frick of Lawrence Berkeley National Laboratory.

# Acronyms and Abbreviations

| | |
|---|---|
| ACEEE | American Council for an Energy-Efficient Economy |
| ADR | automated demand response |
| DER | distributed energy resource |
| DOE | U.S. Department of Energy |
| DR | demand response |
| EE | energy efficiency |
| EM&V | evaluation, measurement, and verification |
| EV | electric vehicle |
| $ft^2$ | square foot |
| GEB | grid-interactive efficient building |
| GW | gigawatt |
| HVAC | heating, ventilation, and air conditioning |
| IRP | integrated resource plan |
| kW | kilowatt |
| kWh | kilowatt-hour |
| LEED | Leadership in Energy and Environmental Design |
| MIDAS | Market Informed Demand Automation Servicer |
| NREL | National Renewable Energy Laboratory |
| PGE | Portland General Electric |
| PUC | public utility commission |
| PV | photovoltaic |
| WA | Washington |

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# 1.0 Introduction

This technical brief supports the research, design, and creation of grid-interactive efficient building (GEB) pilots. GEBs integrate energy efficiency (EE) and demand flexibility with smart technologies and communications to improve affordability, comfort, and productivity. GEBs, which include residential or commercial buildings, also support renewables integration and improved overall building performance.[1]

This brief also builds on the U.S. Department of Energy's (DOE's) recent publication, *A National Roadmap for Grid-interactive Efficient Buildings* (Roadmap), which estimated the national potential for energy and demand savings from GEBs and identified pathways forward to achieve it. The Roadmap found that over the next two decades, national adoption of GEBs could be worth between $100–$200 billion in U.S. electric power system cost savings and could decrease carbon dioxide emissions by 80 million tons per year.[2]

Although GEBs have much to offer, nascent technologies and the difficulties associated with connecting loads in, and across, buildings and responding in a coordinated way to building and utility system needs can make implementing GEBs relatively complex and challenging. Pilots are critical to addressing the challenges associated with development and implementation of GEBs and identifying replicable solutions. Pilot designers may want to determine the types of GEB resources with the potential to address system needs (capacity, energy, voltage, frequency). Pilots can be used to help understand the costs, such as technical components and systems required for interactivity, management, and operations control, of meeting system needs through GEBs compared to traditional means. Replicability is an important factor that should be considered in designing pilots and transitioning from pilots to demonstrations and full-scale implementation.

This guide provides state policymakers, regulatory staff, utilities and other energy stakeholders with information to support GEB pilot design. It lays out potential pathways, beginning with an understanding of what GEBs can offer to the grid, and then identifies utility energy priorities, which will in turn drive relevant pilot research questions and GEB pilot metrics (Figure 1).

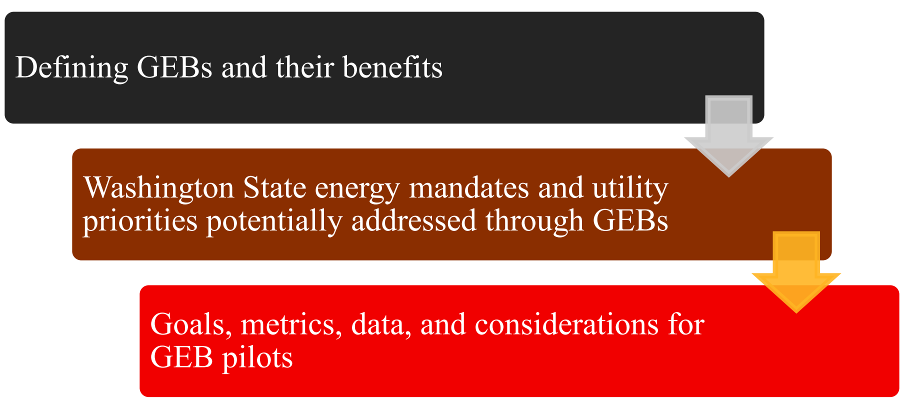


**Figure 1. Overview of the Information Flow in this Technical Brief**

[1] DOE Office of Energy Efficiency and Renewable Energy. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* May 17, 2021. https://gebroadmap.lbl.gov/.
[2] Ibid.

The remainder of the guide is organized as follows:

- Section 1.0 defines GEBs, describes their potential value, explains technology requirements and the evolution of GEBs, describes grid services that GEBs can offer, and provides detailed examples of GEB pilots.
- Section 2.0 lists potential utility energy planning priorities that will drive GEB pilot components. Each utility will have different goals and priorities, so it stands to reason that each pilot composition will be unique.
- Section 3.0 links utility goals with specific measurement metrics and data needs to assess the desired pilot outcomes. Both the technical aspects of GEBs and customer participation are considered.
- Section 4.0 summarizes the technical brief.
- Appendix A provides several examples of GEB pilots.
- Appendix B provides a comprehensive set of questions to complement the considerations to be addressed through a pilot in Section 3.0.
- Appendix C provides some perspective on choosing metrics for a pilot.
- Appendix D lists resources with links to quickly access more detailed or technical aspects of GEBs.

## 1.1 Defining GEB

According to the DOE's Office of Energy Efficiency and Renewable Energy, a *GEB* is "[a]n energy-efficient building that uses smart technologies and on-site distributed energy resources (DERs) to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way."[3] GEBs "utilize analytics and controls to [continuously] optimize energy use" for a predetermined goal.[4]

The DERs that are aggregated to provide demand management through efficiency and flexibility include:[5]

- Demand response
- Energy efficiency
- Solar photovoltaics
- Electric vehicles
- Battery storage

Using buildings as grid assets represents a new, flexible resource to provide energy savings and manage bidirectional control of energy flow using a blend of DERs,[6] including flexible load technologies enabled through smart controls. This interconnectivity and communication between technologies inside GEBs,

[3] U.S. Department of Energy. 2019. *Grid-interactive Efficient Buildings Technical Report Series.* Office of Energy Efficiency and Renewable Energy, Building Technologies Office. December 2019. https://www1.eere.energy.gov/buildings/pdfs/75470.pdf.

[4] Ibid.

[5] U.S. Department of Energy. 2019. "Grid-interactive Efficient Buildings." April 11, 2019. https://www.energy.gov/sites/prod/files/2019/04/f62/bto-geb-factsheet-41119.pdf.

[6] DERs include distributed generation resources, distributed energy storage, demand response, energy efficiency, and EVs that are connected to the electric distribution power grid. Some examples are: "behind-the-meter" solar photovoltaic (PV), micro wind turbine(s), combined heat and power, or battery energy storage systems, along with "smart" or controllable appliances. U.S. Department of Energy. 2017. "Modern Distribution Grid Volume 1: Customer and State Policy Driven Functionality." Version 1.1. March 27, 2017. https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf.

and with the grid, is illustrated in Figure 2. Sensors and controls play an important role in GEBs because they allow resources to respond to grid or building signals and enable continuous and enhanced energy management. Software and communication systems allow signals to be sent to and from the grid and the building and optimize the building's energy use.

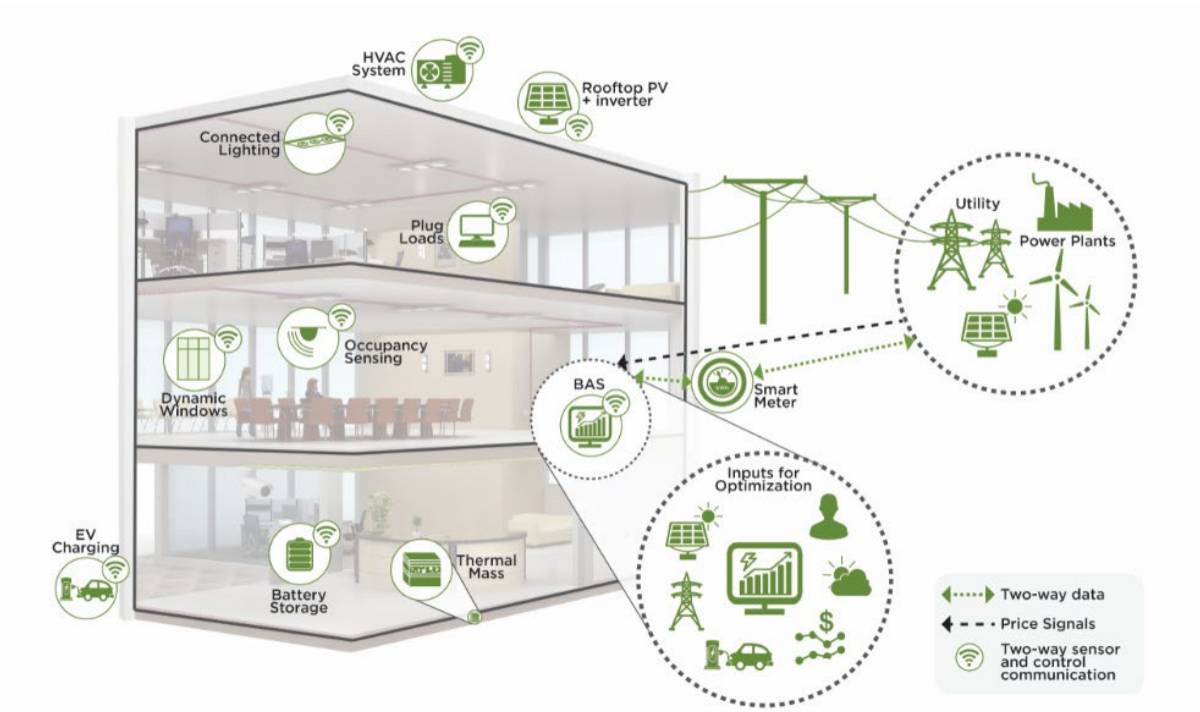


**Figure 2. Example of a Commercial GEB. Image courtesy of Guidehouse©.[7]**

## 1.2 Potential energy and demand savings from GEBs

Several recent publications have identified energy and demand savings from GEB implementation. The Roadmap noted that the magnitude of estimated national annual energy and peak demand savings from GEBs are substantial (Figure 3).[8] The three adoption levels in Figure 3 create a range of peak demand savings from GEBs, between 42 gigawatts (GW) and 116 GW, which translates to a total annual system value between $8 billion and $18 billion.[9] For reference, according to the U.S. Energy Information Agency, the total utility-scale electricity generating capacity in the United States at the end of 2020 was 1,117 GW.[10]

[7] Nubbe, V., M. Yamada, et al. 2019. *Grid-interactive Efficient Buildings Technical Report Series. Lighting and Electronics.* For the U.S. Department of Energy. December 2019. https://www1.eere.energy.gov/buildings/pdfs/75475.pdf.

[8] For more details on adoption level assumptions and methodology for calculating these savings, see the full DOE GEB Roadmap: https://gebroadmap.lbl.gov/.

[9] DOE. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* Office of Energy Efficiency and Renewable Energy. May 17, 2021. https://gebroadmap.lbl.gov/.

[10] Energy Information Administration. 2021. Electricity explained. https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php.

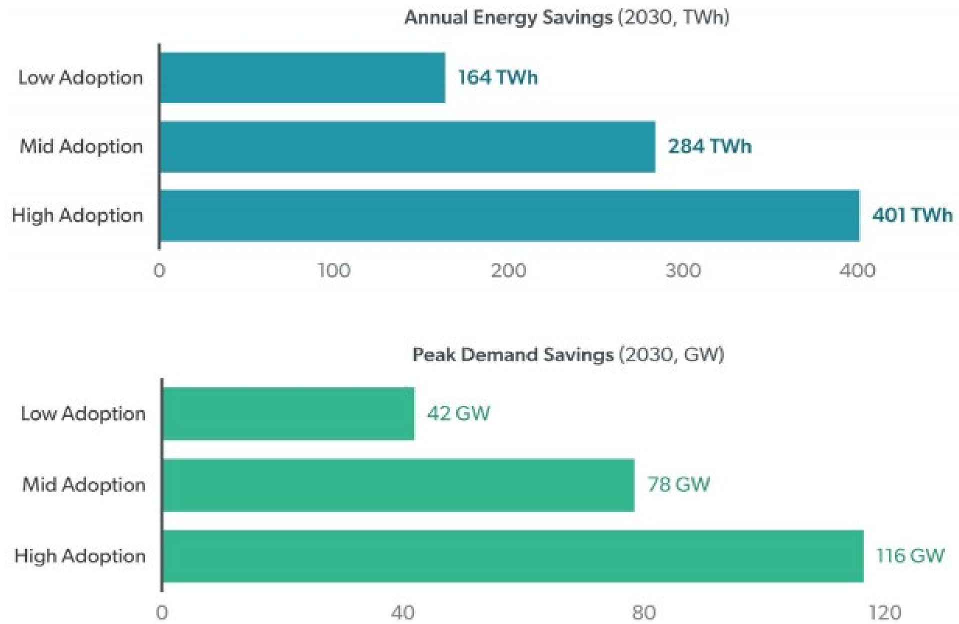


**Figure 3. Potential Value to the U.S. Power System of Peak Demand and Energy Savings from Different GEB Adoption Levels (Source: DOE GEB Roadmap 2021)**

Figure 3 shows energy and peak demand savings by measure type for 2030 for three adoption scenarios. The mid-adoption case in the Roadmap is based on the middle of the range of achievable adoption estimates from an analysis conducted using the National Renewable Energy Laboratory's Scout tool, as detailed in Appendix B of the Roadmap.[11]

Langevin et al. (2020) cites that the IEA has found, in aggregate in the Northwest, that GEBs have the potential to reduce summer peak by 35% and winter peak by 33%,[12] predominantly through EE. This peak reduction translates into utility savings that may be passed along to customers through lower rates.

A study by Brattle shows that GEB investments could result in substantial energy savings for the grid in the form of deferred or avoided capacity expansion and other avoided energy services (Table 1).[13] Brattle estimates U.S. national load flexibility could deliver a 57% reduction in generation capacity costs, 29% reduction in energy costs, and a 12% reduction in transmission and distribution costs.

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[11] Scout is a software program that estimates the impacts of various energy conservation measures in the U.S. residential and commercial building sectors. https://scout-bto.readthedocs.io/en/latest/.

[12] Langevin, et al. 2020. "Grid-interactive efficient buildings: Assessing the potential for energy flexibility alongside energy efficiency." LBNL and NREL. https://www.energy.gov/sites/prod/files/2020/06/f76/bto-geb-potential-062520.pdf.

[13] Hledik, R., et al. 2019. "The National Potential for Load Flexibility; Value and Market Potential through 2030." The Brattle Group. June 2019. https://brattlefiles.blob.core.windows.net/files/16639_national_potential_for_load_flexibility_-_final.pdf.

**Table 1. 2030 Annual Benefits of the National Load Flexibility Portfolio**

| Category | Annual Savings ($) | Percent of Total Savings (%) |
|---|---|---|
| Avoided Generation Capacity | 9.4 billion | 57 |
| Avoided Energy Costs | 4.8 billion | 29 |
| Avoided Transmission and Distribution Capacity | 1.9 billion | 12 |
| Ancillary Services | 0.3 billion | 2 |
| **Total** | **16.4 billion** | **100** |

Another study by DiNola and Punjabi (2019) shows GEBs aggregated across all federal buildings could generate up to $70 million/year in value to grid users from reduced generation capacity, transmission, and distribution expenses. The study found the value could be monetized and benefit all ratepayers, improve grid resilience, balance loads, and reduce grid–carbon intensity.[14]

## 1.3 Value of GEBs

One of the greatest value propositions of GEBs is the ability to aggregate the benefits of EE and demand flexibility across several buildings, transforming buildings into a utility-scale grid resource. Existing buildings that have the capability to shed, shift, and modulate load and generate energy but are not grid connected and act in isolation have little impact on the grid.

GEBs' interconnectivity can act in two ways. First, a utility can scale up the effects of one building to a feeder, community, or region as needed to support the grid, potentially utilizing different resources and services from different buildings. Second, connected buildings can work together and act as a microgrid or connected campus, where loads and generations can flow and compensate building needs within the "network" to provide a given grid need, such as peak shaving or voltage regulation.

GEBs have the potential to enable utilities to actively use buildings as a grid resource by addressing capacity constraints and other long-term resource adequacy needs by providing EE, load flexibility, and generation to the grid. In addition to provide grid services, GEBs may also improve a region's ability to integrate renewable energy, help manage electric vehicle (EV) charging, reduce line losses, help states or utilities achieve mandated emissions goals, or provide other important benefits to the utility, such as resilience.[15]

[14] DiNola, R. and S. Punjabi. 2019. "Federal Building and Grid Integration Roadmap Task Group." September 12. https://www.gsa.gov/cdnstatic/DiNola%20Punjabi%20-%209-12-19%20Bldg%20Grid.pdf.

[15] According to a Presidential Policy Directive on Critical Infrastructure Security and Resilience, *resilience* is "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attaches, accidents, or naturally occurring threats or incidents." https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

Figure 4 shows how GEBs can provide value to the grid. First, efficient buildings result in an overall energy reduction, as shown in the top panel. Next, GEBs can shed load; for example, by dimming lights in response to a grid signal, such as during a peak load event. The impact of a GEB shedding load is illustrated in the second panel. GEBs can also be used to shift load to off-peak periods in response to a grid signal. For example, connected water heaters can pre-heat in response to a grid signal, as shown in the third panel. GEBs can modulate generation and load to help maintain grid frequency or control voltage. Modulation can occur autonomously through the use of batteries and inverters, as illustrated in the fourth panel. Finally, GEBs can generate electricity or provide power to the grid, such as through distributed generation and battery energy storage exports to the grid.

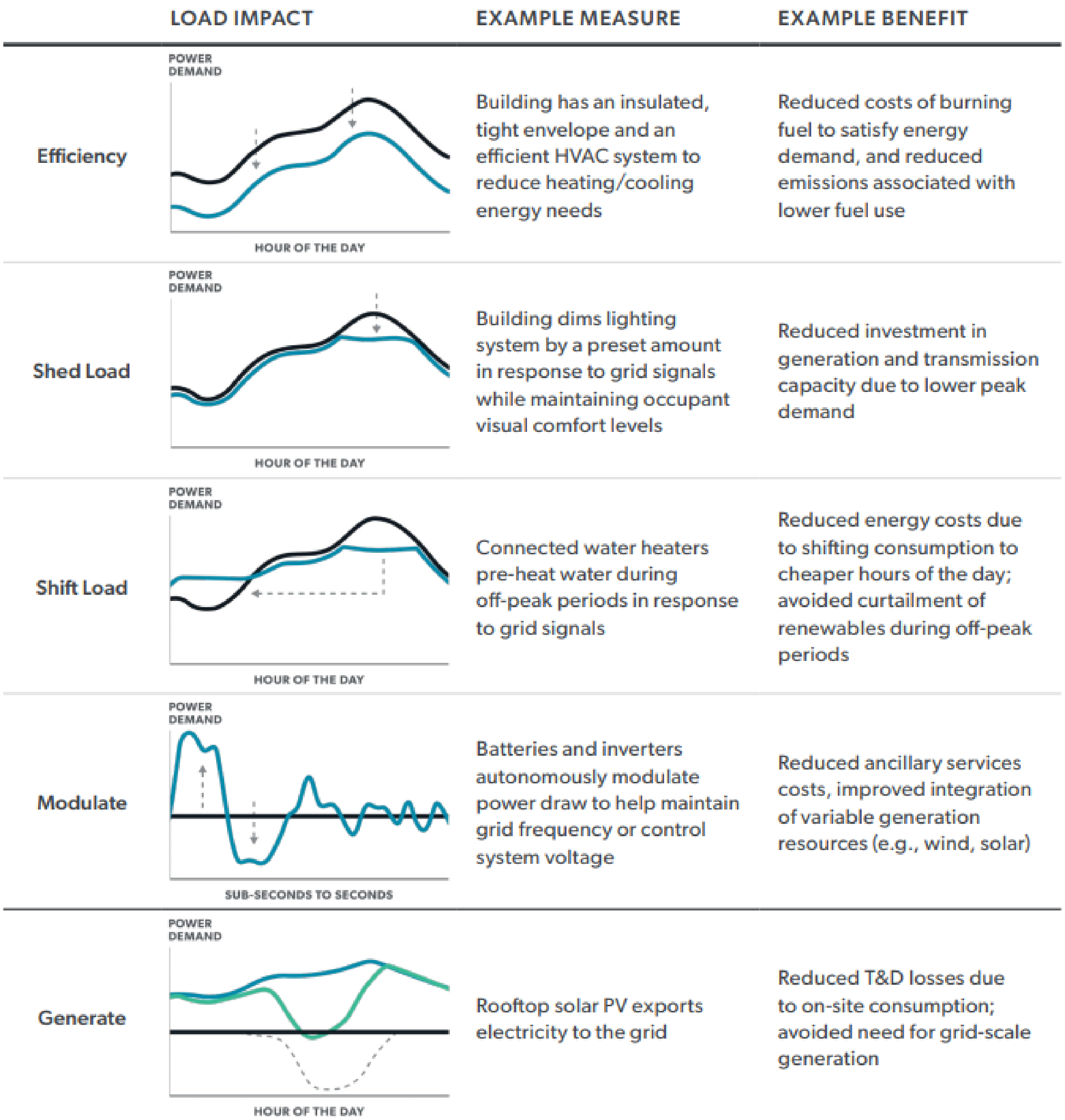


**Figure 4. Grid Services that GEBs Can Provide (Source: 2021 DOE GEB Roadmap[16])**

[16] DOE. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* Office of Energy Efficiency and Renewable Energy. May 17, 2021. https://gebroadmap.lbl.gov/.

Figure 5 shows the culmination of GEB benefits. The ultimate load reduction and management results in the red line labeled "Mitigating the duck curve with GEB" — a combination of EE, distributed generation, and flexible demand. Flexible demand includes the ability to shed load, shift load, or modulate load and generation, as described in Figure 6. Load flexibility encompasses and expands upon conventional demand response (DR) through highly connected and interactive DERs. Traditional DR programs were limited to a set number of curtailment hours (or an individual event) in response to utility signals to consumers to reduce electricity consumption during times of high grid constraints. In contrast, GEBs' integrated communication and control technologies enable buildings to shed, shift, or modulate in response to changing grid needs and market signals. For example, smart controlled heat-pump water heaters, thermostats, and EV chargers can be engaged based on a market signal or during a curtailment event or used in micro-increments to provide frequency and voltage support.[17]

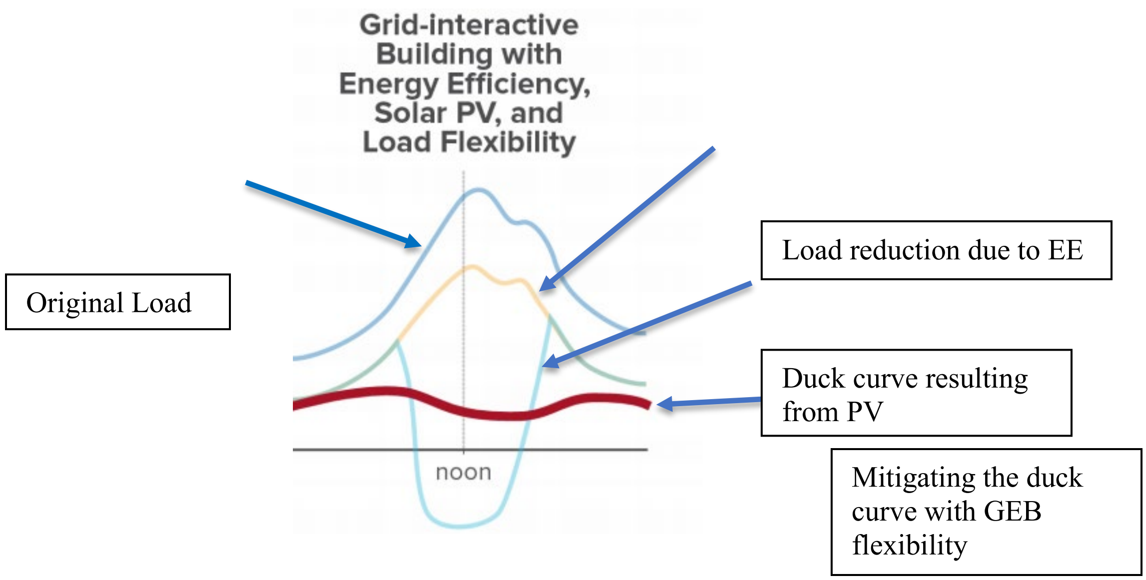


**Figure 5. Culmination of GEB Benefits (Source: Adapted from Carmichael et al. 2019[18])**

As a result of the grid services listed above, potential GEB applications are numerous. From the GEB project examples in Appendix A, we summarize some of the applications:

- Utilities that have a capacity need due to load growth, as well as retiring existing facilities, may be able to use cost-effective flexible demand to meet those needs.
- GEBs may improve a region's ability to integrate renewable energy. Increased adoption of renewable energy creates greater intermittency in supply, which increases the need for load and supply flexibility, potentially provided by GEBs.
- GEBs may help leverage the benefits of flexible EV charging. It is estimated that power needs will have to double to accommodate anticipated light duty EV growth by 2050,[19] making

[17] More examples of the differentiation between individual versus integrated GEB benefits are provided in Table A.1 in Appendix A.
[18] Jungclaus, M., C. Carmichael, and P. Keuhn. 2019. *Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis.* Rocky Mountain Institute. https://rmi.org/insight/value-potential-for-grid-interactive-efficient-buildings-in-the-gsa-portfolio-a-cost-benefit-analysis/.
[19] Groom, N., and T. Bellon. 2021. "EV rollout will require huge investments in strained U.S. power grids." *Reuters Commodity News* March 5, 2021. https://www.reuters.com/article/us-usa-weather-grids-autos-insight/ev-rollout-will-require-huge-investments-in-strained-u-s-power-grids-idUSKBN2AX18Y.

charging management important for both grid operators and customers. From a grid perspective, both smart charge management and burgeoning “vehicle-to-grid” technologies[20] could provide needed bidirectional flexibility. Currently, there is little documentation for using EV batteries as a grid resource, so a GEB pilot could be an appropriate avenue to test the costs and benefits of vehicle-to-grid technologies for both consumers and grid planners. From a customer or building owner perspective, managed EV charging in concert with onsite generation and flexible loads can help manage utility bills.

- With more extreme weather and fire events, resilience is a growing concern. A pilot can test a GEB’s ability to act as a microgrid or improve grid resilience.

## 1.4 Technology requirements and evolution of GEB

GEBs are technology intensive. In order for GEBs to be fully functional, technologies need to enable the following activities:

- Individual systems, such as lighting or heating, ventilation, and air conditioning (HVAC), need to respond to building sensors, such as air temperature and lumens throughout the building.
- Building-wide systems must be able to communicate with each other. GEBs need the intelligence to track building demand and predict patterns that can limit peak demand, and shift or shed demand rapidly in response to building events.
- Buildings need to communicate and coordinate among each other if they are going to act as a grid resource or microgrid.
- GEBs need to communicate with grid signals.

In GEBs, integrating benefits from multiple building services and other DER end uses requires the integration of layers of technology, culminating in supervisory control that can span multiple building services. This idea of a highly complex and interactive set of technological systems is illustrated in Figure 6. As discussed in the Roadmap, Figure 6 depicts the functional attributes that can be integrated with building end-use and envelope systems, as well as DERs, to realize the full opportunities of GEBs. The bottom of the figure shows the services the building provides occupants, including shelter, comfort, hot water, refrigeration, and light. These services are provided by physical end-use systems such as the building envelope and structure, HVAC, appliances, lights, and other equipment. In order for the physical end-use devices to provide services, sensors and actuators are needed to enable the dynamic control of these systems. Fully integrated GEBs may provide more sensing than traditional buildings, with measurements of temperature, occupancy, light levels, hot water, and other key attributes that are used to evaluate the load flexibility. Local or individual device control systems interact with the sensors and actuators to control individual devices and physical systems in a GEB. Supervisory control systems in GEBs are the control systems that integrate the control of multiple devices and systems within a building to optimize overall building performance and ultimately interact with the grid. These technology layers, illustrated in Figure 6 and described above, are the interconnected foundation that enables GEBs to provide benefits to building owners and the grid.

[20] Inferences can be made to vehicle-to-grid contributions from Borge-Diez et al. 2021. “Contribution of Driving Efficiency to Vehicle to Building.” *Energies* 14: 3483.

Integration of DERs with the building can occur at either the supervisory or local control layer. For example, an EV charger may integrate a single EV, but a supervisory control system may integrate building loads and DERs to minimize total costs for a homeowner."[21]

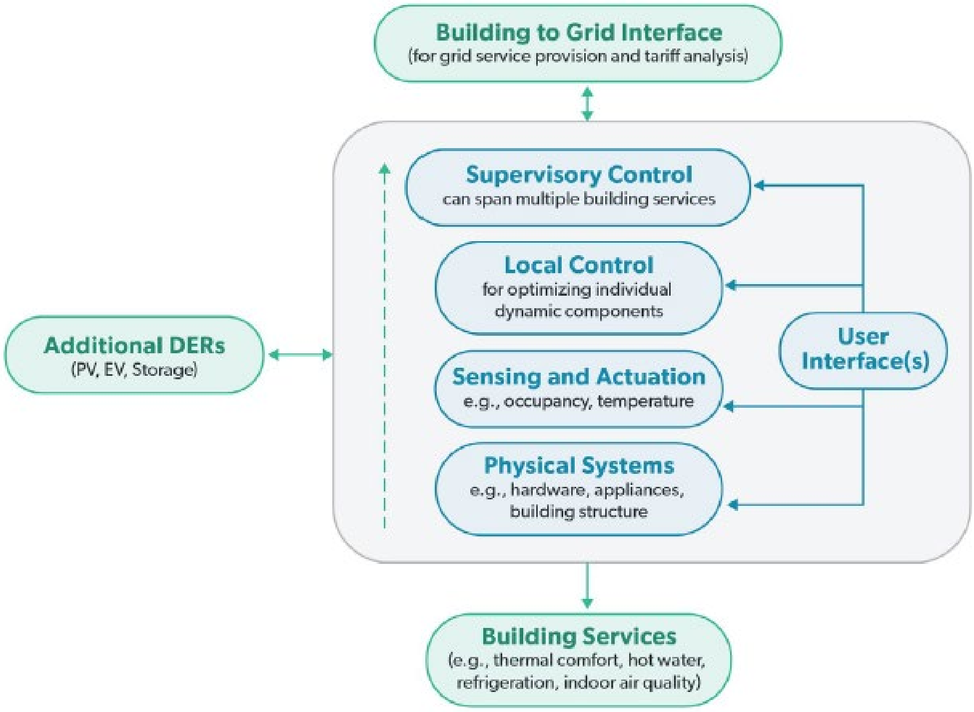


**Figure 6. GEB Technology Layers (Source: 2021 DOE GEB Roadmap)**

Figure 7 illustrates the differences and progression in technological sophistication and benefits from traditional EE and DR near the origin to GEB resources in the upper right quadrant. Over time, utility programs can evolve from isolated automated demand response (ADR) and traditional EE or smart energy management programs to varying degrees of cross-promoted and integrated ADR and EE programs. This evolution requires that traditionally separate departments within utilities start to work together to plan, promote, implement and track these programs in a more holistic way.

DER aggregation pilots are also precursors to GEB programs.[22] In full GEB programs, buildings provide EE services and dynamic grid services through connected, smart control of multiple flexible building loads and DERs. Isolated EE and ADR programs exist currently in many jurisdictions. Integrated and streamlined EE and ADR programs are less common. DER aggregation pilots exist now in multiple states,[23] and a new DER aggregation tariff under development in Arizona would allow for the aggregation

[21] DOE. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* Office of Energy Efficiency and Renewable Energy. May 17, 2021. https://gebroadmap.lbl.gov/.

[22] *DER aggregation* refers to bundling DERs to engage as a single entity, akin to a virtual power plant. Also, aggregation is a service offered by third-party entities for the purpose of providing energy or grid services. An aggregator serves as an intermediator between consumers (who provide DER) and power system participants (such as utilities, who deploy grid services) (Carreiro, A.M., H.M. Jorge, and C.H. Antunes. 2017. "Energy management systems aggregators: A literature survey" *Renewable and Sustainable Energy Reviews* 2017.01.179).

[23] Cook, J.J., K. Ardani, E. O'Shaughnessy, B. Smith, and R. Margolis. 2018. *Expanding PV Value: Lessons Learned from Utility-led Distributed Energy Resource Aggregation in the United States.*

of distributed demand-side resources, such as smart thermostats, connected hot water heaters, and energy storage systems.[24] Challenges to DER aggregation pilots, and ultimately to GEBs, include clear rules for how DERs participate in wholesale power markets and standard communication protocols for connected devices on home energy management platforms.[25] A National Renewable Energy Laboratory (NREL) report on DER aggregation points out that to scale DER aggregation programs, utilities may need to develop DER management systems and find cost-effective pathways to integrate DERs with different communication protocols.[26] In GEB pilot designs, utilities will need to carefully think through how they will address compensation and communication protocols for pilots.

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National Renewable Energy Laboratory. NREL/TP-6A20-71984. November. https://www.nrel.gov/docs/fy19osti/71984.pdf?utm_source=NREL+Solar+Market+Research+and+Analysis&utm_campaign=66f44ace56-EMAIL_CAMPAIGN_2018_11_12_06_13&utm_medium=email&utm_term=0_7e950366d3-66f44ace56-.

[24] Arizona Corporation Commission. 2021. "Arizona Corporation Commission Leads in Energy Policy." News release. January 26. https://www.azcc.gov/news/2021/01/26/arizona-corporation-commission-leads-in-energy-policy.

[25] Shallenberger, K.. 2017. "DER aggregation: Sector experts identify emerging trends in a nascent market." *Utility Dive*, July 24. https://www.utilitydive.com/news/der-aggregation-sector-experts-identify-emerging-trends-in-a-nascent-marke/447670/.

[26] Cook, J.J., K. Ardani, E. O'Shaughnessy, B. Smith, and R. Margolis. 2018. *Expanding PV Value: Lessons Learned from Utility-led Distributed Energy Resource Aggregation in the United States.* National Renewable Energy Laboratory. NREL/TP-6A20-71984. November. https://www.nrel.gov/docs/fy19osti/71984.pdf?utm_source=NREL+Solar+Market+Research+and+Analysis&utm_campaign=66f44ace56-EMAIL_CAMPAIGN_2018_11_12_06_13&utm_medium=email&utm_term=0_7e950366d3-66f44ace56-.

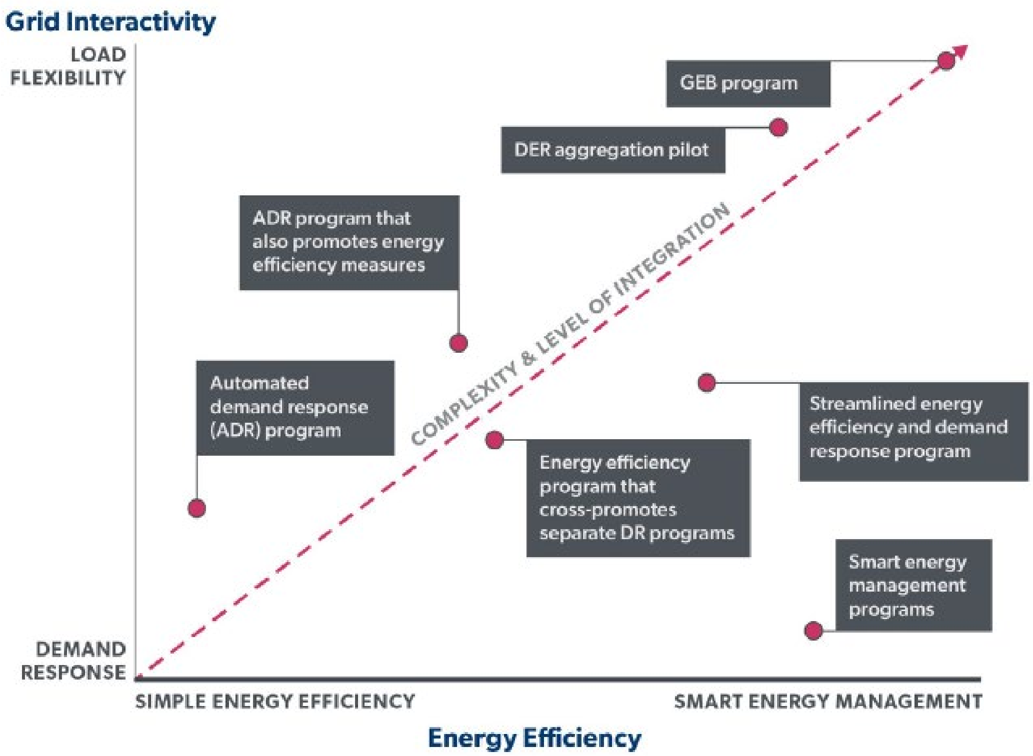


**Figure 7. Scaling Up to GEB (Source: 2021 DOE GEB Roadmap,[27] adapted from 2019 ACEEE[28])**

## 1.5 Communications protocols

Communication protocols are important for GEB pilots and full-scale development. There are communication protocols that are used inside buildings, including BACnet and Modbus (used primarily for commercial buildings) and Wi-Fi (used for both commercial and residential buildings). There are also communications protocols outside the building, between the building and the grid. The most common grid-side communications protocols in the United States are: OpenADR (used in California), IEEE standard 2030.5, SunSpec Modbus, and DNP3. OpenADR and IEEE 2030.5 are the only standards that reach into the building. SunSpec is focused on inverter-based resources such as batteries, inverters, and EVs.

There are also interface specifications such as CTA-2045 that are used for devices within buildings. The state of Washington is the first state in the country to adopt a design standard that requires electric storage water heaters to have a modular DR communication port compliant with CTA-2045.[29] The port will enable utility programs to manage water heating loads. Oregon has followed Washington and will also

[27] DOE. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* Office of Energy Efficiency and Renewable Energy. May 17, 2021. https://gebroadmap.lbl.gov/.

[28] American Council for an Energy-Efficient Economy (ACEEE). 2019. "State of the Market: Grid-Interactive Efficient Building Utility Programs." Prepared by Christopher Perry, Hannah Bastian, and Dan York. October 2019. https://www.aceee.org/white-paper/gebs-103019.

[29] NEEP. 2021. Emerging Codes and Standards for Grid-Interactive Buildings. January. https://neep.org/sites/default/files/media-files/grid_final_formatted.pdf.

require CTA-2045 (or equivalent open-source modular interface standard) ports on electric water heaters starting in January 2022.[30]

On January 1, 2020, California Senate Bill 49 became law, requiring the California Energy Commission to examine enabling appliance and building code standards in order to incentivize smart appliance development. The California Energy Commission has now developed the Market Informed Demand Automation Servicer (MIDAS) database that contains current and future time-varying rates, greenhouse gas emissions associated with electrical generation, and California Flex Alert signals populated by electric load serving entities and other registered entities.[31] The publicly accessible MIDAS database is available in a standard machine-readable format. Load serving entities must have advanced programming skills and in-house software to effectively populate and maintain rate information stored in the database.[32]

Alignment of standards is key to interoperability. Information (semantic) models between standards need to map and similar functionality needs to exist. Many standards are rooted in the Common Information Model, but there is still a lot of work to do to map and align them.

As utilities embark on GEB pilots, internal and external communications protocols should be carefully considered to assure GEBs can appropriately receive signals and respond to system needs.

## 1.6 Cost-effectiveness considerations

In Washington, *cost effectiveness* is defined in RCW 80.52.030 as a project or resource that is reliable and available within the time needed and meets or reduces the electric power demand of the intended consumers at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative project or resource, or any combination thereof. The communications, controls, and other technology systems that are prerequisites to GEB can impact cost effectiveness from both the utility and customer perspective. Smart meters and time-of-use rates are important prerequisites for GEB. It may be necessary to leverage EE savings and develop a GEB's full value stack to overcome the costs of implementing GEB measures in cost-effectiveness tests. If possible, the full value stack should include rare but extreme events where GEBs can help prevent system outages and catastrophic outcomes.

In addition, there can be multiple benefits of communications systems and other technology systems needed for GEB. Therefore, it may not be appropriate to allocate the full costs of these systems to GEBs in cost-benefit analyses.

Over time, technology costs will decrease, equipment will get smarter, and the amount of variable renewable resources will increase, all of which will contribute to improving the opportunities and benefit-to-cost ratio of GEBs. It is important that a holistic and long-term view of both costs and benefits of GEB be taken. Pilots can help develop both.

[30] Ibid.

[31] California Energy Commission. 2021. Market Informed Demand Automation Server (MIDAS) Documentation: Connecting to and Interacting with the MIDAS Database. CEC-400-2021-009. September 15. https://www.energy.ca.gov/publications/2021/market-informed-demand-automation-server-midas-documentation-connecting-and.

[32] Ibid.

## 1.7 Illustrative examples

Most GEB pilots are so new, they have yet to reveal their full financial potential. However, a field experiment involving price-responsive devices within the GridWise™ Testbed in Washington's Olympic Peninsula[33] shows that real-time price responses result in a customer peak demand reduction of 15% with accompanying bill savings.[34] The GridWise Testbed features five 40-horsepower water pumps between two municipal water-pumping stations, two distributed diesel generators, and residential DR for electric water and space heating provided by 112 homes. The goals of the project were to manage feeder congestion and peak load reduction. The project validated its ability to shift some demand to off-peak as a result of price signals. More specifically, the project demonstrated that local marginal retail price signals, coupled with the project's communications and the market clearing process, successfully managed the bidding and dispatch of loads, while accounting for customer needs and distribution congestion.[35] Further, the GridWise project in the Olympic Peninsula demonstrated the following:

- Management of imposed feeder constraint using innovative automated technologies for an entire year was successful.
- Market-based control was an effective tool for obtaining useful price-based responses from single premises and an entire feeder.
- Peak load reduction was successfully accomplished.
- Internet-based communications performed well for the control of distributed resources.
- Residents eagerly accepted and participated in price-responsive contract options.
- Automation was particularly helpful for obtaining consistent responses from both supply and demand resources.
- The ease of participation, automation, and ability to override controls, or "friendliness" with which the project invited and practiced DR, may be a key to attaining the needed magnitude of resources.
- Real-time price contracts were especially effective in shifting thermostatically controlled loads to take advantage of off-peak opportunities.

Another GEB project (although yet to post results) that more comprehensively demonstrates the potential benefits of a grid-interactive community is the Basalt Vista community. The Basalt Vista (Colorado) community is an affordable housing development designed to have net-zero energy consumption through connected homes creating their own microgrid, with the ability to act independently of the regional electricity grid.[36] Basalt Vista was a partnership between the local energy cooperative, Holy Cross

[33] Hammerstrom, D.J. et al. 2007. "Pacific Northwest GridWise Testbed Demonstration Projects Phase 1. Olympic Peninsula Project." PNNL Staff Paper 17167. October 2007. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-17167.pdf.

[34] Kiesling, L. and D. Chassin. 2018. Beneficial Complexity: A Field Experiment in Technology, Institutions, and Institutional Change in the Electric Power Industry. Draft paper distributed to the Harvard Electricity Policy Group Fifty-Fourth Plenary Session. Updated 10/02/2018. https://hepg.hks.harvard.edu/publications/beneficial-complexity-field-experiment-technology-institutions-and-institutional.

[35] Hammerstrom, D.J. et al. 2007. "Pacific Northwest GridWise Testbed Demonstration Projects Phase 1. Olympic Peninsula Project." PNNL Staff Paper 17167. October 2007. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-17167.pdf.

[36] Office of Energy Efficiency and Renewable Energy (EERE). 2020. "GEB Webinar Series: Distributed Energy Resources (DER) Integration." Buildings Technology Office. June 30, 2020. https://www.energy.gov/sites/prod/files/2020/07/f76/bto-geb-webinar-der-integration-070120.pdf.

Energy, and NREL, who supplied the system software called Network Optimized Distributed Energy Systems,[37] an algorithm allowing the exchange of energy between homes while adhering to reliability limitations of the local grid. The major impetus for this testbed project was Holy Cross Energy's goal of being 70% carbon-free by 2030. This project features 27 all-electric, new-construction townhomes. Attributes of the townhomes include high-efficiency appliances and building envelope,[38] cold-climate heat-pump water heaters, connected thermostats, rooftop photovoltaic (PV), battery storage, and EV chargers. More so, the group of homes acted as a "virtual power plant," generating and storing electricity for the wider grid. The homeowners do not need to interpret or interact with the blinking LED cues or Ethernet connections because the system is autonomous, or "self-driving."[39]

One of the primary goals of the project was to reduce the adverse impact of solar variability on distribution grid voltage by at least 20% and support critical loads for up to five days with DERs throughout the community. Additional goals and metrics were improving home EE to be 35% better than code and reducing peak demand by 10%. An additional goal was a positive comfort rating by the residents.[40] The system was further managed to reduce energy bills. The main benefits of the test bed were lowered energy bills, grid support, and resilience in case of power outage because of stored power in batteries and the ability to share power across homes through dedicated communication devices and algorithms.

Appendix A provides a more comprehensive list of GEB pilots. The variety of features tested in the various pilots listed here, and in the appendix, highlights the potential complexity of creating a GEB pilot. Also, most utilities have never tested the grid-applicable scalability of GEB or may not have had exposure to the technologies and software required for interconnectivities, potentially creating many "unknowns" when creating a pilot. Even so, pilot and program designers may save time and resources by gleaning design features, such as stated goals, technological features, vendors of technologies, and local results, along with important learnings of what did and did not work from existing pilots, to apply to their own pilot choices.

[37] The Network Optimized Distributed Energy Systems program manages energy controls to create a virtual energy storage system based on the use of flexible load and DERs. https://www.arpa-e.energy.gov/technologies/programs/nodes.

[38] *Building envelope* consists of its roof, foundation, exterior doors, windows, and exterior walls. Building envelopes, with the help of insulation, works to reduce the transfer of heat (or cool air from air conditioning) from the interior climate to the outside climate.

[39] NREL. No date. "Small Colorado Utility Sets National Renewable Electricity Example Using NREL Algorithms." https://www.nrel.gov/news/features/2019/small-colorado-utility-sets-national-renewable-electricity-example-using-nrel-algorithms.html.

[40] A *comfort rating* is a qualitative metric that makes sure customers were satisfied with any resulting changes in housing attributes such as ambient temperature, water temperature, lumens, etc.

# 2.0 Utility/State Energy Mandates and Priorities Potentially Addressed through GEB

As can be seen from the variety of pilots in Appendix A, there are different combinations of technologies that a utility could chose to include in a pilot. How this suite of technologies and systems are used and optimized depends upon utility goals working in concert with building owner's acceptance of GEB technologies and is further dependent upon the individuality of each distribution system. Therefore, after understanding the potential resources and benefits GEB can provide, it is important for the utility to define the goals that GEB development may serve in order to best serve its needs. Further, not all goals may be complementary. For example, if carbon emissions reduction is the primary goal, that may not necessarily translate into lowest customer utility bills if targeting carbon emissions does not provide the biggest reduction in the customer's peak demand and the corresponding demand charges. So, a utility must have a clear understanding of the GEB pilot objectives and ways to engage and compensate building owners for their time or any perceived or actual inconvenience.

Given the potential complexity of GEB pilots, one way to begin is by assessing utility priorities and the ways in which GEBs may serve these priorities. For example, Washington's Clean Energy Transformation Act commits the state to an electricity supply free of greenhouse gases by 2045.[41] Coal resources, which currently make up approximately 14% of the supply-side mix, are to be removed by 2025. It is expected that renewably sourced electricity will make up most of the energy shortfall. This growth in intermittent renewable energy creates a proportional need for ancillary services, requiring substantially more flexible resources. Further, replacing baseload plants with renewable energy may not coincide with peak demand needs. A pilot could test a GEB's ability to address both ancillary services and capacity needs.

In general, utility priorities are driven by policy mandates or business objectives. Other needs may be stated energy goals that are desired but not mandated through state or federal policy. Instead, these goals may be anticipated as an inevitability or highly desirable by their constituency. Therefore, Table 2 lists some of the key drivers underlying utility planning priorities and the ways in which GEBs may be able to address these energy goals and priorities.

**Table 2. List of Potential Utility Priorities and GEB Contributions for Washington State**

| Key Drivers | Potential GEB Contribution |
|---|---|
| **Reliability** – Outages are inconvenient, costly, and potentially unsafe; also, the North American Electric Reliability Corporation penalizes utilities for failure to meet reserve margins. | GEB flexibility helps utilities in emergency and high-risk situations, such as extreme high and low temperatures and other emergencies. GEBs as system resources can perform under all operating conditions, regardless of weather. |
| **Clean Energy Transformation Act** – Clean energy implementation plans by 2022, coal phaseout by 2025, greenhouse gas neutral electricity by 2030 (with alternative compliance | The EE, flexible demand, and battery storage components of GEBs can reduce overall supply-side needs, while distributed generation used by the grid may directly contribute to clean energy generation goals. |

41 Washington State Legislature. 2019. Senate Bill 5116-2019-20. Supporting Washington's clean energy economy and transitioning to a clean, affordable, and reliable energy future. https://app.leg.wa.gov/billsummary?BillNumber=5116&Initiative=false&Year=2019.

| Key Drivers | Potential GEB Contribution |
|---|---|
| options), and 100% clean renewable or non-emitting electricity by 2045.[42] | |
| **Greenhouse gas targets (decarbonizing electricity)** – 45% below 1990 levels by 2030, and 95% below 1990 levels by 2050.[43] | GEBs make it possible to manage the DERs so they reduce the time of consumption corresponding to the most carbon dioxide production. |
| **Resource adequacy** – Washington (WA) holds an annual meeting with utility representatives and other stakeholders on the short-term and long-term adequacy of resources to serve the state's electric needs. | GEBs can reduce the marginal need for additional resource purchases/development or may be used as a potential supply-side resource. |
| **Lowest reasonable cost**[44] – All utilities regulated by the Washington Utilities and Transportation Commission are required to develop plans for how they will obtain future energy resources to meet future customer needs at the lowest reasonable cost.[45] | EE in buildings is the "most cost-effective path" to carbon reduction.[46] Past studies have shown other GEB measures to be very cost-effective,[47] with short payback periods.[48] The cost effectiveness for the grid potential of GEB is unique for each system and therefore can be determined through the pilot. |
| **All cost-effective EE** – Electric utilities are required to pursue all cost-effective conservation. | GEB technologies can potentially support achieving all cost-effective EE. |

[42] Washington State Legislature. 2019. Chapter 19.405 RCW: Washington Clean Energy Transformation Act. https://app.leg.wa.gov/RCW/default.aspx?cite=19.405.
[43] Washington State Legislature. 2008. Chapter 70A.45 RCW: Limiting Greenhouse Gas Emissions. https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.45.
[44] Washington State Legislature. 2019. RCW 19-280. Electric Utility Resource Plans. https://app.leg.wa.gov/rcw/default.aspx?cite=19.280.
[45] WAC 480-100-605. *Lowest reasonable cost* means the lowest cost mix of generating resources and conservation and efficiency resources determined through a detailed and consistent analysis of a wide range of commercially available resources. At a minimum, this analysis must consider resource cost, market-volatility risks, demand-side resource uncertainties, resource dispatchability, resource effect on system operation, the risks imposed on the utility and its customers, public policies regarding resource preference adopted by Washington or the federal government, and the cost of risks associated with environmental effects, including emissions of carbon dioxide. The analysis of the lowest reasonable cost must describe the utility's combination of planned resources and related delivery system infrastructure and show consistency with chapters 19.280, 19.285, and 19.405 RCW.
[46] Schiller, S., et al. 2020. *Cost of saving natural gas through efficiency programs funded by utility customers: 2012–2017*. Berkeley Lab. Electricity Markets and Policy. May 2020. https://emp.lbl.gov/publications/cost-saving-natural-gas-through.
[47] *Cost effectiveness* is defined in RCW 80.52.030 as a project or resource that is reliable and available within the time needed and meets or reduces the electric power demand of the intended consumers at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative project or resource, or any combination thereof.
[48] DiNola, R. and S. Punjabi. "Federal Building & Grid Integration Roadmap Task Group." September 12, 2019. https://www.gsa.gov/cdnstatic/DiNola%20Punjabi%20-%209-12-19%20Bldg%20Grid.pdf.

| Key Drivers | Potential GEB Contribution |
|---|---|
| **All cost-effective DR** – Electric utilities are required to pursue all cost-effective DR. | GEB technologies can potentially support achieving all cost-effective DR. |
| **Electrifying transportation** – WA adopted the California vehicle emission standards. The WA Energy Strategy also suggests the state set targets for EV adoption, aligning with ambitious targets in existing agreements with other states. | Smart electric vehicle charging will allow utilities to manage the large, anticipated loads on the grid. Further, EV with vehicle-to-grid capability may provide grid resources and resilience. |
| **Electrifying and decarbonizing buildings** – This is part of the decarbonization strategy.[49] | GEBs directly decarbonize through EE and solar PV. GEB can help the grid decarbonize through strategically shedding, shifting, and modulating loads. |
| **Resilience for all customers** – The need for grid modernization for the purposes of resilience is mentioned numerous times in the 2021 State Energy Strategy.[50] | The ability for connected buildings to smooth load by "sharing" resources allows a connected community to act as a microgrid. |
| **Equity** – Revised WA Code 19.405.040(8) requires utilities to make sure all customers are benefiting from the transition to clean energy:<br>"Washington's building decarbonization strategy must couple non-energy policy with energy policy, such as EE mandates that protect against increases in rent leading to displacement…"[51] | GEB pilots and programs can be targeted to reduce burdens to vulnerable populations and highly impacted communities. |
| **Workforce development –** The Washington 2021 State Energy Strategy mentions "workforce development" numerous times, including "Washington's building decarbonization strategy must…. support workforce development efforts to make sure equitable access to career track jobs in and beyond building decarbonization."[52] | GEB pilots could assess impacts on local workforce growth or potential growth in regional gross domestic product. |

Utilities will need to consider the primary goals they wish to address with GEB, along with all of the potential secondary and tertiary impacts they wish to study through the pilot. For deeper context, a comprehensive set of questions detailing GEB considerations are provided in Appendix B.

[49] Washington State Department of Commerce. 2019. Clean Buildings. https://www.commerce.wa.gov/growing-the-economy/energy/buildings/.
[50] Washington State Department of Commerce. 2020. "F. 100% Clean Electricity to Meet the Needs of a Decarbonized Economy." *Washington 2021 State Energy Strategy.* https://www.commerce.wa.gov/wp-content/uploads/2021/01/WA_2021SES_Chapter-F-Electricity.pdf.
[51] Washington State Department of Commerce. 2020. *Washington 2021 State Energy Strategy.* Washington-2021-State-Energy-Strategy-December-2020.pdf.
[52] Ibid.

# 3.0 Goals, Metrics, Data, and Other Considerations for GEB Pilots

Once a state has established its energy-related priorities and developed an accompanying set of research questions, they will need metrics to track the success of a particular pilot aspect. Metrics are one of the most important features of a pilot because they provide the measurement related to a desired goal or outcome. Metrics can span all facets of the pilots, from specific grid services to particular customer needs. Each metric requires qualitative or quantitative data collection that can be tracked and used in the measurement and evaluation process.

## 3.1 Goals, metrics, and data

Below, we list and describe potential goals, metrics, and accompanying data needs that could be tested through a GEB pilot (Table 3). Additional goals may also be used. For example, the first potential metric in Table 3 is year over year energy savings. If overall energy savings is a high priority for the state or utility, they may instead want to specify a target, such as a 20% reduction in electricity consumption.

**Table 3. Potential GEB Pilot Metrics and Data[53]**

| Goal | Potential Metrics | Data (units) |
|---|---|---|
| **Grid objectives** | | |
| Energy savings | Energy saving over a year — as compared with an established building energy consumption baseline | kWh/year |
| | Energy intensity saving over a year — pre and post program | kWh/ft$^2$/yr |
| | Total energy consumption reduction | kWh |
| | Total annual energy cost savings | $/yr |
| | Persistence of savings/performance over time | Measure the persistence of savings and performance over time |
| Capacity contributions | Coincident peak load reduction | kW |
| | Non-coincident peak load reduction | kW |
| | Reduced investment in generation, transmission, and distribution capacity as a result of GEBs | $ |
| Renewable energy and | Total renewable energy generation | kWh/year |

[53] Metrics were taken from three sources: (1) Priotoni, M., et al. 2020. "Project: Framework and Method to Define Flexible Loads in Buildings to Integrate as a Dynamic and Predictable Grid Resource." Lawrence Berkeley National Laboratory. August 5. Prepared for the U.S. Department of Energy. (2) Miller, Alexi. 2020. "Gridoptimal Metrics Offer Guidance on Optimizing Building-Grid Interaction." New Buildings Institute. May 18. https://newbuildings.org/gridoptimal-metrics-offer-guidance-on-optimizing-building-grid-interaction/ (3) NREL. GEB Evaluation Plan Template. Currently in development.

| Goal | Potential Metrics | Data (units) |
|---|---|---|
| **Grid objectives** | | |
| Behind-the-meter generation | Renewable energy consumed onsite | Hourly consumption (kWh) |
| | Renewable energy exported to the grid | Hourly export (kWh) |
| | Avoided bulk or local renewable energy curtailment | kWh |
| Grid–carbon alignment | Reduced carbon emissions | Avoided carbon per/kWh, per year |
| Short-term/long-term demand flexibility | Shed –A building's ability to reduce demand for 15 minutes, 1 hour, 4 hours | kW reduced over specified time frames |
| | Shift – A building's ability to shift load from peak to off-peak periods | kW, kWh |
| | Ability to modulate power draw up for the purpose of frequency and voltage support | kW and response time |
| | Ability to modulate power draw down for the purpose of frequency and voltage support | kW and response time |
| | Ramp rate | kW/min |
| | Demand change intensity | W/ft$^2$ |
| Resilience | A building's ability to island for 4–24 hours | Islandable time |
| | Contribution to the local microgrid | % capacity and energy contribution to the local microgrid |
| | Ability to support critical functions during an outage | Critical function and time sustained |
| | Ability to support black start following a power outage with a motor soft start | Black start capability (kW) |

Metrics in Table 3 were compiled from different sources, as described in the footnote accompanying the table. One source was the New Buildings Institute's GridOptimal Metrics. These metrics are being applied in a Leadership in Energy and Environmental Design (LEED) pilot program called the GridOptimal Buildings Pilot Alternative Compliance Path, which attempts to incorporate grid benefits into LEED certification. Through this GridOptimal LEED pilot, up to three points can be awarded to buildings seeking LEED certification for building-grid optimization measures.[54] The points are available for building improvements that support:[55]

- Grid peak contribution
- Grid-carbon alignment
- Onsite renewable utilization efficiency

[54] Miller, A.. 2021. "GridOptimal LEED pilot credit encourages designers to help solve grid issues." U.S. Green Building Council. April 1. https://www.usgbc.org/articles/gridoptimal-leed-pilot-credit-encourages-designers-help-solve-grid-issues.
[55] Ibid.

- Short-term demand flexibility
- Long-term demand flexibility
- Dispatchable flexibility

To recognize the value of GEBs, utilities must be confident that grid services will be available when they are needed. Persistence of each of the grid objectives in Table 3 must also be established.

Pilots can be developed to identify information and data that supports understanding persistence of savings and performance. For example, a goal of the pilot may be to help utilities understand the GEB potential in their service territory. In development of the Roadmap, the research team identified specific GEB measures and the national potential energy and peak saving potential for each type of measure. Figure 8 shows the projected energy and peak demand savings potential for different groups of residential and commercial measures, by measure type, in 2030. In aggregate, HVAC and envelope EE and demand flexibility measures provide the most potential energy and peak demand savings. As Figure 8 shows, these measures also tend to coincide with time of net system peak demand, which makes energy savings from these measures (i.e., commercial and residential envelope improvements, commercial HVAC, and residential central air conditioning) more valuable to the power system than measures that do not coincide with peak system demand.

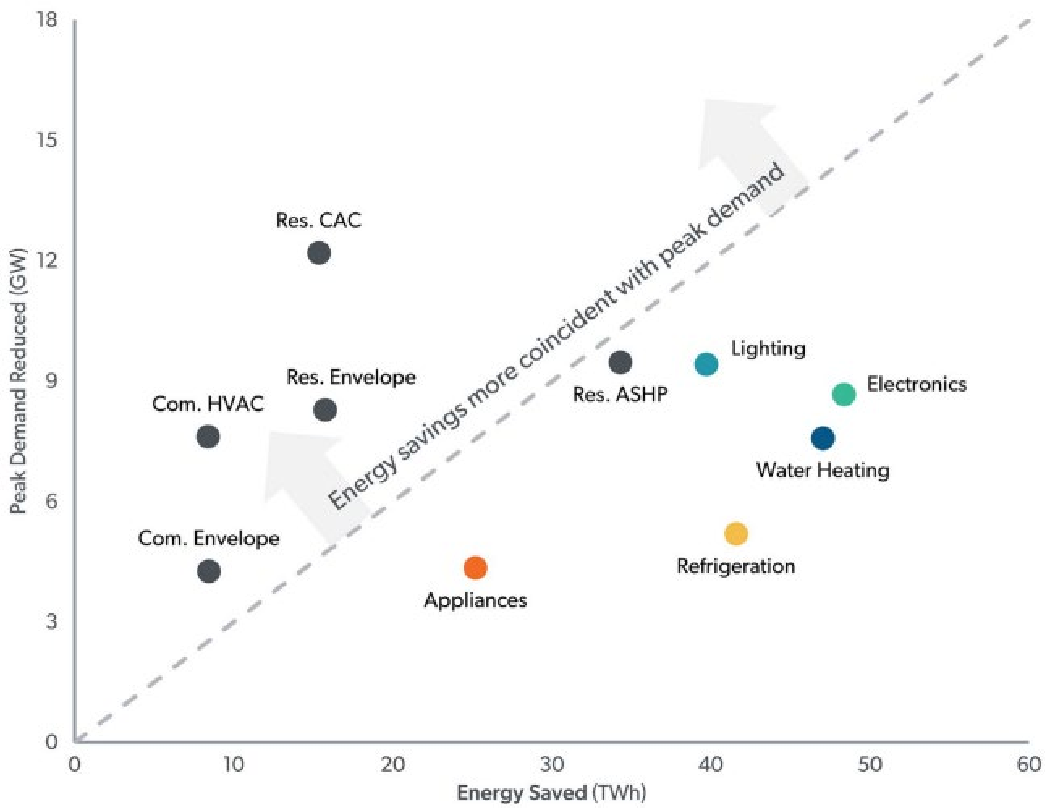


**Figure 8. U.S. Energy and Peak Demand Savings Potential by Measure Type in 2030 (Source: 2021 DOE GEB Roadmap)[56]**

[56] Acronyms in Figure 8: residential (Res); commercial (Com); heating ventilation, air conditioning (HVAC); central air conditioning (CAC); air source heat pump (ASHP).

Utilities may wish to locate and design pilots to address specific grid needs. System grid needs will be revealed during utility distribution and transmission system planning activities. GEBs can ease congestion and stress in grid locations that are constrained or that may become constrained. GEBs can be part of a strategy to increase the hosting capacity of circuits and/or as part of non-wires alternatives considered during distribution system planning. Utilities may want to consider pairing their hosting capacity and non-wires analysis activities with GEB pilot planning. PacifiCorp has a program in Salt Lake City, where they are using air conditioning controls to provide frequency response to the grid. GEBs can be part of non-wires solutions, providing a lower cost alternative to conventional poles and wires investments.

Pilots can be targeted to an existing set of building or new construction; both have very different potential and costs depending upon the technologies involved. Figure 9 shows technology pipeline examples for different technology layers. Development of these technologies will affect building efficiency and building performance and will greatly enable flexible demand potential going forward. Pilots can be used to support the development and demonstration of new GEB technologies.

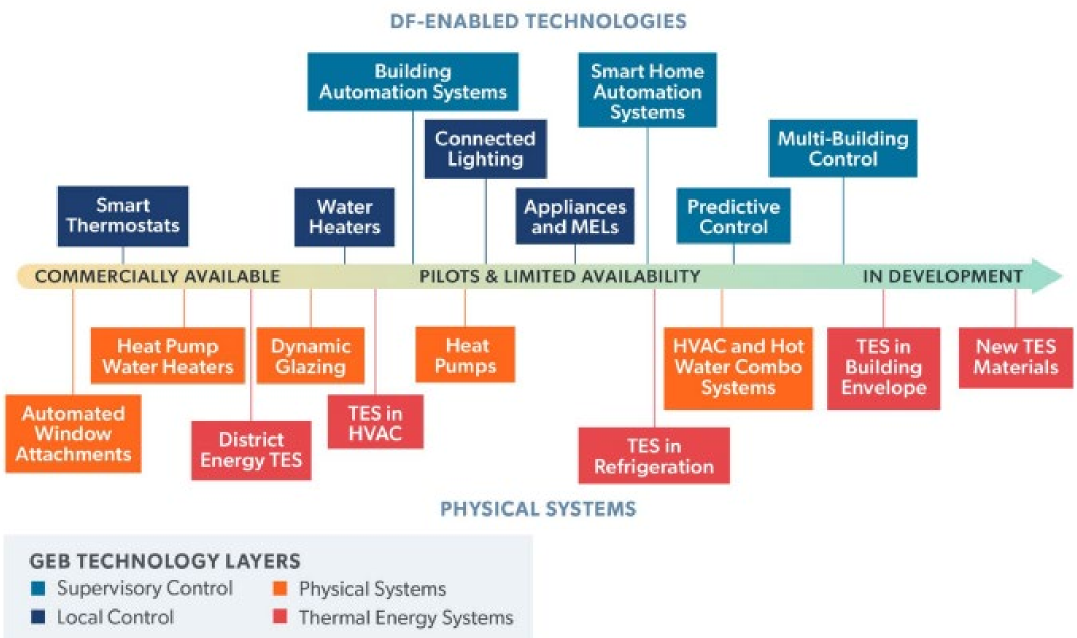


**Figure 9. Technology Pipeline Examples for Each GEB Layer (Source: DOE 2021 GEB Roadmap)[57]**

### Customer Participation

The counterpart to the grid metrics and specific technologies described above are customer considerations. Customer participation is an important aspect of pilot success. For example, the Roadmap estimated customer participation. In Section 1.2, Figure 3 shows energy and peak demand savings for a mid-adoption case that assumes that 30% of residential thermostats, water heating, and pool pumps participate in demand flexibility programs, along with 15% of residential smart appliances. It also assumes that 25% of commercial HVAC and lighting, and 15% of miscellaneous commercial electric loads, participate in demand flexibility programs.

[57] Acronyms in Figure 9: Demand Flexibility (DF); Thermal Energy Storage (TES); Miscellaneous Electric Load (MEL).

Customer participation is directly tied to the amount of efficiency, load shedding, shifting, and modulating and distributed generation available to utilities. Therefore, along with technical feasibility, pilots should also focus on identifying barriers and accelerators for participation. A pilot can assess the participation and retention rates as a function of marketing, customer economics, and impacts on the building occupants. Participation and marketing promotions, such as various types of messaging, are important to evaluate. Various value propositions to customers, including rate of return on infrastructure investments, bill impacts, rebates, incentives, and assistance with installation and operation, are also important to consider when assessing participation and retention rates. Additionally, pilots should consider the impact of rate structure on participation. Types of rate structures or pricing programs include time-of-use, critical peak pricing, peak time rebate, net energy metering, and real-time pricing.[58] Opt-out versus opt-in rate structures also can have a significant impact on participation.[59]

Participation impacts that can be tested through pilots also include non-market effects. These include comfort and work productivity impacts, such as ease of use, interruption of service, and impacts on the work environment. Surveys can be used to gauge GEB impacts on building occupants. Table 4 lists some of the participant metrics, along with various types of metric analysis.

**Table 4. Examples of Metrics Affecting Customer Participation**

| Metric | Analysis Method |
|---|---|
| Customer retention | Measure customer retention (%) in different program and rate designs, including opt-in versus opt-out programs. |
| Customer satisfaction | Survey participant satisfaction. |
| GEB performance relative to comfort settings | Track performance of measures relative to established comfort settings. |
| Bill and revenue impacts associated with:<br>• Energy savings<br>• Demand/peak savings<br>• Revenues from exporting energy<br>• Revenues from providing grid services<br>• Utility incentives for participation in DR programs<br>• Non-utility incentives<br>• Renewable Energy Certificate revenues<br>• Other | Track overall impact to customer bills and revenues. |
| Technology investment costs including measure costs, IT/communication system costs, and operations and maintenance costs ($) | Track costs to participants. Conduct surveys to understand customer thresholds for costs relative to different potential short-/long-term savings through GEB measures. |
| Customer and building owner overall cost effectiveness | Calculate simple payback in years and net present value. |
| Messaging impacts | Survey customers to understand marketing potential and the most effective messaging. Determine what messaging is most appropriate for each consumer group? |

58 What-when-how. No date. "Pricing Programs: Time-of-Use and Real Time (Energy Engineering). Accessed December 16, 2020. http://what-when-how.com/energy-engineering/pricing-programs-time-of-use-and-real-time-energy-engineering/#:~:text=This%20rate%20design%20is%20a,all%20of%20a%20customer's%20load.
59 Portland General Electric. No date. Welcome to the Smart Grid Test Bed. https://portlandgeneral.com/about/smart-grid/smart-grid-test-bed.

## 3.2 General considerations for GEB pilots

There is a long history of utilities using pilots to encourage innovation, and several reports have documented best practices for developing electricity sector pilots. Many of the findings from utility pilot best practices also apply to GEB pilots.

Berkeley Lab's 2020 report, *A Handbook for Designing, Implementing, and Evaluating Successful Electric Utility Pilots,* identified five fundamental steps of pilot design that are applicable to GEB pilot design (Figure 10). Much of the discussion of those steps is drawn from that report.[60]

- Step 1: Identify the key pilot elements. To design the pilot, first determine which issues or topics must be better understood by the utility, regulators, and possibly stakeholders.
- Step 2: Determine the level of power[61] and precision required to test the hypotheses.[62] (In this case, *power* and *precision* refer to statistical definitions as defined in the footnotes.) From a statistical standpoint, a pilot with a high degree of power provides greater precision in the estimation of the effect being measured than a pilot with lower power does.
- Step 3: Establish the degree of internal validity.[63] Consider what constitutes an acceptable chance that confounding effects could distort the outcome of a hypothesis test. That is, could something other than what the pilot is trying to test be the cause for the outcome that is observed or derived?
- Step 4: Settle on the degree of external validity.[64] Determine if the pilot design has consequences on the ability to extrapolate findings from the pilot to any group (e.g., other customers at the same utility, customers at a different utility, customers that did not participate in the pilot).
- Step 5: Determine the most appropriate design. Using the first four steps, complete the pilot design. The report discusses four designs: experimental or quasi-experimental methods, non-experimental observation methods, non-experimental survey methods, and non-experimental case studies.

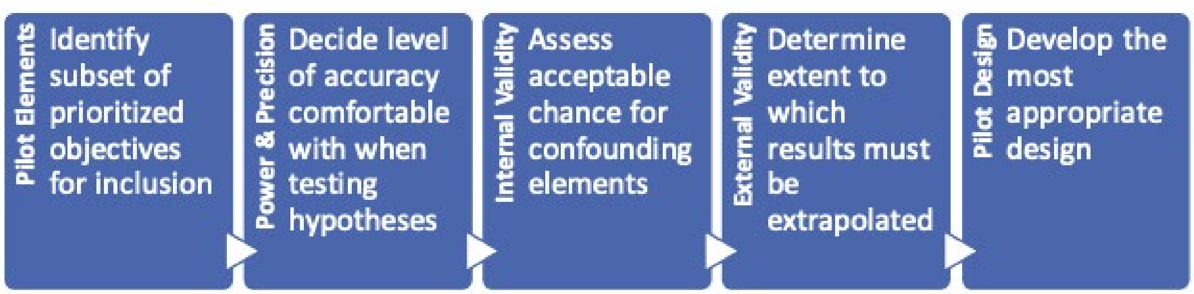


**Figure 10. Five Steps of Pilot Design. (Source: Cappers and Spurlock 2020)**

[60] Cappers, P.A. and C.A. Spurlock. 2020. *A Handbook for Designing, Implementing, and Evaluating Successful Electric Utility Pilots.* Berkeley Lab. September. https://eta-publications.lbl.gov/sites/default/files/pilot_best_practices_final_20200904.pdf.
[61] *Power* in this context refers to the probability of rejecting a null hypothesis when, in fact, it is false.
[62] *Precision* in this context refers to the extent to which estimates from different samples are close to each other.
[63] *Internal validity* refers to the extent to which one can be confident that a cause-and-effect relationship established in a study cannot be explained by other factors.
[64] *External validity* refers to the extent to which one can generalize the findings of a study to other situations, people, settings, and measures.

The first step — identifying key pilot elements — is particularly relevant to GEB pilot design. Given the complexity of GEBs, identifying critical issues that the pilot will solve may be difficult. The report recommends identifying a comprehensive list of highly specific research questions and ranking them based on their level of importance and urgency relative to the other questions (Figure 11). This will enable the utility (or pilot implementer) to use the questions with the highest importance and urgency to shape the pilot.


**Figure 11. Prioritizing Research Questions for Pilot Design (Source: Cappers and Spurlock 2020)**

A 2017 Rocky Mountain Institute report that was focused on the role of pilots in promoting electricity sector innovation found that pilots can be used to test approaches to integrating new technologies and benefit customers if implemented in a collaborative manner.[65] The report highlighted the difference between pilot and demonstration projects (Figure 12), noting that pilots test products and technical integration, while demonstrations address issues such as business models, pricing and markets, and customer adoption. Some key recommendations from the report that apply to GEB pilots include the following:

- **Designing to scale:** Design pilots and demonstrations to maximize learning and prepare for full-scale deployment.
- **Organization:** Create leadership support and accountability, dedicated resources, and cross-functional collaboration within the utility for effective innovation.
- **Stakeholder engagement:** Collaborate effectively across industry stakeholder groups to design and execute meaningful projects.
- **Cross-utility collaboration:** Share best practices and lessons learned among utilities to accelerate effective innovation.

Other GEB pilot factors for states and utilities to consider include the following:

- **Utility alignment and preparedness:** GEBs require coordination between traditionally disparate departments within utilities (EE, customer generation, DR, distribution system planning, and integrated resource planning). For GEB pilots to be meaningful and successful, utilities need to integrate across departments to prepare for and appropriately execute and learn from GEB pilots.

[65] Fairbrother, C., L. Guccione, M. Henchen, and A. Teixeira. 2017. *Pathways for Innovation: The Role of Pilots and Demonstrations in Reinventing the Utility Business Model.* Rocky Mountain Institute. https://rmi.org/insight/pathways-for-innovation/.

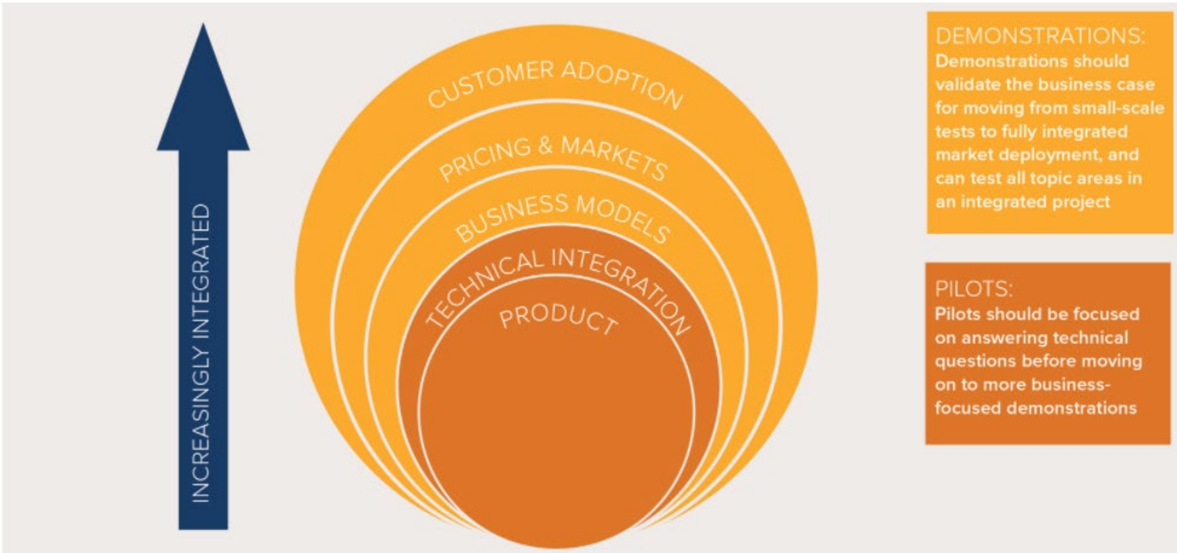


**Figure 12. Focus Areas for Pilots and Demonstrations (Source: Fairbrother et al. 2017)[66]**

- **Policy and regulatory aspects to pilots:** Physical pilot projects can be combined with policy and regulatory aspects in order to test different approaches. Policy and regulatory approaches that can be tested include utility ownership and control of certain customer-sited DERs, non-wires alternatives, performance-based regulation or other nontraditional utility compensation models, shared savings schemes, and rate-basing of different non-capital utility GEB investments.[67]
- **Role of third-party service providers:** The role of third-party companies, such as DR aggregators and energy savings performance contacts through energy-as-a service arrangements and other arrangements, can be important in full-scale deployment of GEBs. Operating and contracting arrangements between and with third-party providers can be important and innovative aspects of GEB pilots. Data sharing with third-party providers is also important and can be worked out in a pilot arrangement.
- **Building owner versus utility control:** A pilot should consider who controls the GEB's interactive features. Interactive features may be directly controlled by a utility or controlled through a building energy management system or a third party. A building owner may allow the utility to control certain equipment but retain the right to override a load shed or shift event in certain cases.[68] These types of details can be important aspects of GEB pilots.
- **Cybersecurity:** The interconnectivity associated with GEB will require extra protocols to assure customer data security.
- **Review and vetting of pilot design:** Given the complexity of GEB pilots, it will be helpful for utilities to do as much up-front work as possible on the pilot. Third-party review of pilot design is important to identify potential fatal flaws before years-long pilot projects are implemented.

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[66] Fairbrother, C., L. Guccione, M. Henchen, and A. Teixeira. 2017. *Pathways for Innovation: The Role of Pilots and Demonstrations in Reinventing the Utility Business Model.* Rocky Mountain Institute. https://rmi.org/insight/pathways-for-innovation/.
[67] Ibid.
[68] Ibid.

- **Evaluation, measurement, and verification (EM&V):** EM&V is a large component of a pilot. Every metric requires the collection, synthesis, and analysis of data, and a clear EM&V plan must be part of a pilot.
- **Equity:** Low-income householders spend nearly twice as much of their income on energy expenses. DERs such as solar, storage, EE, and demand management may assist with long-term affordability; however, low-income individuals typically are less likely to participate in clean DERs due to critical barriers such as lack of access to capital, lower credit scores, and lower rates of homeownership. This may be a consideration for GEB pilot designers to address in their plans. It is possible that pilots include or consider how disadvantaged communities can participate in GEB, as they did in the Basalt Vista pilot.

## 3.3 Considerations for public utility commissions

Below are GEB pilot considerations that are particularly important to public utility commissions (PUCs).

- **Regulatory flexibility:** Regulatory flexibility allows utilities to experiment with minimal risk and with less legal uncertainty. PUCs have the authority to approve or require innovative, nontraditional approaches in pilot projects. Regulators can provide utilities with opportunities to pilot different demand flexibility programs, which can enable utilities to figure out designs that best meet their system and market needs, as well as the needs and preferences of their customers.
- **Sharing results:** Although pilots are physical demonstrations, they generate important technical and economic performance data. In order to magnify the impact of utility pilots, PUCs could require utilities to make technical and economic data and results from pilots publicly available, while appropriately anonymizing customer data to protect privacy. In this way, the benefits and learning from pilots could be leveraged widely.
- **Pilot design reviews:** PUCs can encourage or require utilities to have their pilot designs vetted in advance through a public stakeholder process, a formal third-party review by a consultant, or both.
- **Coordination signals:** As utilities embark on GEB pilots, regulators should work with utilities to assure that communications protocols are in place and coordinated signals (be they price or marginal carbon intensity) exist so that GEBs can meaningfully participate.
- **Cost effectiveness:** Regulators can help ensure that cost-effectiveness tests, if used for GEB pilots, are appropriately applied. Communications and technology systems that support GEBs can provide multiple benefits, so it may not be appropriate to burden GEB pilot's cost effectiveness with the full magnitude of those costs. The full suite/stack of GEB benefits should also be considered. Benefits may include reliability and resilience.

# 4.0 Summary

An ideal pilot program outcome will identify the costs and benefits of GEBs to building owners and operators, utilities, and grid managers. For building owners and users, GEB pilots can measure ways to help customers be comfortable and productive, and quantify the potential to save money on their energy bills, while testing ease and affordability of participation. For grid or utility managers, GEB pilots present an opportunity to study a means in which GEB can cost effectively provide least-cost security and stability for the grid. A pilot can be geared to test and reveal the financial and technical capabilities of the several interconnected concepts and metrics pertaining to GEB. Also, a GEB pilot can be used to study climate and conservation goal potential. Overall, there is still a great deal of opportunity to test different aspects and components of GEBs.

Utilities themselves have much to learn about how to plan for and operate or interact with GEBs. Pilot success will be aided by a well-made plan that begins by assessing the greatest energy needs that can potentially be served by GEB. Having a clear view of future grid needs, seasonally and locationally, will drive the valuation of GEB via avoided cost. In turn, the economic valuation of GEB as a grid resource influences financial incentive levels and program budgets that occur at the planning stage. Next, the pilot plan should ask the right questions, to make it functional in terms of implementation, execution, and outcomes from building owner, utility, and state perspectives. A thorough list of metrics should be mapped to desired goals. Additionally, top-down policies will potentially make GEB part of state, city, and jurisdiction plans. Therefore, careful planning should be given to all aspects of GEB pilot design, from technological aspects to policy considerations and utility readiness.

# Appendix A: More Grid-Interactive Efficient Building Features and Examples

## Features

**Table A.1. Differentiating between Energy Efficiency, Demand Response, and Flexible Demand**[1]

| Building System | Energy Efficiency | Demand Response | Demand Flexibility in a Grid-Interactive Efficient Building (GEB) |
|---|---|---|---|
| Thermal Comfort Systems | • Building has insulated, tight envelope, and efficient HVAC system to provide occupant thermal comfort with low energy use.<br>• Building has moderate amount of thermal mass to reduce heating/cooling needs. | • Building changes temperature setpoint in response to grid signal.<br>• Building can cycle HVAC systems in response to external grid signals. | • Building dynamically adjusts R-value of envelope to efficiently modulate internal temperature.<br>• Building has significant amount of thermal mass potentially using phase change materials, to support pre-cooling/coasting for long periods.<br>• Building is aware of occupancy and occupant preferences and can raise cooling setpoints by varying amounts depending on electricity prices and grid signals.<br>• Building integrates owner and occupant priorities for thermal comfort and other services and sheds load in priority order.<br>• Buildings can adjust solar heat gain to reduce heating/cooling needs through dynamic windows with automatic shading. |
| Lighting | • Building leverages daylighting.<br>• Building uses SSL along with daylighting and occupancy sensors to dynamically adjust lighting levels. | • Building dims lighting by a preset amount in response to grid signals. | • Building incorporates occupants lighting preferences and can dim lighting by varying amounts in response to changes prices.<br>• Building can prioritize lighting vis-à-vis thermal comfort and other building services.<br>• Building can modulate lighting levels and power features to provide frequency regulation with integrated batteries. |
| Appliances | • Building has high-efficiency appliances. | • Building has high-efficiency programmable connected appliances that can be scheduled in response to grid signals. | • Where appropriate and economic, appliances are co-optimized to efficiently switch between fuel types.<br>• Building prioritizes appliances vis-à-vis one another and other building services such as lighting and thermal comfort. |
| Water Heating | • Building has high efficiency heat pump or electric water heaters. | • Building has connected water heaters that shift loads by pre-heating | • Building has high efficiency and connected/controlled water heaters used to shift loads in response to external grid signals or to store excess energy from on-site generation. |

[1] Adapted from Table III.1 in DOE Office of Energy Efficiency and Renewable Energy. 2019. *Grid-interactive Efficient Buildings Technical Report Series: Overview of Research Challenges and Gaps.* December. https://www.nrel.gov/docs/fy20osti/75470.pdf.

| Building System | Energy Efficiency | Demand Response | Demand Flexibility in a Grid-Interactive Efficient Building (GEB) |
|---|---|---|---|
| | | water during off-peak periods in response to grid signals. | • Building has connected and controlled pumped-heated electrical storage using a heat pump to store thermal energy (in response to external grid signals) that can be recovered as electricity through reversing the heat pump cycle. |

## GEB Project Examples

The following list of GEB projects contain various combinations of GEB elements and may be informative to states considering pilot projects. Distinctive GEB features and goals of each project are summarized below.

**Southern Company Smart Neighborhoods Initiative (Atlanta, Georgia and Birmingham, Alabama)[1]**

- *Features:* Each technology-enhanced home in the Georgia Power Smart Neighborhood will be served by Georgia Power with power supplemented by individual rooftop solar installations and in-home battery energy storage. Homes also will be equipped with the latest energy technologies, such as optimal insulation for maximum efficiency, advanced heating and cooling systems, and LED lighting. They will feature home automation, including smart thermostats, smart locks, and voice control.
- *Goals and metrics:* They simulate what the future may hold for the energy industry and provide Southern Company and its subsidiaries information on how homes of the future will function, improved reliability, increased use of distributed energy resources, and lower costs.

**Connected Communities (National Renewable Energy Laboratory and Rocky Mountain Institute)**
This pilot is being implemented in at least 23 sites across the United States with a variety of building types. Some sites have up to 46 apartments, others up to 2,900 homes, and multiple mixed use and commercial buildings participate, as well.[2]

- *Features:* Buildings have the capability to: shed, shift, or modulate energy use in response to grid signals using a connected controls platform that enables grid-interactivity at the multi-building scale; incorporate multiple energy technologies, including building load flexibility, renewable energy generation, and energy storage; and increase resource utilization and leverage economies of scale with regard to costs and load balancing. Some connected communities incorporate physically connected, shared systems, such as district thermal plants, community solar, or energy storage installations.
- *Goals:* To optimize energy use and dispatch of distributed energy resources (DERs) across multiple buildings. Maximizing the benefit across multiple value streams exists beyond that of a building-by-building approach.

[1] Southern Company. 2018. "Southern Company subsidiaries Alabama Power and Georgia Power continue building the future of energy with innovative Smart Neighborhood projects." February 2018. https://www.southerncompany.com/newsroom.html.
[2] Olgyay, et al. 2020. Connected Communities: A Multi-Building Energy Management Approach. NREL and RMI. REL/TP-5500-75528. May 2020. https://www.nrel.gov/docs/fy20osti/75528.pdf.

**Transactive Campus (Richland, Spokane, Washington)**[1]

- *Features:* This pilot consists of four to eight existing commercial buildings on each of two campuses. Energy efficiency (EE) measures: Agent-based transactive controls for existing heating, ventilation, and air conditioning, and lighting. DERs: Photovoltaic, battery and thermal storage, and electric vehicle chargers.
- *Goals and metrics:* Energy: Consumption and bill savings per building and for campus. Load: Coincident and non-coincident peak load reduction and distribution feeder congestion reduction. Scalability: Deployment and integration time and effort.

**Post House (Evansville, Indiana)**[2]

- *Features:* Fifty-two multifamily units in two mixed-use buildings (the second building is the control). EE measures: Cold-climate heat pumps, advanced air sealing, connected water heater and appliances, and LED lighting. DERs: Rooftop solar and electric vehicle chargers. GEB controls: Apartment units are aggregated for a load-shed demand response program. Response is optimized using heating, ventilation, and air conditioning, lighting controls, and smart appliance loads.
- *Goals and metrics:* Energy: Savings per unit and by measure type. Load: Average and peak load reduction and demand response (DR) snapback. Occupant experience: Comfort, opt-out rate, satisfaction, and experience with smart home devices. DER: Photovoltaic/smart inverter performance and cost effectiveness.

**Portland General Electric Smart Grid Test Bed (Portland, Oregon)**[3]

- *Features:* The test bed is a multiyear test with approximately 22,000 participants to gain learning on communal shifting of electricity use away from peak times. Portland General Electric's (PGE's) smart grid testbed project is an example of a pilot project that was designed to test GEB-type multiple measures while simultaneously using concerted marketing within a specified geographic region, rather than one measure spread widely over the utility's service territory.[4] PGE's smart grid test bed is focused in large part on customer participation and identifying the impact of different messaging strategies on customer participation. With regard to participation, some of the elements the test bed is trying to assess focus on the impact of voluntary versus default participation. The test bed is trying to assess the many facets of customer participation through awareness/satisfaction surveys. The following are some other participant questions targeted by the test bed:
  - Can customers be recruited in sufficient numbers to achieve more significant peak demand offsets and renewable integration cost benefits?

[1] Office of Energy Efficiency and Renewable Energy (EERE). 2020. "GEB Webinar Series: Distributed Energy Resources Integration." Buildings Technology Office. June 30, 2020. https://www.energy.gov/sites/prod/files/2020/07/f76/bto-geb-webinar-der-integration-070120.pdf.

[2] Office of Energy Efficiency and Renewable Energy (EERE). 2020. "GEB Webinar Series: Distributed Energy Resources (DER) Integration." Buildings Technology Office. June 30, 2020. https://www.energy.gov/sites/prod/files/2020/07/f76/bto-geb-webinar-der-integration-070120.pdf.

[3] Portland General Electric. 2018. "Portland General Electric announces ambitious Smart Grid Test Bed." News release. October 11. https://www.portlandgeneral.com/our-company/news-room/news-releases/2018/10-11-2018-portland-general-electric-announces-ambitious-smart-grid-test-bed.

[4] Portland General Electric. No date. Welcome to the Smart Grid Test Bed. https://www.portlandgeneral.com/our-company/energy-strategy/smart-grid/smart-grid-test-bed.

- How many customers can be recruited from a defined geographical area with a concerted outreach program, and how long will it take to achieve full adoption?
- Will customers who sign up for direct-load control programs accept them being dispatched with the frequency and duration needed to achieve substantial reductions in peak loads for the system as a whole or local transmission and distribution systems?
- Do pricing-based programs mitigate mandatory dispatch issues for consumers?
- Do portfolios of DR offerings increase recruiting as compared to a single offering?
- How much more cost effective is DR, and what level of increased penetration rate can be achieved by programs targeting new buildings?

Some of the institutional questions/hypotheses of the PGE testbed that were considered included the following:

- Can the utility establish meaningful replacement programs, working with supply chain partners?
- Can the utility accomplish a regional branding program, and if so, what works well?
- What are the issues and opportunities associated with joint EE/DR programs?
- What level of customer service staff and program operating staff is needed within the utility to run the programs?

# Appendix B: Additional Questions that May Be Answered through Grid-Interactive Efficient Building Pilots

Once utility pilot planners have a clear understanding of their energy system and potential state priorities, they can identify specific grid-interactive efficient building (GEB) research questions that should be tested, then answered, through the pilot. What is important is that pilots be designed with specific policy outcomes in mind and supported by rigorous metrics to help track success toward those goals. Several questions provided below give utilities a fuller understanding of the technological, economic, and sociological modeling characteristics that may need to be answered to make GEB a successful resource or tool. A comprehensive set of research questions and considerations are organized into the following topic areas: program and rate design impacts on participation, occupant response to technologies, potential[1], resource planning, resilience, technology questions, performance assessments, stakeholder relationships, policy and regulatory issues, and institutional.

***Program and rate design impacts on participation***

- Are price signals, such as time-of-use rates, adequate to garner participation? Which kinds of rates and price signals garner which kinds of participation rates?
- How is participation affected by mandatory, opt-out, or purely voluntary rate structures?
- How is customer willingness affected by direct-load control versus voluntary program offerings?
- How is customer participation impacted by different kinds of messaging (i.e., save money, support renewables, reduce carbon emissions, support the grid)?
- What incentive levels are needed to spur action? What non-monetary incentives (e.g., administrative support) influence participation?
- How do you test the effectiveness of incentives for achieving specific or desired outcomes?
- What is the economic value proposition to the customer? Can GEBs save occupants money?
- Can utilities develop and send price signals that customers can respond to in a transactive arrangement?
  - Establish what enabling technologies are needed for transactive GEB arrangements.
  - Determine what end-use devices can best be utilized for transactive energy arrangements and customers' willingness to participate.

***Occupant response to technologies***

- What, if any, are the impacts of demand flexibility on occupant comfort and productivity, and what is the value of those impacts?
- What kind of satisfaction do building owners and occupants get from participating in GEB programs?
- What type of sustained performance can be expected through voluntary programs?
- What technologies and messages appeal to commercial building managers versus multifamily housing owners or residents, or single-family homeowners?

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[1] Potential speaks to the availability of the resource.

***Potential***

- What are the types and amounts of demand flexibility available from different types of energy assets (traditional loads, on-site generation, and storage) in different climate zones and building types?
- How does the energy performance of different GEB components match needed grid services?
- What is the achievable potential of different GEB elements at the service territory?
- What is the potential of demand flexibility in groups and districts of buildings?
- Is a building stock assessment available or needed that includes building information such as size, type, vintage, energy use intensity, and history of recommissioning? Is the stock assessment at the feeder level or less granular?
- What is the cost effectiveness of targeting existing stock versus new construction?

***Resource planning***

- How can GEBs be appropriately considered in integrated resource plans (IRPs) and distribution system platforms?
- To what extent can GEB defer capital expansion projects (in generation, transmission, and/or distribution systems) corresponding to energy and capacity load growth?
- To what extent can GEBs provide value during system emergencies or when wholesale market prices exceed the utility's supply cost?
- How is the value of GEB affected by low hydro-availability years? How should considerations around hydro variability and GEB performance be modeled in IRPs?
- What are the installed and commissioned costs of different GEB measures, return on investment, and/or cost to benefit ratios in different climate zones and building types?
- Are there opportunities to improve the cost effectiveness of smart GEB-enabling technologies (e.g., sensors, communication mechanisms), including through increased interoperability and more automated configuration?
- Based on the cost of GEB measures, what is the threshold where it could be more advantageous for utilities to buy on the market as opposed to investing in GEBs? How is risk considered in such an analysis?
- What are the marginal cost/benefits of day-ahead, hour-ahead, 15-minute ahead, and real-time calls?
- How can GEBs be used to reduce costs associated with renewable energy integration locally and at scale? Can GEBs be used for renewable energy curtailment?

***Resilience***

- What combination of GEB measures can most cost effectively provide four-hour building islanding capabilities?
- How can GEB measures be combined to support re-energization of the grid after a disturbance and/or provide black start support to a microgrid?
- How can the impact of GEB on resilience and other indirect benefits be measured?

- How can GEB be used in community resilience hubs to reduce the cost of providing energy services and/or improve resilience performance?
- Can GEBs help provide or improve resource adequacy for targeted communities?

***Technology questions***

- Which end-use technology options (both emerging and on the market) have the greatest potential to provide demand flexibility in different regions?
- What is the appropriate role for customer-owned electric vehicle battery storage systems? What is the state of vehicle-to-grid battery technology?
- What are the energy efficiency (EE) benefits when a traditional thermostat is replaced with a connected "smart" thermostat?
- Can data gathered by a utility during a GEB pilot be leveraged to provide EE improvement recommendations?
- What are the interactive effects of demand flexibility strategies on one another and on EE?
- What are the efficiency gains from replacing gas water heaters with connected, efficient heat-pump water heaters?
- What are best practices for communication and data tracking?
- What are the best ways to incorporate and update state-of-the-art security features and best practices into the design process of control architectures, and to understand limitations?
- What are the impacts of demand flexibility on equipment lifetime?

***Performance assessments***

- What is the best way for GEB systems, for different building types and scales, to be dispatched and managed (i.e., utility or third party)?
- Are multiple measures being tested in the pilot so interactive effects and true potential can be determined, or is the pilot only testing one aspect of GEBs?
- What performance benefits can be achieved by EE, flexible demand response, distributed generation, and energy storage, and what are subsequent impacts on grid?
  - Overall energy and peak reduction potential
  - Demand flexibility potential
  - Ability and impacts of aggregating building (scaling up)
  - Magnitude of scalability required to be meaningful to the grid
  - Capture locational and seasonal variations
  - Building EE gains using smart technologies over traditional technologies
  - Co-optimize GEB components for various outcomes — choose if you want to reduce overall capital costs for participants, target long-run savings, or emphasize a combination of GEB components that target something else that is grid-need oriented
  - Interconnectivity and communication/control of devices

***Stakeholder relationships***

- What savings and performance improvements can be achieved by leveraging stakeholder participation with specific experience in the Northwest? Both the Northwest Energy Coalition and Northwest Energy Efficiency Alliance have decades of experience with market transformation of EE, distributed energy resources, and/or demand response in the Pacific Northwest.
- Are there needs to be addressed relative to accessibility/commercialization of and contractor familiarity with GEB technology?
- What is the best way to leverage national laboratory (e.g., Pacific Northwest National Laboratory, Lawrence Berkeley National Laboratory, Department of Energy) participation in the development of new technologies or operational impacts?

***Policy and regulatory issues***

- How can GEBs cost effectively support achievement of state policy goals?
- How can GEBs best be integrated into existing planning requirements?
- Are third-party services cost effective and safe for data aggregation and sharing?
- What are options and best practices for dealing with data access and data privacy concerns?
- What performance assurance and revenue models remove disincentives for utilities to forego poles and wires investments and engage with GEBs instead?
- Are there regulatory constraints for aggregating GEB measures across buildings and/or exercising interbuilding exchanges?
- Could GEB investments be applied to clean power requirements?
- What regulatory framework is needed to fully enable GEBs? What rate alignment and rate incentives between utilities and customers are needed?
- What technology and interconnected technologies codes and standards are needed?
- Is there a place for involvement or coordination with major supply-side actor entities, such as the Northwest Energy Efficiency Alliance? How could supply-side issues be included early in the planning and program design phase?

***Institutional***

*Institutional* refers to formal and informal organizational or business structures, from industry-wide and individual corporate organizations to business culture customs. This section pertains to how GEBs may be integrated into these institutional norms. As a simple example, some of the GEB technologies, including new sensors, software systems, and the algorithms required to operate them, will be required as utilities fully implement GEBs. Therefore, additional staff may be needed, and/or there may be a need for retraining existing staff to address these new technologies. In addition, more time may be necessary to provide customer service. Another important aspect that could be included in pilot programs and designs includes flexible demand and battery storage for electricity infusion into the grid more meaningfully in resource planning. This could include training and or other innovations in capacity expansion modeling and risk assessment modeling, and integration between distribution system, transmission system, and generation planning. These practical and institutional considerations could be incorporated into technology pilots. Functional GEB programs may include breaking down silos within utilities and helping long-time staff become comfortable with this new type of resource. This culture change is significant and should not be underestimated. Therefore, utilities may want to consider a cohort model when it comes to

GEB pilots, where sister utilities can learn and grow together. A mentoring modeling may be beneficial, in which a more experienced or resourced utility works with a smaller or newer utility to implement GEB programs.

Utility cross-departmental engagement with upper management support is important to the success of GEB pilots and full-scale roll out. Key questions and considerations that can be answered through GEB pilots from an institutional perspective include the following:

- What is the level of integration across departments at the utility? Which department is proposing the pilot and what coordination is happening between the EE, demand-side management, distributed generation, and resource planning/IRP departments within the utility? Is high level management part of the pilot proposal?
- Has the pilot design been vetted by an external party prior to implementation?
- Has the utility demonstrated that there is a need for the pilot? Have similar pilots already been run in the region or elsewhere and can information and learnings from those pilots be used in larger scale implementations rather than pilots?
- Is there a plan for moving from pilot scale to larger implementation?
- Does it make sense to do a trial or demonstration project of a particular GEB feature prior to the pilot?
- Is there a plan for sharing results with other utilities?
- Does the utility have a habit of perpetually running pilots that are not taken to the next level? Is there accountability that be added in this regard?
- Is a cohort model being used where utilities are working together and learning from each other? Or is a mentor model being used in which more experienced utilities are partnering with less experienced utilities?

# Appendix C: Methods to Choose Pilot Elements

Given the need to implement and conduct a pilot in a timely manner, along with finite budgets, pilot developers cannot include every grid-interactive efficient building (GEB) feature and metric in their pilot. Once priorities are developed, the appropriate research questions are asked, and the corresponding pilots metrics are established, pilot developers may need to drill down further to a subset of metrics or questions to ultimately define pilot success. Table C.1 illustrates a rudimentary weighting scheme to assess pilots against each other based on a set of priorities and functionality. Pilot developers would apply a value based on the contribution of the GEB pilot features to the state. Conversely, a pilot designer could set up an optimization routine that maximizes certain outcomes subject to budget and other constraints. Regardless of which decision method planners use, both GEB features stemming from state needs and more functional considerations, such as cost and scalability, will need to be part of the decision process.

**Table C.1. Hypothetical Pilot Choice Weighting Scheme**

| | **Pilot A** | **Pilot B** | **Pilot C** | **…** |
|---|---|---|---|---|
| **Sample Priorities** | | | | |
| Capacity demand reduction/control | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Demand flexibility | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Equity | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Resilience | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| … | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| **Sample Pilot Functionality** | | | | |
| First cost | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Return on investment | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Utility alignment | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| Scalability | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| … | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) | Value Scale (1 to?) |
| **Total** | **Total** | **Total** | **Total** | **Total** |

# Appendix D: Grid-Interactive Efficient Buildings Resources

Although grid-interactive efficient building (GEB) pilots are relatively new, there are several good resources on background information pertaining to GEB. Below we provide some of these resources.

**What is GEB?**


DOE Office of Energy Efficiency and Renewable Energy. May 2021. *A National Roadmap for Grid-Interactive Efficient Buildings.* https://gebroadmap.lbl.gov/.

DOE Office of Energy Efficiency and Renewable Energy. April 2019. *Grid-interactive Efficient Buildings: Overview of Research Challenges and Gaps.* https://www1.eere.energy.gov/buildings/pdfs/75470.pdf.

DOE Office of Energy Efficiency and Renewable Energy. Grid-interactive Efficient Buildings: Useful Resources. https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.

Lave, M. "Grid Modernization Laboratory Consortium Testing Network (GMLC 1.2.3)." March 22, 2018. https://www.osti.gov/servlets/purl/1506192.

Sobin, R. No date. "Considerations for Grid-interactive Efficient Buildings (GEB) Pilot Projects." National Association of State Energy Officials. https://naseo.org/data/sites/1/documents/publications/NASEO%20GEB%20Pilot%20Considerations%20Nov%202019.pdf.

Fairbrother, C., L. Guccione, M. Henchen, and A. Teixeira. 2017. *Pathways for Innovation: The Role of Pilots and Demonstrations in Reinventing the Utility Business Model.* Rocky Mountain Institute. https://rmi.org/insight/pathways-for-innovation/.


**GEB Equipment and Operation**


Connected Devices Alliance. 2018. *Intelligent Efficiency – A Case Study of Barriers and Solutions – Smart Homes.* March 2018. https://www.iea-4e.org/wp-content/uploads/publications/2018/03/Case_Study_HEMS_Final_Report.pdf.

DOE Office of Energy Efficiency and Renewable Energy. April 2019. *Grid-interactive Efficient Buildings Technical Report Series: Whole-Building Controls, Sensors, Modeling, and Analytics.* December 2019. https://www1.eere.energy.gov/buildings/pdfs/75478.pdf.

DOE Office of Energy Efficiency and Renewable Energy. April 2019. *Grid-interactive Efficient Buildings Technical Report Series: Windows and Opaque Envelope.* December 2019. https://www1.eere.energy.gov/buildings/pdfs/75387.pdf.

DOE Office of Energy Efficiency and Renewable Energy. April 2019. *Grid-interactive Efficient Buildings Technical Report Series: Heating, Ventilation, and Air Conditioning (HVAC); Water Heating; Appliances; and Refrigeration.* December 2019. https://www1.eere.energy.gov/buildings/pdfs/75473.pdf.

DOE Office of Energy Efficiency and Renewable Energy. April 2019. *Grid-interactive Efficient Buildings Technical Report Series: Lighting and Electronics.* December 2019. https://www1.eere.energy.gov/buildings/pdfs/75475.pdf.

Brambley, M.R. et al. "Transactive Control and Coordination for Residential and Commercial Grid-interactive Efficient Buildings" Proceedings in ACEEE Summer Study on Energy Efficiency in Buildings 2020. Not available online, but available by request.

**GEB Valuation**

State and Local Energy Efficiency Action Network. 2020. *Determining Utility System Value of Demand Flexibility from Grid-Interactive Efficient Buildings.* Prepared by Tom Eckman, Lisa Schwartz, and Greg Leventis. Lawrence Berkeley National Laboratory. https://www.energy.gov/sites/prod/files/2020/04/f74/bto-see-action-GEBs-valuation-20200410.pdf.

EPRI. "Estimating the Cost and Benefits of the Smart Grid." https://www.epri.com/research/products/1022519.

DOE. *Smart Grid Investments Improve Grid Reliability, Resilience, and Storm Responses.* https://www.smartgrid.gov/document/smart_grid_investments_improve_grid_reliability_resilience_and_storm_response_0.

**GEB Metrics**

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