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Grid-Interactive Efficient Buildings: An Introduction for State and Local Governments

April 2020

The State and Local Energy Efficiency Action Network is a state and local effort facilitated by the U.S. Department of Energy and U.S. Environmental Protection Agency to offer resources, discussion forums, and technical assistance to state and local decision makers as they provide low-cost, reliable energy to their communities through energy efficiency. Learn more at www.seeaction.energy.gov

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All opinions, errors, and omissions remain the responsibility of the authors. All reference URLs were accurate as of the date of publication.

Other Reports in This Series

- ***Determining Utility System Value of Demand Flexibility from Grid-Interactive Efficient Buildings:*** Describes how current methods and practices that establish value to the electric utility system of investments in energy efficiency and other distributed energy resources (DERs) can be enhanced to determine the value of grid services provided by demand flexibility
- ***Issues and Considerations for Advancing Performance Assessments for Demand Flexibility from Grid-Interactive Efficient Buildings:*** Summarizes current practices and opportunities to encourage robust and cost-effective assessments of demand flexibility performance and improve planning and implementation based on verified performance.

In addition, DOE offers a fact sheet, overview, and series of technical reports with more information on technologies and strategies for grid-interactive efficient buildings: https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.

Acronyms

AMI	advanced metering infrastructure
BAS	building automation system
C&I	commercial and industrial
DER	distributed energy resource
DOE	U.S. Department of Energy
DSM	demand-side management
EV	electric vehicle
HVAC	heating, ventilating, and air-conditioning
NYSERDA	New York State Energy Research and Development Authority
PGE	Portland General Electric
PUC	public utility commission
PV	photovoltaic
RPS	renewable portfolio standards
RTEM	Real Time Energy Management
SMUD	Sacramento Municipal Utility District
T&D	transmission and distribution

Glossary

These definitions are for the purposes of grid-interactive efficient buildings. They may be defined differently or more generally in other contexts.

Distributed energy resource (DER): A resource sited close to customers that can provide all or some of their immediate power needs and/or can be used by the utility system to either reduce demand or provide supply to satisfy the energy, capacity, or ancillary service needs of the grid.

Demand flexibility: Capability of DERs to adjust a building's load profile across different timescales; energy flexibility and load flexibility are often used interchangeably with demand flexibility.

Demand response: Change in the rate of electricity consumption in response to price signals or specific requests of a grid operator.

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

Energy efficiency: Ongoing reduction in energy use to provide the same or improved level of function.

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

Grid services: Services that support the generation, transmission, and distribution of electricity and provide value through avoided electricity system costs (generation and/or delivery costs); this report focuses on grid services that can be provided by grid-interactive efficient buildings.

Load profile: A building's load profile describes when—time of day or hour of the year—the building is consuming energy (typically used to refer to electricity consumption but can also describe on-site fuel use); load shape and load curve are often used interchangeably, but all refer to the timing of energy use.

Smart technologies for energy management: Advanced controls, sensors, models, and analytics used to manage DERs. Grid-interactive efficient buildings are characterized by their use of these technologies.

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1. Overview of Grid-Interactive Efficient Buildings and Demand Flexibility

By 2030, according to one estimate, the United States will have nearly 200 gigawatts (GW) of cost-effective load flexibility potential, equal to 20% of estimated U.S. peak load. That is three times the existing demand response capability, with savings for consumers from avoiding utility system costs estimated at $15 billion annually.[1] This flexibility, largely in buildings, can help cost-effectively address several grid challenges, from growth in peak demand, to higher levels of variable renewable energy generation, to increasing electrification of transportation and other loads.

Buildings have served as energy assets for decades, providing load management or energy efficiency services and generating electricity on-site, with owners and occupants often participating in programs that state and local governments run or oversee. But today, these programs typically do not require frequent changes in building loads. Further, most distributed generation programs pose few constraints on electricity that consumers export to the grid when on-site energy production exceeds consumption.

New technologies can monitor and communicate building operating conditions and coordinate control of loads and multiple types of distributed energy resources (DERs) in concert with grid conditions. In the future, both residential[2] and commercial buildings will continuously manage loads and DERs to better serve the needs of building owners and occupants, electric utility systems, and regional grids.

The potential impacts are significant. Buildings account for 75% of electricity consumption (Figure 1) and a comparable share of peak power demand. With many adjustable loads, buildings can be part of the solution to peak demand issues and offer a broader range of grid services to help meet other electricity system requirements.

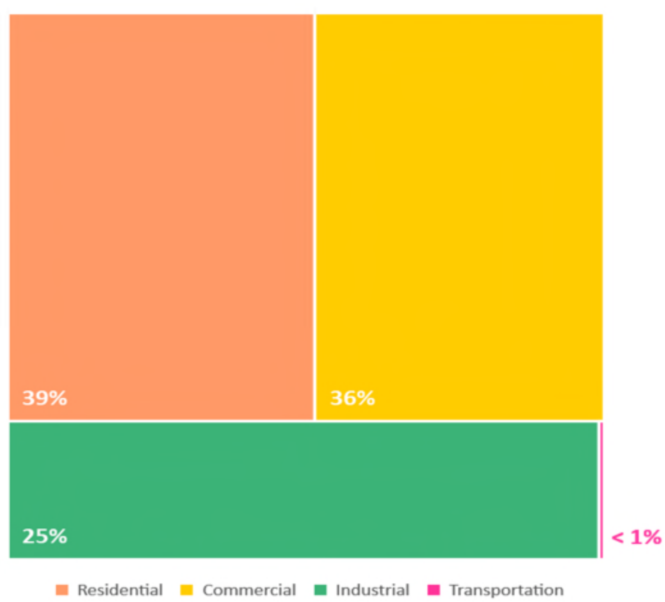


Figure 1. Electricity Use by Market Sector[3]
Buildings (residential and commercial) represent the majority of U.S. electricity use.

[1] Hledik et al. 2019. The study considered a broad range of demand response technologies and applications and managed charging for electric vehicles (EVs), but did not explicitly account for active energy efficiency controls, distributed generation, or battery storage.
[2] Single- and multifamily dwellings.
[3] EIA 2019.

Applying control strategies over various timescales to loads like lighting and air conditioning, as well as distributed photovoltaic (PV) systems, micro combined heat and power, energy storage, EV charging, and microgrids, buildings can provide demand flexibility by:

- reducing electricity consumption
- shifting energy use to another time
- increasing power draw from the grid to store electricity generated on-site for later use.

Such demand flexibility (also called load flexibility) is the core characteristic of grid-interactive efficient buildings. Demand response is a resource that provides demand flexibility and is included in many utility programs across the nation. However, a grid-interactive efficient building expands demand flexibility options beyond traditional demand response because of the smart technologies like advanced sensors and controls and data analytics that can actively manage DERs and adjust a building's load profile to co-optimize for energy costs, grid services, and occupant needs and preferences in a continuous and integrated way (Figure 2 and Figure 3).[4]

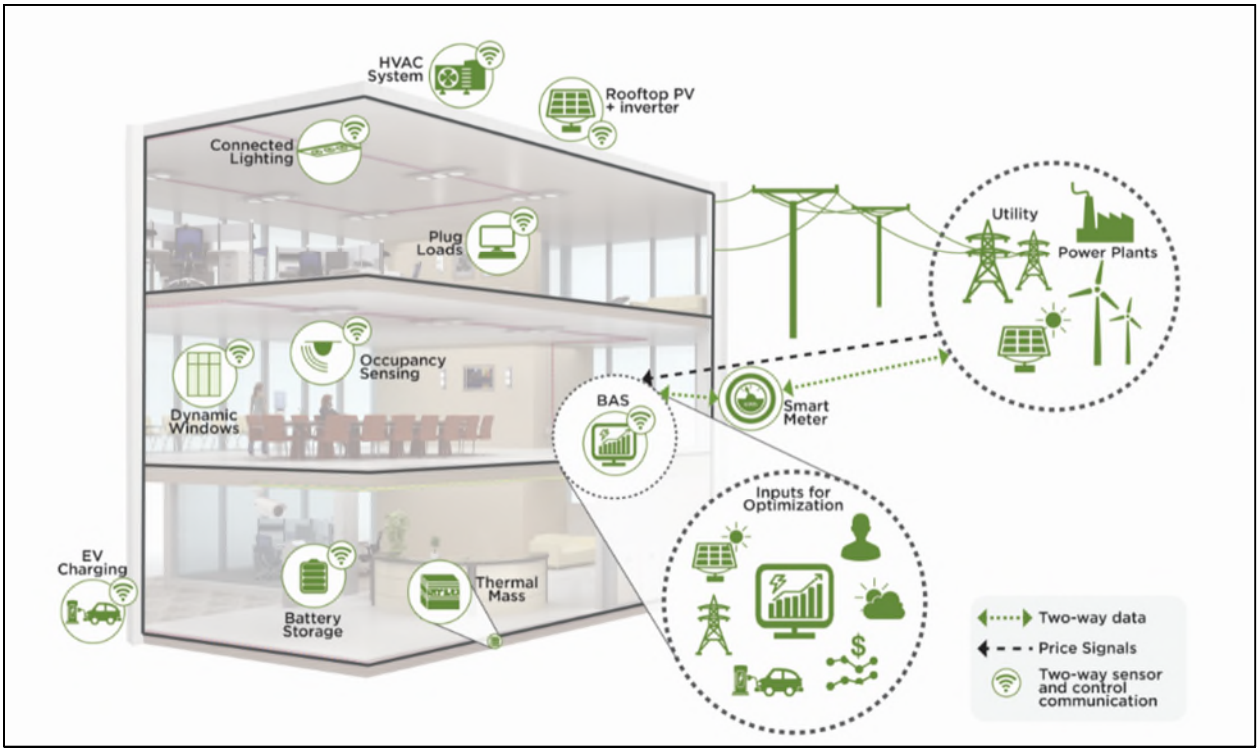


Figure 2. Example Commercial Grid-interactive Efficient Building[5]
Advanced building technologies—including heating, ventilating, and air-conditioning (HVAC) controls, connected lighting, dynamic windows, occupancy sensing, thermal mass, and on-site generation such as solar PV and combined heat and power—are optimized to meet occupant and grid needs. A building automation system (BAS) responds to inputs such as sensors, weather forecasts, and price or event signals from utilities, regional grid operators, and third-party service providers.

[4] For more information, see https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.
[5] Neukomm et al. 2019.

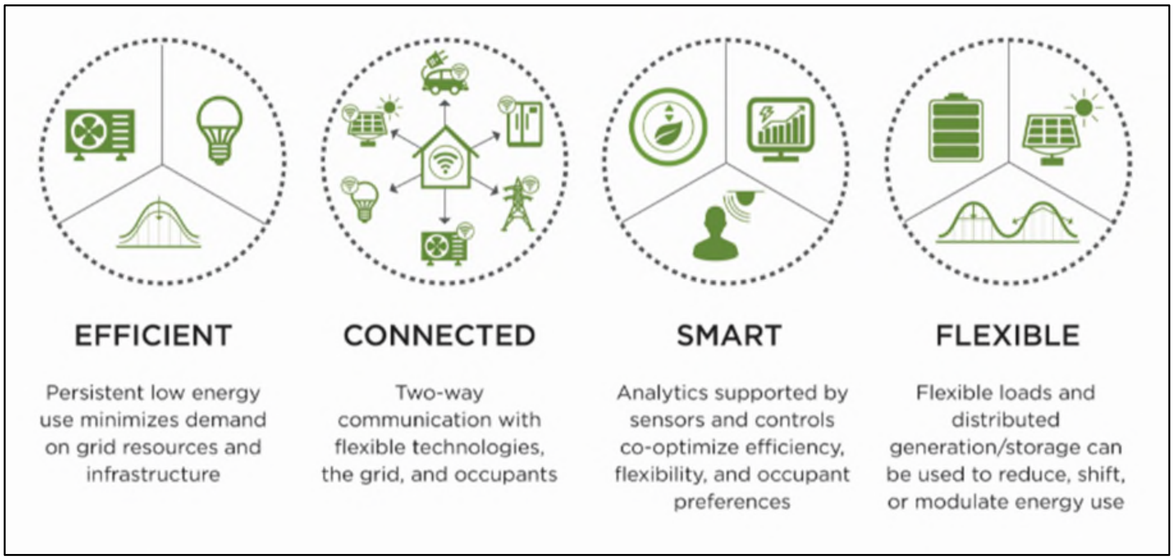


Figure 3. Characteristics of Grid-interactive Efficient Buildings[6]

Builders and utilities already are gaining experience with grid-interactive efficient buildings. For example, Xcel Energy is demonstrating integrated operation of distributed PV, batteries, grid-interactive water heaters, and EVs in both residential and commercial applications. A "Smart Neighborhood" in Birmingham, Alabama, integrates 62 high-performance homes, energy-efficient systems and appliances, connected devices, and a microgrid on a community-wide scale in partnership with Southern Company.[7] Hawaiian Electric is using Grid Services Purchase Agreements to aggregate, forecast, and coordinate DERs like PV, battery systems, and grid-enabled water heaters for energy, capacity, reserves, and frequency control to keep electric grids stable and reliable.[8]

Demand flexibility can support state and local governments in many ways. One, it can support multiple energy-related goals, including greater reliability and resilience of the power grid, reduced electricity costs through peak management, achieving renewable energy and energy efficiency targets, lower air pollutant emissions, and affordability. Two, demand flexibility can directly improve performance of public facilities. A growing number of states, cities, and counties are leading by example with their facilities to reduce energy waste and emissions, control costs, and improve resilience.[9]

Specifically, grid-interactive efficient buildings and the demand flexibility they provide support:

- *Reliability and resilience*[10]—Reducing peak demand, and adjusting a building's load profile across different timescales, makes the electricity system less vulnerable to stress-related outages. Reducing generation and transmission and distribution (T&D) capacity needed for recovery from disruptions improves system resilience. Distributed generation, storage, and microgrids also may be able to provide critical electricity services for buildings during outages. In addition, energy-efficient buildings can maintain habitable conditions for residents for longer periods and help preserve commercial operations.

[6] Neukomm et al. 2019.
[7] More information at https://naseo.org/event?EventID=6945.
[8] See https://www.hawaiianelectric.com/hawaiian-electric-and-open-access-technology-international-plan-for-innovative-grid-services-wins-puc-approval; https://sepapower.org/knowledge/two-birds-one-water-heater-how-shifted-energy-and-hawaiian-electric-are-helping-hawaii-meet-its-clean-energy-goals/.
[9] For example, see https://database.aceee.org/state/public-building-requirements.
[10] Reliability is maintaining the delivery of electric services to customers in the face of routine uncertainty in operating conditions. Resilience is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, including deliberate attacks, accidents, or naturally occurring threats or incidents (Kintner-Meyer et al. 2017).

- *Energy efficiency and affordability*—Energy savings targets are a key driver for energy efficiency in 30 states. Of those, 18 states require the utility (or third-party administrator) to meet binding energy savings or minimum spending requirements for a long-term period.[11] Four of these states address the time-sensitive value of efficiency in their standard by requiring peak demand reductions (Colorado, Illinois, Ohio, and Texas).[12] By cost-effectively reducing energy use and peak demand, and participating in utility programs and electricity markets for a broad range of grid services, grid-interactive efficient buildings and demand flexibility can help keep down electricity costs for households, businesses, and institutions.
- *Improved integration of new resources and loads*—Demand flexibility supports state and local policies to achieve higher levels of renewable energy generation, and better integrate EVs and other new electric loads, by contributing to grid services needed for these purposes—**see text boxes on Colorado and Massachusetts**. Twenty-nine states have adopted renewable portfolio standards (RPS).

About half of all growth in U.S. renewable electricity generation and capacity since 2000 is associated with these policies. RPS demand will require roughly a 50% increase in U.S. renewable energy generation by 2030, equating to 67 GW of new capacity. More than 200 cities and counties also have adopted renewable energy goals.[13] Several states have adopted electrification plans.[14] In addition, 15 states have adopted storage policies, such as procurement targets, demonstration programs, and financial incentives. All of these states have RPS policies, underscoring the role of storage as a potentially cost-effective way to integrate renewable energy generation.[15]

COLORADO

Holy Cross Energy: Charge at Home and Demand Flexibility Tariffs
Grid service: Ramping

In exchange for providing a free home charger for EVs, customers of Holy Cross Energy, a Colorado electric cooperative, consent to the utility shifting or modulating charging behavior through a Wi-Fi interface. The Charge at Home program offers a full rebate for the cost of a Level 2 EV charger (or two chargers for two EVs). On-bill financing is available for up to three years for local electrician installation of the charger and service to the charging equipment. The utility owns and maintains the charger for that period. Ownership then transfers to the customer.

Participation includes opting into a Distribution Flexibility tariff, which gives the utility operational control of other controllable DERs. Participants earn a monthly credit on utility bills based on performance when called on to provide grid flexibility. The offer also is open to nonresidential customers through the Charge at Work program. The average program participant keeps their EV plugged in for 11 hours a day, but requires only two hours of charging—8 kilowatt-hours (kWh) or ~32 miles/day)—illustrating that EV charging may be the most flexible load in homes and work places. The programs are part of the utility's Electrification of Transportation plan.

Sources: https://www.holycross.com/charge-at-home/; https://www.holycross.com/electrification-of-transportation/; Chris Bilby, Holy Cross Energy

[11] Goldman et al. 2018. Five states have nonbinding savings targets. In four states, electricity savings from efficiency programs are eligible for compliance with state RPS or clean energy standards.

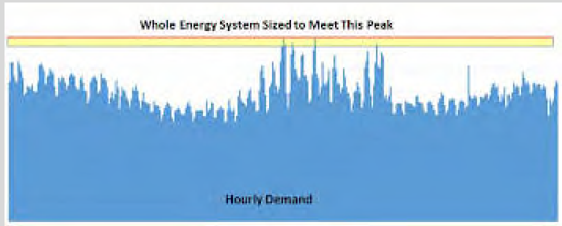
[12] Mims Frick and Schwartz 2019.

[13] Barbose 2019. Not all of this renewable energy development is strictly attributable to state RPS policies.

[14] For example, California, Massachusetts, Minnesota, New York, and Vermont.

[15] Twitchell 2019.

MASSACHUSETTS



Active Demand Management

Grid services: Generation Energy and Capacity, Non-Wires Solutions

The state's Act to Advance Clean Energy enacts a number of strategies that require demand flexibility:

- Integrating "active demand management" measures such as storage—dispatched through automation, programming, or control—into statewide programs
- Establishing a Clean Peak Energy Standard with incentives for eligible technologies that can supply electricity or reduce demand during seasonal peak demand periods
- Supporting electrification for thermal and transportation needs.

The Act informed the 2018 Comprehensive Energy Plan, an analysis of the state's energy use and supply "to determine optimal policies to achieve economic competitiveness and emission goals and maintain reliability." The plan highlights the importance of demand flexibility as electricity use for transportation and heating grows. The Act also guided the 2019-2021 statewide energy efficiency plan, which harnesses advanced demand flexibility technologies toward peak demand reductions of 665 megawatts (MW) in summer and 500 MW in winter.

For example, the Commercial & Industrial (C&I) Active Demand Reduction and Residential Behavior initiatives in the statewide efficiency plan link participants' devices to an Internet-connected platform that allows the utility to communicate directly with buildings. The C&I program is technology-agnostic, providing incentives for verifiable load shedding in response to a signal or communication from the program administrator. The customer value proposition includes reduced demand and regional capacity charges on utility bills, plus any revenue from regional markets. The customer only needs to change operations a few times a year (e.g., controlling lighting, space temperature, or process loads) using energy management systems, controls, and Open ADR. Among programs for residential customers is one that reduces demand during summer peak events, using communicating thermostats to control central air-conditioning, as well as batteries, lighting, water heaters, and pool pumps.

Sources:
https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter227

http://ma-eeac.org/wordpress/wp-content/uploads/Term-Sheet-10-19-18-Final.pdf

http://ma-eeac.org/wordpress/wp-content/uploads/2019-2021-Three-Year-Energy-Efficiency-Plan-April-2018.pdf

This report considers five strategies that can be implemented in buildings to manage loads:

- **Efficiency:** The ongoing reduction in energy use while providing the same or improved level of building function.[16]
- **Load shed:** The ability to reduce electricity use for a short time period and typically on short notice. Shedding is typically dispatched during peak demand periods and during emergencies.
- **Load shift:** The ability to change the timing of electricity use. In some situations, a shift may lead to changing the amount of electricity that is consumed. Load shift in this report focuses on intentional, planned shifting for reasons such as minimizing demand during peak periods, taking advantage of the cheapest electricity prices, or reducing the need for renewable curtailment. For some technologies, there are times when a load shed can lead to some level of load shifting.
- **Modulate:** The ability to balance power supply/demand or reactive power draw/supply autonomously (within seconds to subseconds) in response to a signal from the grid operator during the dispatch period.
- **Generate:** The ability to generate electricity for on-site consumption and even dispatch electricity to the grid in response to a signal from the grid. Batteries are often included in this discussion, as they improve the process of dispatching such generated power.

Figure 4 illustrates four of these strategies.

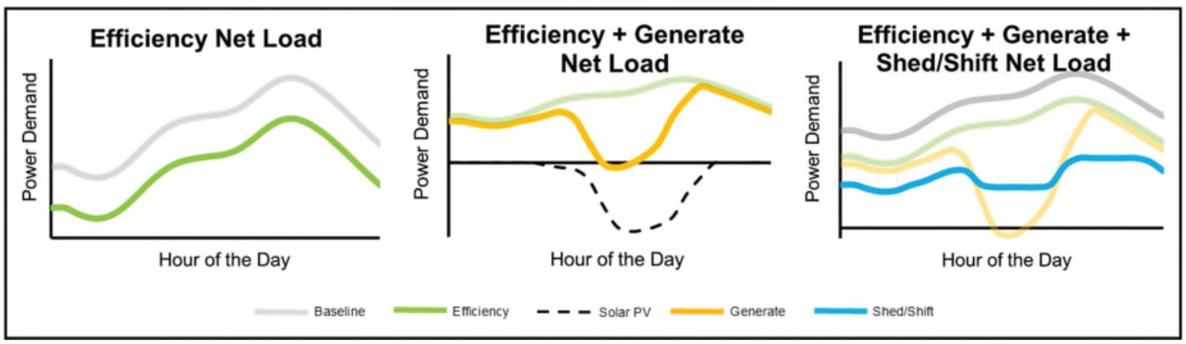


Figure 4. Daily Average Load Profiles for a Grid-interactive Efficient Building[17]
Left: Energy efficiency alone pushes down the load curve. Middle: Energy efficiency plus distributed generation (in this case, solar PV) reduce overall energy use, but the building's peak load coincides with utility peaks. Right: Adding load shedding and shifting flattens the building load profile, providing the greatest support to the grid.

At a given baseline load, a building can provide additional value by changing its load profile in response to grid or price signals. This report primarily focuses on these demand flexibility capabilities, which are typically enabled by the controls and analytics found in a grid-interactive efficient building. The ability to shed, shift, and modulate load comes from DERs that are inherently flexible, including batteries and on-site distributed generation, such as rooftop PV.

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[16] This has the greatest impact for the grid during high-cost periods and minimizes utilization of costly generation resources.
[17] Neukomm et al. 2019.

These demand flexibility strategies in buildings can provide a wide range of grid services:

- Generation—energy and capacity
- Ancillary services[18]—contingency reserves, ramping, and frequency regulation
- Delivery—non-wires solutions[19] and voltage support.

Appendix A describes in more detail grid services that demand flexibility can provide and specifies requirements for duration, load change, response time, and event frequency. For example, responding to signals from a utility, regional grid operator, or DER aggregator, grid-interactive water heaters can quickly shed load, use preheated water and thermal storage to sustain the load reduction for several hours to reduce peak capacity needs, and provide other grid services (Figure 5). Both the electric utility system and participating building owners and occupants reap the benefits (Table 1).

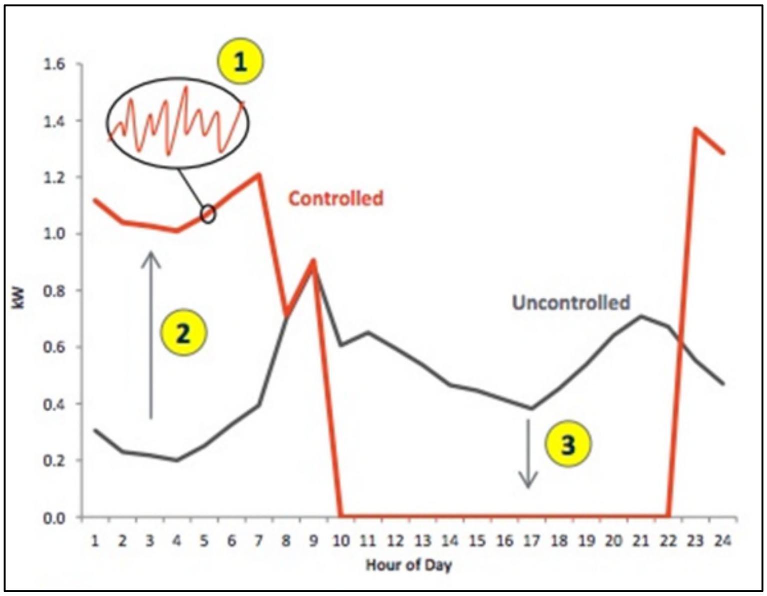

Figure 5. Water Heating Load Profile.
Heating element control provides near-instantaneous response for balancing services (1). Increasing load during off-peak hours can reduce curtailment of wind and solar generation and ramping of thermal generation (2). Reducing peak demand relieves stress on generation and T&D capacity and reduces exposure to peak prices (3).[20]

[18] "Those services necessary to support the transmission of electric power from seller to purchaser, given the obligations of control areas and transmitting utilities within those control areas, to maintain reliable operations of the interconnected transmission system…." Source: https://www.ferc.gov/market-oversight/guide/glossary.asp.
[19] DER investments or market operations that provide specific services at specific locations to defer, mitigate, or eliminate the need for T&D investments.
[20] Source: Hledik et al. 2019.

Table 1. Demand Flexibility Benefits[21]

Benefit	Utility System	Building Owners/Occupants
Reduced utility operation & maintenance costs	✓	-
Reduced generation capacity costs	✓	-
Reduced energy generation costs	✓	-
Reduced T&D costs	✓	-
Reduced T&D losses	✓	-
Reduced ancillary services costs	✓	-
Reduced environmental compliance costs	✓	-
Increased resilience	✓	✓
Increased DER integration	✓	✓
Improved power quality	-	✓
Reduced owner/occupant utility bills	-	✓
Increased owner/occupant satisfaction	-	✓
Increased owner/occupant flexibility and choice	-	✓

In most cases, demand flexibility must be aggregated across a number of buildings to reach a sufficient magnitude and serve as a meaningful resource for a utility or regional grid operator. Toward meeting their own goals—including reliability, resilience, energy affordability, integration of variable generation, and strategic electrification—a growing number of state and local governments, utilities, and regional grid operators (regional transmission operators or independent system operators [RTO/ISOs]) are developing demand flexibility programs that integrate demand-side management (DSM) approaches to provide a broader range of grid services. For example, some states (e.g., Massachusetts and California) are updating energy efficiency and renewable energy policies to incorporate demand flexibility. Table 2 lists example programs featured throughout this report, including Appendix B, that use integrated DSM approaches to provide multiple grid services.

Utilities and centrally organized wholesale electricity markets procure grid services differently. Further, whether DERs providing demand flexibility are eligible to participate in procurements varies by type of grid service and by utility and regional grid operator (for example, **see text box on ISO New England**).

[21] Adapted from Woolf et al. Forthcoming.

Table 2. Integrating Demand-Side Management Approaches for Multiple Grid Services: Programs Featured in This Report

	Grid Services							
	Generation - Energy	Generation - Capacity	Contingency Reserves	Frequency Regulation	Ramping	Avoid renewable generation curtailment	Non-wires Solutions	Voltage Support
State Programs								
California—Title 24	●	●				●	●	
Massachusetts—Active Demand Management	●	●					●	
New York—Real-Time Energy Management Program	●	●	●				●	
Southern Company Smart Neighborhood™	●	●						
Utility and Regional Programs								
Austin Energy—Power Partner℠		●	●					
ConEd and Orange & Rockland Smart Home Rate		●	●					
Consumers Energy—Swartz Creek Energy Savers							●	
Green Mountain Power—Bring Your Own Device		●	●			●	●	●
Hawaiian Electric—Grid Services Purchase Agreement	●	●	●	●		●		●
Holy Cross Energy—Charge at Home					●			
ISO-New England Forward Capacity Market/Sunrun		●						
PG&E—Home Energy Optimization		●				●	●	
PGE—Smart Grid Test Bed		●	●				●	
SMUD—PowerDirect®		●	●		●			

ISO-NEW ENGLAND—FORWARD CAPACITY MARKET

Grid Service: Generation Capacity

The New England Independent System Operator (ISO-New England) holds Forward Capacity Market auctions each year to ensure the region's power system has sufficient resources to meet future demand. In ISO-New England's February 2019 auction, the energy services company Sunrun won a bid to provide 20 MW of aggregated capacity from its integrated solar and battery systems for about 5,000 homes in four states: Vermont, New Hampshire, Massachusetts, and Rhode Island.

The project will provide customer and grid benefits without increasing the need for T&D infrastructure. This example shows that integrated DERs, like solar plus storage systems, can meet the operational requirements of a regional grid operator—in this case, committing future capacity resources to meet a region's needs. It also illustrates DERs successfully competing against traditional generation resources in centrally-organized wholesale electricity markets.

Sources: https://www.iso-ne.com/markets-operations/markets/forward-capacity-market/

https://www.globenewswire.com/news-release/2019/02/07/1712238/0/en/ISO-New-England-Awards-Sunrun-Landmark-Wholesale-Capacity-Contract.html

2. Trends, Challenges, and Opportunities

Demand flexibility is gaining traction, with evolving trends and opportunities for DERs, buildings, and electricity services. These include advances in demand response controls and communications,[22] cost reductions and longer duration for battery storage,[23] and continued falling prices for distributed PV.[24] Other trends are socio-economic, such as changes in electricity consumption by end use[25] and consumer interest in and drivers for smart technologies.[26] Changing business practices and strategies by utilities, vendors, and service providers also offer new ways for buildings to participate in providing grid services.[27] That is why the cost-effective potential is so high—nearly 200 GW of load flexibility by 2030, some 20% of U.S. peak load.[28]

In addition, utilities and regional grid operators are investing in new technologies and systems to modernize increasingly complex electricity grids. Growth in peak demand, infrastructure constraints for T&D systems, and an increasing share of utility-scale and distributed variable renewable generation are stressing electricity grids across the United States (Figure 6 and Figure 7). At the same time, electrification of space and water heating, industrial processes, and transportation is increasing.[29] Grid operators must balance loads and resources within acceptable voltage and frequency limits and have sufficient T&D infrastructure to deliver energy where and when it is needed.

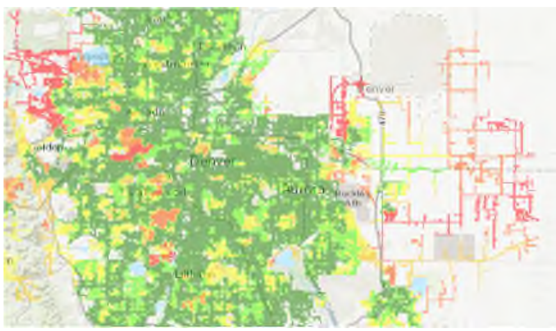

Figure 6. Hosting Capacity Challenges on the Distribution System
This map of the Denver area indicates areas where only limited (orange) or no (red) solar PV can be installed without infrastructure upgrades or additional demand flexibility.[30]

[22] Potter and Cappers 2017.
[23] See https://www.energy.gov/oe/activities/technology-development/energy-storage.
[24] Barbose et al. 2018.
[25] Schwartz et al. 2017; EIA's commercial buildings survey and residential buildings survey. The terms energy management control systems and building automation systems are synonymous and also may be called smart building controls: http://www.eia.gov/consumption/commercial/data/2012/guide.cfm.
[26] See, for example, Smart Energy Consumer Collaborative, 2019 State of the Consumer Report.
[27] Blansfield et al. 2017.
[28] Hledik et al. 2019. A Berkeley Lab study concluded that EVs alone could provide services comparable to 5 GW of stationary storage for valley-filling and ramp-up mitigation in California, equivalent to $12.8–$15.4 billion in stationary storage investment. Coignard et al. 2018 Environ. Res. Lett. 13 054031.
[29] Deason et al. 2018; Jones et al. 2018.
[30] Source: https://www.xcelenergy.com/working_with_us/how_to_interconnect/hosting_capacity_map.

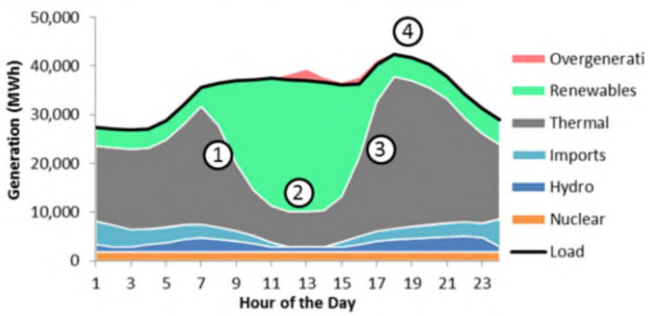

Figure 7. Example Bulk Power System Challenges

High levels of variable renewable generation increase multi-hour ramping (1, 3) and intra-hour variability and short duration ramps (1-4) for thermal power plants. To maintain reliability, system operators procure resources—day-ahead and day of—to accommodate these predicted ramps. Generation curtailment also may occur (2). Source: E3 2014

Buildings can provide grid services to help address these challenges at least cost, improve grid reliability and resilience, reduce energy waste, improve energy affordability, and integrate a variety of generation sources, EVs, and other loads. Harnessing two-way connectivity and communications between smart building technologies and the grid and multiple demand flexibility modes (load shed, load shift, modulate, and generate), building energy loads can be dynamically shaped and optimized for the electric grid and for building owners and occupants' own DSM strategies. State and local governments can take incremental steps to advance demand flexibility by encouraging adoption of the necessary hardware and systems to optimize energy-consuming and energy-producing equipment for occupants, which can be co-optimized for the grid in the future (see **text box on New York**). But challenges remain to realizing this vision. The following subsections provide examples.[31]

NEW YORK—REAL TIME ENERGY MANAGEMENT (RTEM) PROGRAM

Grid services: generation energy and capacity, contingency reserves, non-wires solutions

The New York State Energy Research and Development Authority (NYSERDA) established this program to improve energy management in commercial (including small- and medium-size businesses, retail, universities, and hospitals), multifamily, and industrial buildings. The program helps meet the state's energy efficiency, carbon, and electrification goals, accommodate retirement of aging peaking power plants, and enables automated demand response services for the grid.

Hardware, software, and systems continuously collect data and use sophisticated analytics to provide visibility into the live operation of energy-consuming and energy-producing equipment and identify opportunities for energy savings and optimizing performance.

The program provides a 30% cost share to encourage building owners to install RTEM systems offered by many qualified vendors. The systems may be integrated into existing building management systems, or wireless sensors and meters can be installed to enable monitoring and analysis. Total funding for the RTEM program is $70 million, with $30 million allocated to date supporting 450 projects (representing about 125 million square feet), delivering an average of 12% to 15% annual energy savings. Participants also may use RTEM systems to reduce on-peak consumption and demand charges. In addition, the systems provide ongoing fault detection and diagnostics, predictive analytics, and information to optimize equipment performance for building occupants.

The RTEM systems can receive and react to demand response signals from grid operators or third parties by using advanced controls and intelligent automation to rapidly shed and shift loads. In support, NYSERDA is developing a Grid-responsive Energy Management program to further investigate the technologies and market structures necessary for buildings to provide demand flexibility in a way that would benefit a highly renewable grid and support electrification of heating and transportation.

Sources: NYSERDA (nd), "Real Time Energy Management (RTEM) Program," https://www.nyserda.ny.gov/All-Programs/Programs/Real-Time-Energy-Management
NYSERDA (nd), "Raising the Bar for Smart Building Solutions," https://www.nyserda.ny.gov/-/media/Files/Programs/RTEM/rtem-solutions.pdf
NYSERDA 2019, https://annualmeeting2019.naseo.org/data/energymeetings/presentations/NYSERDA--RTEM-GEM.pdf

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31 See Neukomm et al. 2019 for a more detailed list.

2.1 Market Adoption of Building Technologies and Systems

Just 12% of commercial buildings smaller than 25,000 ft^2, representing about a third of commercial floor space, had some kind of energy management control system for HVAC as of 2012, compared to more than 70% of U.S. commercial buildings larger than 100,000 ft^2. Further, only 3% of small commercial buildings used energy management control systems for lighting. Innovations are needed that lower the cost and simplify the installation and operation of control systems. Other barriers and challenges to their adoption in commercial buildings include:[32]

- Capability to respond to price signals
- Low-cost control networks and optimization functionality
- Accuracy and access to energy use and end-use performance data for sensors
- Technologies and protocols to track and assess performance
- Interoperability of proprietary or legacy systems with new technologies, services, tools, and DERs.

In the residential sector, thermostat technologies are a bellwether. Berkeley Lab estimates that some 10 million homes, roughly 8%, have connected smart thermostats.[33] Studies focusing on U.S. households with broadband found that 13% owned a smart thermostat in 2017.[34]

2.2 Utility Adoption of Grid Technologies and Systems

Utilities can invest in a variety of advanced grid technologies and systems. Utility-facing initiatives support more efficient and effective operation of T&D systems, including improved reliability and resilience. Customer-facing initiatives support adoption of DERs and access to third-party service providers and markets.[35] Both types of initiatives may facilitate demand flexibility. For example, in the first category, Distributed Energy Resource Management Systems connect and manage the integration of all types of DERs on the grid. As part of an Advanced Distribution Management System, Distributed Energy Resource Management Systems improve situational awareness and help increase distribution system hosting capacity for DERs. Such systems are just beginning to be deployed across the country.

Advanced metering infrastructure (AMI) is an example in the second category. Only about half the nation's electric meters are "advanced," meaning they record usage data at least hourly and provide data at least daily to energy companies (and potentially consumers). AMI enables two-way communication capable of recording and transmitting instantaneous data.[36] While time-varying pricing requires advanced meters, not all demand flexibility strategies require AMI.[37] Where installed, AMI can serve as a communications backbone for utilities to transmit and receive information during demand flexibility events. AMI also facilitates assessments of demand flexibility performance.

2.3 Technical Challenges

Among these technical challenges are cybersecurity, interoperability standards, grid operator visibility into distribution systems and buildings, understanding impacts of multiple DERs interacting with each other, and co-

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[32] Schwartz et al. 2017. Most recent data are for 2012: http://www.eia.gov/consumption/commercial/data/2012/. Data for 2018 are expected to be available starting mid-2020.
[33] Alan Meier, Berkeley Lab, email communication with author, Nov. 22, 2019.
[34] http://www.parksassociates.com/events/smart-energy-summit/media/ses2018-6.
[35] Woolf et al. Forthcoming.
[36] https://www.ferc.gov/legal/staff-reports/2018/DR-AM-Report2018.pdf; http://www.eia.gov/survey/form/eia_861/instructions.pdf.
[37] For example, technical specification ANSI/CTA-2045 facilitates demand response from grid-enabled water heaters. See Bonneville Power Administration's study: https://www.bpa.gov/EE/Technology/demand-response/Pages/CTA2045-DataShare.aspx.

optimizing demand flexibility for the grid and building owners and occupants—all the subject of ongoing research and development. Specifically, for grid-interactive efficient buildings, DOE's Building Technologies Office is funding research in three areas:[38]

- Technology characterization and development
- Valuation and optimization
- Field validation and implementation

2.4 Potential Demand Flexibility Barriers

The following are potential barriers to demand flexibility for programs administered by investor- and publicly owned utilities or state and local governments, or for centrally organized markets operated by RTOs/ISOs.

Program/Market Design and Participation

- **Consumer value proposition not well known**—If utilities, regional grid operators, and state and local agencies do not understand why building owners and occupants might be interested in participating in demand flexibility programs and markets, they may not be designed in a way that attracts significant participation. Understanding the value proposition for various customer segments is key to reaching meaningful aggregations of buildings that provide demand flexibility for grid services.
- **Potential not well characterized**—Assessments of the technical, economic, and achievable potential of demand flexibility (e.g., by market sector, operating mode, and grid services provided) are nascent. Such studies are needed for utility distribution and bulk power system planning, developing utility and state and local demand flexibility programs, and forecasting demand flexibility participation in RTO/ISO markets.
- **Insufficient integration of DSM programs**—Integrated DSM programs deliver customer-centric strategies in a way that integrates measures and technologies to improve their collective performance and penetration; however, they remain the exception. Energy efficiency and demand response programs typically are not well-integrated within a utility. Further, they often are not coordinated with programs for other DERs, such as distributed PV and storage or managed EV charging. Among the regulatory barriers are separate budgets, lack of metrics for evaluating cost-effectiveness of integrated programs, absence of rules for evaluating such programs, and separation of responsibilities.[39]
- **Lack of coordination across programs**—Similarly, programs and markets operated by different entities within a jurisdiction—utilities, RTOs/ISOs, and state and local governments—typically lack coordination. In addition to reduced performance and penetration, this can lead to double-counting and conflicting rules, roles, and responsibilities.
- **Constraints on third-party aggregation**—Demand flexibility must be aggregated across buildings to provide a substantive resource for utilities and markets. Except for very large buildings, third-party aggregators are needed to facilitate participation by building owners and occupants. Some states have laws or regulations that impede third-party aggregation services.

Financial Motivation

- **Split incentives—**Builders may have little incentive to invest in advanced equipment and systems that enable demand flexibility because subsequent owners or tenants will pay the energy bills and reap the benefits. Building owners have similar disincentives when tenants pay these bills.

[38] Neukomm et al. 2019.
[39] Potter et al. 2018.

- **Misaligned compensation mechanisms for consumers**—Retail rate design,[40] program incentives, and market compensation mechanisms for consumers may not be aligned with demand flexibility value to electricity systems. Rate design may have a critical impact on the adoption of demand flexibility,[41] and time-varying rates are not offered in many locales. Except for demand response, program incentives for DERs often ignore time-sensitive value. Compensation from centrally organized markets may not account for locational value of demand flexibility.[42]
- **Misaligned compensation mechanisms for utilities**—Demand flexibility may reduce utility revenue between rate cases, as consumers shift electricity to lower-priced times, and raise utility concerns about recovery of fixed costs for providing electricity service. In addition, utilities lack positive financial incentives to use buildings and DERs as energy assets. Further, demand flexibility may reduce the need for capital investments that provide an opportunity for utilities to earn a rate of return.[43]

Planning and Analysis

- **Deficient economic valuation methods**—Current valuation practices for bulk power system and distribution system planning typically do not consider demand flexibility on a par with traditional solutions.[44]
- **Lack of integration in utility planning processes**—Demand flexibility is not well recognized today in utility planning processes, such as integrated resource planning,[45] distribution system planning,[46] transmission expansion planning, and DSM planning. Further, these planning processes are not well integrated.[47]
- **Inadequate benefit-cost analysis methods**—Traditional approaches for analyzing proposed utility grid investments do not work well for "core," or foundational, components that are necessary for providing the services required of modern grids. Example core components that are applicable to demand flexibility include sensing and measurement, distribution automation, and advanced distribution management systems.[48]
- **Improvements needed for performance metrics and assessment practices**—While metrics and assessment practices can be adapted from demand response programs, enhancements can improve confidence in results for demand flexibility participating in programs and markets. In addition, metrics for state and local programs and policies, such as building energy ratings, building performance requirements and energy efficiency targets, may require changes to better align with demand flexibility and the grid services it can provide.

Other Regulatory Issues

- **Data access and data privacy concerns**—Building owners and occupants, and the third-party service providers they choose, need access to energy consumption data to understand potential benefits and costs of investing in demand flexibility technologies and participating in programs and markets. At the same time, data-sharing between utilities, third-party providers, and customers raises data privacy concerns.
- **Barriers to entry in centrally-organized markets**—While storage will be able to participate in all centrally-organized markets under Federal Energy Regulatory Commission Order 841—as a generator, a load (e.g., "Dispatchable Asset-Related Demand" in ISO-New England), and a frequency regulation resource, not all

[40] Satchwell et al. 2019; Hledik et al. 2016.
[41] Satchwell et al. 2019.
[42] SEE Action Network 2020.
[43] Lowry and Woolf 2016; Lowry et al. 2017.
[44] SEE Action Network 2020.
[45] Kahrl et al. 2016.
[46] Cooke et al. 2018; Homer et al. 2017.
[47] Hadley and Sanstad 2015.
[48] DOE's Modern Distribution Grid; Woolf et al. Forthcoming.

DERs can participate in markets for energy, capacity, and ancillary services, even when they can meet grid service requirements.

Additional barriers are specific to the type of DER providing demand flexibility. For example, a building's participation in demand flexibility programs may be limited by duration and cycling requirements for energy storage. And distributed PV systems face interconnection barriers that other types of DERs do not experience.[49]

2.5 Opportunities to Address Barriers

Toward meeting their own energy-related goals, state and local governments can take actions to address these demand flexibility barriers. Table 3 maps potential barriers to potential actions. The illustrative list that follows describes these actions, based on steps jurisdictions throughout the country have taken over decades to address barriers to DERs.[50]

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[49] Community choice aggregation may pose barriers to demand flexibility programs, as well as opportunities. This topic is beyond the scope of this report.
[50] See NASEO 2019a and 2019b.

Table 3. Mapping Potential Demand Flexibility Barriers to Potential Actions to Address Barriers

Potential Barrier	Potential Actions to Address Barriers									
	Lead by Example	Studies and Pilots	Enhanced Analytical Methods/ Practices	Model Standards and Protocols	Building and Product Programs	Financial Incentives for Utilities	Energy Planning	Building Codes and Appliance Standards	Public Utility Commission Actions	Other State Actions
Consumer value proposition not well known	●	●			●		●		●	
Potential not well characterized	●	●	●				●		●	
Insufficient DSM program integration	●	●	●		●	●	●		●	●
Lack of coordination across programs	●	●			●		●		●	●
Constraints on third-party aggregation									●	●
Split incentives					●			●		
Misaligned compensation for consumers					●		●		●	●
Misaligned compensation for utilities		●				●	●		●	●
Deficient economic valuation methods			●		●	●	●		●	
Lack of integration across utility planning processes							●		●	
Inadequate benefit-cost methods			●				●		●	
Metrics and assessment needs	●	●	●	●						
Data access/data privacy concerns				●					●	●
Barriers to entry in markets		●	●							

1. **Lead by example**—A first step state and local governments can take is to test demand flexibility technologies and approaches for several of their own buildings. Agencies with operational responsibilities for public buildings can lead this effort, in cooperation with the state energy office and other interested departments and stakeholders. As a next step, these agencies can consider establishing performance standards for all publicly owned buildings.

2. **Studies and pilots**—Public utility commissions (PUCs) can explore changes to investor-owned utility DER programs and rate options through pilots (see **text box on Oregon - Portland General Electric Smart Grid Test Bed**), including understanding the value proposition[51] and cost-effective achievable potential, testing new program designs, and acquiring performance data. Commissions also can review retail rate structures for impediments to demand flexibility strategies that are valuable to electric utility systems.

OREGON

Portland General Electric Smart Grid Test Bed
Grid services: generation capacity,
contingency reserves, non-wires solutions

Portland General Electric's (PGE) new project is testing demand flexibility to "…help rethink how we use energy through new technologies, programs and products, while still allowing customers to have control over their comfort settings, use more renewable energy, and keeping it reliable and affordable." Service area-wide, the utility is targeting 69 MW of demand flexibility in summer and 77 MW in winter to fill a 2021 capacity gap identified in its Integrated Resource Plan.

The utility is testing a wide range of DER home technologies, including smart thermostats, heat pump water heaters, EV chargers and batteries. Residential customers served by three distribution substations, representative of PGE's service area, are enrolled automatically in a peak time rebate program and can decide whether to change their energy profile on an event-by-event basis, with day-ahead notice. Customers will earn a rebate of $1 for each kWh in reduced energy consumption during events, compared to their individual usage baseline. The pilot also will test approaches to move customers from rebates to an opt-in direct load control program. Distribution substation-level data will help inform technical achievable potential, scenarios and modeling for DERs, and distribution system planning. A planned second phase of the test bed will further explore DERs as non-wires solutions.

Customer value propositions for demand flexibility are a key part of the pilot. PGE is testing customer drivers such as earning incentives, supporting renewable resources, reducing air pollution, competing with neighbors to reduce peak demand, and donating credits to charity.

For small- and medium-size business customers, PGE is testing direct installation of smart thermostats and plans to add EV charging and storage. The utility also is coordinating with Energy Trust of Oregon on incentives for energy efficiency upgrades and rooftop solar.

Sources: https://www.portlandgeneral.com/our-company/energy-strategy/smart-grid/smart-grid-test-bed
https://edocs.puc.state.or.us/efdocs/UAA/uaa173123.pdf
https://www.portlandgeneral.com/-/media/public/documents/rate-schedules/sched_013.pdf

[51] Understanding consumer value proposition is a primary motivation for Portland General Electric's Smart Grid Test Bed.

3. **Enhanced analytical methods and practices**—Determining the economic value of demand flexibility provides basic information needed to design programs, market rules, and rates that align the economic interest of utility customers with building owners and occupants. Enhancements to current methods and practices are needed to treat demand flexibility on a par with traditional options for meeting distribution and bulk power system needs so that all grid impacts, costs, and benefits to the utility system can be quantified and monetized. Enhanced practices also would improve retrospective performance assessments for demand flexibility, building on longstanding experience with demand response programs.[52] Other areas for improved analytical methods or practices include demand flexibility potential studies, integration and coordination of DSM programs, benefit-cost methods for core grid modernization investments, and participation models for centrally-organized wholesale electricity markets.

4. **Model standards and protocols**—States and utilities can help develop and further adoption of standards and protocols to ensure data access, protect data privacy, and enable communication interoperability. Equipment, systems, and controls must be cybersecure, maintaining end-to-end data privacy and protection against unauthorized access, while allowing secure communication of information. Interoperability also is required to effectively and securely exchange data and control signals among connected devices and control systems and share information in real time between buildings and grid operators.

5. **Programs for buildings and products**—State energy offices can begin to incorporate demand flexibility and grid-interactive functionality into technical assistance and incentive programs they offer for privately owned residential and commercial buildings. State and local agencies also can adopt national standards, such as ENERGY STAR®, for appliances, equipment, buildings, and smart home energy management systems. Other voluntary programs, such as certification, rating, and labeling for buildings and products, can begin adding grid-interactive features and functionality.

6. **Financial incentives for utilities**—Revenue decoupling is a regulatory tool that breaks the link between utility revenues and energy sales. Specifically, it is a price adjustment mechanism that ensures the regulated utility recovers its allowed revenue for fixed costs, as determined by the state public utility commission, regardless of the utility's actual energy sales during the specified period. Under a typical revenue-per-customer allowance, decoupling tends to result in small annual increases in revenues. Whether prices increase or decrease under decoupling depends on whether average energy consumption by customers is declining or rising as the number of customers changes.[53] In addition, positive financial incentives for utilities can help achieve demand flexibility objectives:[54]

   - Performance incentive mechanisms are metrics, targets, and financial incentives (rewards, penalties, or both) designed to strengthen performance incentives in targeted areas, such as demand flexibility. For example, some states provide an opportunity for utilities and third-party program administrators to earn financial incentives for achieving or exceeding specified peak demand savings targets for energy efficiency programs. The most common stand-alone approach to performance incentive mechanisms for DERs, shared savings, requires an estimate of realized energy and capacity savings and the monetary benefits of these savings (i.e., the avoided costs).
   - Multiyear rate plans are a common approach to performance-based regulation. They feature a moratorium on utility rate cases for several years, an attrition relief mechanism,[55] and performance incentive mechanisms.

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[52] See section 3 in this report, SEE Action Network 2020, and SEE Action Network forthcoming.

[53] Revenue decoupling should include consumer protections such as requisite investments in energy efficiency and demand flexibility programs, a requirement to file full rate cases within established time periods to review any changes in the utility's cost structure and risk profile, and limiting any rate increases (prices also may go lower) to a fixed percentage.

[54] For details, see Lowry and Woolf 2016; Lowry et al. 2017.

[55] An attrition relief mechanism automatically adjusts rates or revenues between rate cases to address cost pressures without closely tracking the utility's own cost. Methods used to design attrition relief mechanisms include forecasts and indexation to quantifiable cost drivers, such as inflation and customer growth.

7. **Energy planning—**State energy offices can include demand flexibility in their statewide energy plans. Utilities can integrate demand flexibility across utility resource, transmission, and distribution system planning.[56] Regional grid operators can include demand flexibility in load forecasting and plan for changes in market participation.

8. **Building energy codes and appliance standards**—Codes and standards address common barriers to energy-efficient building design and appliances, such as split incentives and higher upfront costs. Agencies that set codes and standards can consider demand flexibility options that provide benefits for building owners and occupants. For example, California integrated demand flexibility into its building energy code (see **text box on California Title 24**) and recently adopted standards for cost-effective deployment of flexible demand technologies for appliances.[57] These agencies also can establish "demand flexibility-ready" requirements,[58] conduct time-dependent valuation for cost-effectiveness assessments,[59] and consider new load management provisions.

CALIFORNIA

Residential Building Energy Code (Title 24)

Grid services: generation capacity, contingency reserves, avoid renewable generation curtailment, non-wires solutions

California's 2019 standards for newly constructed low-rise residential buildings require solar PV systems sized to offset the annual electricity consumption of a highly efficient dual-fuel home—typically a 2.8-kW system for a single-family dwelling. Demand flexibility code provisions allow builders to use energy efficiency, demand response, thermal storage, and energy storage technologies to reduce the size of the solar PV system by 40% or more, while maximizing benefits to homeowners, the grid, and the environment. The reduction is based on time-dependent valuation of modeled energy consumption of the building, accounting for generation from the solar PV system and the building's demand flexibility measures. Communication and control technology for measures such as battery storage and end uses like HVAC and water heating shift electricity use across hours of the day, both to decrease energy use on-peak and increase energy use off-peak.

Compliance incentives are available for demand response and "grid harmonization" measures, such as precooling, thermal storage, and battery storage systems. "These complementary technologies maximize self-utilization of PV electricity generated on-site and minimize hourly exports back to the grid, and as they come into common use, they will benefit distribution systems and enhance local reliability."

Sources:
https://ww2.energy.ca.gov/title24/2019standards/documents/Title24_2019_Standards_detailed_faq.pdf

https://ww2.energy.ca.gov/title24/2019standards/documents/Title24_2019_Standards_detailed_faq.pdf

[56] For details, see SEE Action Network 2020.
[57] California Senate Bill 49 (2019), https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49.
[58] Equipment and systems that are capable of varying their electricity demand in response to signals from building operators, aggregators, or grid operators through some form of automation, from simple on/off controls to sophisticated control algorithms with feedback.
[59] See Mims Frick and Schwartz 2019.

9. **PUC proceedings**—Commissions can specify consideration of demand flexibility in utility planning processes, enable participation of demand flexibility in utility procurements for grid services, authorize pilot programs, review retail rate structures, and consider utility financial incentives. Commissions can convene stakeholders to discuss ways to enable demand flexibility using informal workshops, a formal proceeding dedicated to the wide range of related issues and processes involving all regulated utilities, or as they address relevant filings by individual utilities over time.

10. **Other state actions**—Executive branch initiatives can engage all relevant state agencies in supporting demand flexibility, articulate state goals that demand flexibility can support, set demand flexibility targets, establish a forum to consider potential state targets for action, and lay the groundwork for a state action plan. In some cases, state legislative action may be required to remove barriers. For example, such action may enable third-party aggregation of demand flexibility in buildings (in a manner that preserves consumer protections), provide data access for consumers and their designated third parties, adopt established protocols for data privacy and communication interoperability, and authorize state agency actions that support demand flexibility.[60]

Tapping these opportunities, state and local governments can advance demand flexibility in a number of ways, supported by building owners, utilities, and regional grid operators (Table 4 in section 4 and Appendix C). Utilities, regional grid operators, consumer groups, building owners' organizations, and other stakeholders can support these activities.

[60] Navigant Consulting, Inc. 2015; Mims et al. 2017; DOE 2016.

3. Assessing Value and Performance of Demand Flexibility[61]

3.1 Assessing Value for Electric Utility Systems, Customers, and Society

Establishing the value of demand flexibility for electric utility systems provides information state and local governments can use to implement complementary programs and policies and, through oversight functions, align utility program incentives and retail rate structures with that value. The costs and benefits for the "utility system" are those impacts on the entire system used to provide electricity services to retail electricity customers—generation and T&D—regardless of whether the utility is vertically integrated or a distribution company. These benefits (and costs) are the foundation on which other benefits can be built.

Demand flexibility also directly impacts participating customers and provides societal benefits that are external to the utility system. Understanding impacts for consumers and society is part of the broad cost-benefit framework for valuing DERs and the demand flexibility that buildings can provide (Figure 8).

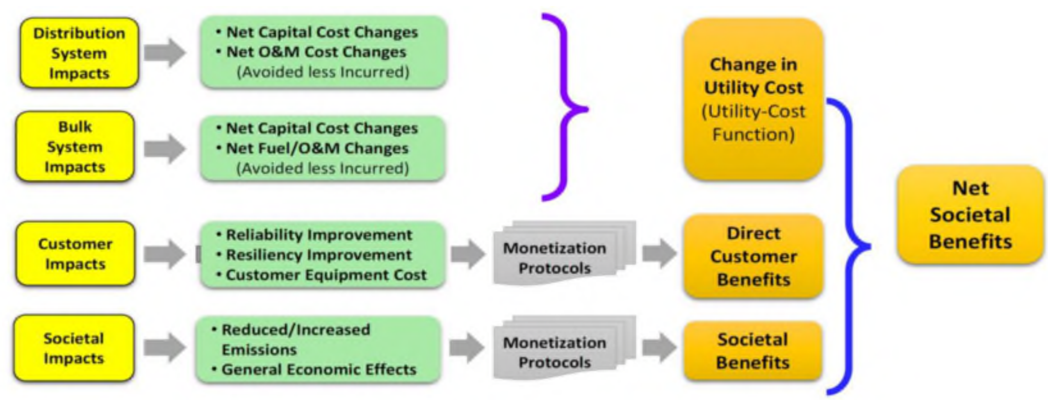

Figure 8. Benefit-Cost Framework[62]

The Electric Power Research Institute's methodology for evaluating benefits and costs associated with DERs includes changes in capital and O&M costs for distribution systems and bulk power systems—for example, impacts on wholesale power generation and transmission (top of chart) and impacts on electric utility customers and societal impacts that are external to the utility system (bottom of chart).

Value to electric utility systems. The value of a resource often is estimated using the avoided cost—the cost of acquiring the next least expensive alternative resource that provides comparable services. To address demand flexibility value requires enhancements to traditional methods, particularly to address:

- *Impacts across generation and T&D systems*—The valuation of demand flexibility should at a minimum establish its economic value to the utility system, accounting for all substantive and reasonably quantifiable generation and T&D benefits, including the value of risk reduction and increased reliability and resilience, and costs.
- *Time- and location-dependent value*—The value of demand flexibility for adjusting loads across different timescales, in a manner optimized for the grid as well as building owners and occupants, is dependent on the specific timing of when the service is delivered. Locational-specific value also is critical, as a large component of the economic value of demand flexibility stems from deferring or avoiding investments in additional distribution or transmission system capacity.[63]

[61] SEE Action Network 2020; SEE Action Network forthcoming.
[62] Electric Power Research Institute 2015.
[63] Mims Frick et al. forthcoming.

- *Interactions of DERs with each other and the grid*[64]—If two or more types of DERs are deployed in combination to provide demand flexibility, the load shape impacts on generation and T&D capacity needs should reasonably reflect the interaction of these resources with each other. Changes in these interactions through time also should be considered. Many supply-side resources have limited dispatchability (e.g., wind, solar, nuclear). Demand flexibility helps integrate them.
- *Variations in timing and amount of grid services DERs provide over their expected lifetimes*—Potential variations in the timing and amount of the electric grid service provided by demand flexibility over the expected lives of the DERs should be taken into account.

Value to consumers and society. Demand flexibility from buildings can provide more than the electric grid services described earlier in this report and in Appendix A. Additional energy-related benefits may include greater energy resilience. Further, demand flexibility may provide higher value than traditional electricity solutions as a result of potential additional net benefits for consumers and society.

Consumers overall benefit from grid services provided by buildings that are part of the portfolio of resources that provide safe, reliable, and resilient electricity service at least cost and risk. Participants in demand flexibility programs are positioned to reap additional benefits, including lower utility bills and in some cases payments for grid services, such as utility rebates or payments from third parties that aggregate resources for utilities or centrally organized wholesale electricity markets.

Other potential benefits for consumers and society include:[65]

- Improved equipment functionality, performance, and life; higher building value; and greater ease of selling building
- Better economic well-being, including fewer bill-related calls to the utility and a greater sense of control
- Higher satisfaction, including improved self-sufficiency and contribution to addressing environmental and other societal concerns
- Reduced consumption of water resources and generation of wastewater
- Economic development and jobs
- Greater energy security
- Environmental benefits
- Improved public health.

For example, demand flexibility strategies for homeowners and renters increase choices for using and producing electricity, and automation makes it easier to manage household energy costs. For businesses, demand flexibility assets can improve resilience to power outages and help meet sustainability and deferred maintenance goals. Ultimately, what is of interest is *net* benefits to consumers and society, after considering costs.

3.2 Assessing Performance

Retrospective assessments provide information on historic, verified performance to document whether demand flexibility strategies actually delivered the expected benefits. Building owners and occupants can use this information to understand and improve demand flexibility performance and better control their electricity bills. In the context of utility programs and wholesale electricity markets, these assessments form the basis for compensation under tariffs and contracts, as well as impact evaluations for time-varying retail rates. Retrospective

[64] Mims Frick et al. 2018.
[65] Adapted from National Efficiency Screening Project's Database of State Efficiency Screening Practices, https://nationalefficiencyscreening.org/state-database-dsesp/; Sutter et al. forthcoming; U.S. Environmental Protection Agency 2018.

assessments also are critical to assessing cost-effectiveness, supporting electricity system planning (including DER potential studies) and validating demand flexibility value (Figure 9).

Assessing demand flexibility performance of an individual building is the starting point for determining performance of aggregations of buildings. In most cases, demand flexibility must be aggregated across a number of buildings to reach a sufficient magnitude to serve as a meaningful resource for generation and T&D systems.

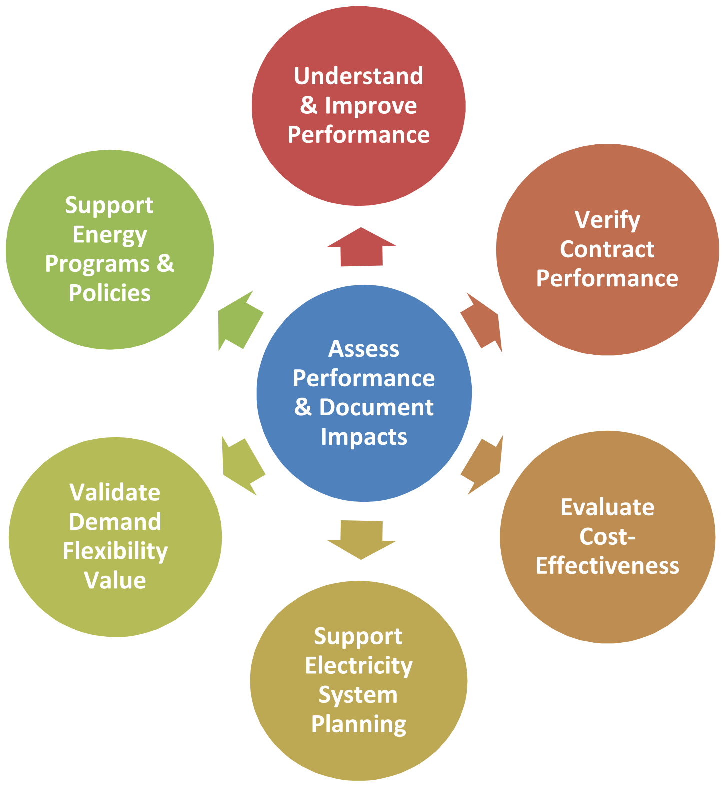

Figure 9. Multiple Values for Demand Flexibility Performance Assessments
Performance assessments are integral to planning and implementing demand flexibility.

For energy efficiency, load shed, and load shift flexibility modes, the primary performance metrics for assessing performance currently are defined as quantified changes in the power draw (demand, kW) of a building as compared to a power draw baseline—the business as usual scenarios or load shapes from which impacts are assessed. Utilities and regional grid operators also are interested in assessments that indicate whether actual load matched predicted and desired load shapes. This could lead to new metrics that do not rely on historic baselines.

Assessments can build on existing approaches for performance verification, such as measurement and verification protocols for demand response utility programs and forward capacity markets, and impact evaluations of time-varying retail rates. Existing infrastructure, such as building energy management systems and utility AMI deployments, also facilitate documentation of impacts. Other relevant practices that may be updated include load measurement protocols, data access and privacy provisions, cybersecurity requirements, data quality needs, and use of independent third parties to conduct performance assessments.

At the same time, new assessment strategies may be needed given integration of multiple DERs and multiple flexibility modes, potential continuous demand flexibility, and refined demand flexibility metrics. For example, demand response programs today typically call for infrequent changes in building loads—perhaps only once a day for a few hours or several times a season. In the future, demand flexibility will increasingly include load modulation at a time scale of a few minutes or even seconds to subseconds. These new demand flexibility attributes will likely require new baseline constructs, integrated building system interoperability and communication protocols, and new analytical tools for assessments.

4. Looking Forward

Demand flexibility from grid-interactive efficient buildings is an emerging area. This report (including Appendix B) highlights several examples of utility, state, and local programs that are planning, piloting, or demonstrating benefits from demand flexibility from grid-interactive efficient buildings. State and local governments can address barriers to demand flexibility with their partners and stakeholders (see Table 4 and Appendix C) to help cost-effectively address several grid challenges, including growth in peak demand, higher levels of variable energy generation, and increasing electrification of transportation and other new loads.

Table 4. Typical DER Actions Taken by Decision Makers Applied to Demand Flexibility

	State and Local Governments[66]	Utility Regulators	Utilities[67]	Regional Grid Operators	Building Owners
1. Gather information and identify opportunities	Articulate state or local goals that demand flexibility can support Catalog existing pilots, standards, programs, procurements, policies, and regulations that address demand flexibility Establish a statewide (or municipal or county) forum to consider potential state and local targets for action	Engage with regulated utilities and stakeholders to identify benefits and opportunities related to demand flexibility for utility programs, planning, procurements, and operations Identify DER requirements that may need updating	Assess achievable potential of demand flexibility for residential and commercial buildings and most cost-effective opportunities Conduct pilot projects Build on results to advance use of demand flexibility	Engage with states, utilities, DER aggregators, and other stakeholders to identify DER participation requirements and compensation mechanisms that may need updating	Participate in pilot projects and share best practices
2. Develop and implement strategies to integrate demand flexibility	Develop a roadmap with stakeholders to advance demand flexibility in support of state and local goals Conduct outreach and education about opportunities and benefits	Provide direction on utility cost recovery and compensation mechanisms for participating customers and third-party service providers Enable incentives and rate designs to facilitate use of demand flexibility for utility programs, procurements, and time-varying rate options	Incorporate demand flexibility in programs, planning, procurements, and operations Test incentive and rate design approaches	Update participation requirements and compensation methods	Participate in roadmap development (e.g., through building owners' organizations)

[66] State energy offices may perform many of these roles at the state level. Other state agencies and local governments that have policy, regulatory, or program responsibilities (e.g., economic development, building codes, environment, financing) or that operate buildings and facilities (e.g., general services, K-12 and higher education, public hospitals) also may have roles. Public utility commissions are addressed separately in the next column. Overcoming some barriers may require state legislative action.
[67] Both investor-owned and publicly owned utilities.

	State and Local Governments	Utility Regulators	Utilities	Regional Grid Operators	Building Owners
3. Accelerate adoption	Regularly assess and report on progress toward metrics identified in roadmap Identify strategies to overcome remaining barriers and ways to improve demand flexibility implementation to achieve state or local goals Continue to support sharing of project and program results and best practices and provide recognition for outstanding achievements	Provide guidance for enhanced economic valuation methods Establish requirements for robust and cost-effective retrospective assessments of demand flexibility performance Continue to assess barriers and opportunities	Implement enhanced economic valuation methods Conduct retrospective assessments consistent with regulatory guidance	Report on demand flexibility participation in regional markets and assess impact on cost of grid services procured Continue to assess barriers and opportunities	Participate in forums discussing ways to improve access to utility programs and regional markets for demand flexibility from buildings

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Appendix A: Grid Services That Demand Flexibility in Buildings Can Provide[68]

Demand Side Management Strategies	Grid Services	Description of Building Change	Key Characteristics	
Efficiency	*Generation: Energy* *Generation: Capacity* *T&D: Non-Wires Solutions*	Persistent reduction in load. Interval data may be needed for M&V purposes. This is not a dispatchable service.	Duration	Continuous
			Load Change	Long term decrease
			Response Time	N/A
			Event Frequency	Lifetime of equipment
Shed Load	*Contingency Reserves*	Load reduction for a short time to make up for a shortfall in generation.	Duration	Up to 1 hr
			Load Change	Short term decrease
			Response Time	<15 min
			Event Frequency	20 times per year
	Generation: Energy *Generation: Capacity* *T&D: Non-Wires Solutions*	Load reduction during peak periods in response to grid constraints or based on time-of-use (TOU) pricing structures.	Duration	2 to 4 hrs
			Load Change	Short term decrease
			Response Time	30 min to 2 hrs
			Event Frequency	<100 hrs per yr/seasonal
Shift Load	*Generation: Capacity* *T&D: Non-Wires Solutions*	Load shifting from peak to off-peak periods in response to grid constraints or based on TOU pricing structures.	Duration	2 to 4 hrs
			Load Change	Short term shift
			Response Time	<1 hour
			Event Frequency	<100 hrs per yr/seasonal
	Contingency Reserves	Load shift for a short time to make up for a shortfall in generation.	Duration	Up to 1 hr
			Load Change	Short term shift
			Response Time	<15 min
			Event Frequency	20 times per year
	Avoid Renewable Curtailment	Load shifting to increase energy consumption at times of excess renewable generation output. This is not a dispatchable service but can be reflected through TOU pricing.	Duration	2 to 4 hrs
			Load Change	Short term shift
			Response Time	N/A
			Event Frequency	Daily
Modulate Load	*Frequency Regulation*	Load modulation in real time to closely follow grid signals. Advanced telemetry is required for output signal transmission to grid operator; must also be able to receive automatic control signal.	Duration	Seconds to minutes
			Load Change	Rapid increase/decrease
			Response Time	<1 min
			Event Frequency	Continuous
	Voltage Support		Duration	Sub-seconds to seconds
			Load Change	Rapid increase/decrease
			Response Time	Sub-seconds to seconds
			Event Frequency	Continuous
	Ramping	Load modulation to offset short term variable renewable generation output changes.	Duration	Seconds to minutes
			Load Change	Rapid increase/decrease
			Response Time	Seconds to minutes
			Event Frequency	Continuous
Generate	*Ramping*	Distributed generation of electricity to dispatch to the grid in response to grid signals. This requires a generator or battery and controls.	Duration	Seconds to minutes
			Load Change	Rapid dispatch
			Response Time	Seconds to minutes
			Event Frequency	Daily
	Generation: Energy *Generation: Capacity* *T&D: Non-Wires Solutions*		Duration	2 to 4 hrs
			Load Change	Dispatch/negative load
			Response Time	<1 hour
			Event Frequency	<100 hrs per yr/seasonal
	Generation: Energy *Generation: Capacity* *T&D: Non-Wires Solutions*	Distributed generation of electricity for use onsite and, when available, feeding excess electricity to the grid. This is not a dispatchable service, though metered data is needed.	Duration	Entire generation period
			Load Change	Reduction/negative load
			Response Time	N/A
			Event Frequency	Daily

Note: Response time is the amount of time between receiving a signal from the utility or regional grid operator and the building asset responding to change the load. Duration is the length of time that the load change occurs.

[68] Neukomm et al. 2019.

Appendix B: Other Examples of Utility Programs Integrating Demand-Side Management Approaches

These utility programs supplement the examples interspersed throughout the report. See Table 2 for a guide to the utility, state, and local programs highlighted in the report.

Texas—Austin Energy Power PartnerSM

Grid services: generation capacity, contingency reserves

Austin Energy offers residential, multifamily, and small commercial customers the Power PartnerSM Thermostats program to provide demand flexibility to help meet bulk power system capacity needs through demand response. The program provides rebates and incentives for smart thermostats that control air conditioning systems in buildings.

The utility uses public networks and a demand response automation server to communicate demand response events. While Austin Energy has offered demand response programs since the 1990s, it primarily used one-way radio frequency communication systems until 2013 when it began the Power PartnerSM program. For larger commercial customers, a move to OpenADR through the Load Cooperative program increased response to event calls by more than four times compared to manual demand response. Approximately 65 facilities in Austin Energy's service area currently receive OpenADR signals.

The program provides customers a $25 energy efficiency rebate for each smart thermostat they install in their existing home or commercial building. (The local energy code requires smart thermostats for new construction of single- and multifamily dwellings.) Over 30 types of thermostats are eligible for the program. Austin Energy offers an additional $85 incentive for each approved, Wi-Fi-connected thermostat that enrolls in the demand response program.*

**Commercial customers can receive Power PartnerSM rebates unless they also participate in the Load Co-op program. If a commercial customer uses OpenADR in the Load Co-op program, they are eligible for $1.45/kWh saved during curtailment events.*

Sources: https://savings.austinenergy.com/rebates/residential/offerings/cooling-and-heating/pp-thermostat
https://www.peakload.org/AustinAwardDR
https://savings.austinenergy.com/rebates/commercial/offerings/load-management/load-co-op

Vermont—Green Mountain Power, Bring Your Own Device

Grid services: generation capacity, contingency reserves, avoided renewable curtailment, non-wires solutions, voltage support

Green Mountain Power provides incentives for allowing the utility to access energy stored at customer sites through a variety of technologies. The utility taps the stored energy during peak demand hours to help meet bulk power system capacity needs, instead of purchasing more expensive power. The program provides incentives for participants, lowers costs for all customers (since the utility needs to acquire less power during times of peak demand), and is designed to provide demand flexibility in places where it is most needed—in locations with distribution system constraints.

Energy storage units enrolled in the program earn $850 per kW. The program takes steps so customers have the reliability they need. For example, if a weather event is expected to cause outages in the area, the utility adjusts its use of the battery to ensure it has stored energy. Participants with an EV charger can receive a $10 per month bill credit.* Customers who live in areas with distribution system constraints are eligible for an additional $150 incentive for adding a battery to their existing solar PV system. Water heaters with tanks that store thermal energy also are eligible for the program. The program is capped at 2 MW (about 600 customers).

Battery owners may opt for bill credits instead of an upfront payment. The battery must be enrolled in the program for 10 years.

Sources: https://greenmountainpower.com/bring-your-own-device/
https://greenmountainpower.com/news/gmp-offers-new-bring-device-program-cut-energy-peaks/

Michigan—Consumers Energy, Swartz Creek Energy Savers Club

Grid service: Non-wires solutions

Consumers Energy developed the Energy Savers Club program to test the efficacy of using non-wires solutions to reduce load at the Swartz Creek substation. Due to increases in load growth, the substation was experiencing high peak loadings. There was time to explore deferring the substation upgrade using non-wires solutions.

To reduce load requirements below 80% of maximum summer capacity (reduce peak load by 1.4 MW by 2018 and 1.6 MW by 2019)—and potentially defer a $1.1 million infrastructure investment, saving customers money—the utility turned to ramping up participation in their energy efficiency and demand response programs in the area served by the distribution substation.

The Swartz Creek Energy Savers Club was a uniquely branded marketing campaign in the target area to connect: (1) C&I customers to existing energy efficiency programs and (2) residential customers to existing energy efficiency and demand response programs (AC Peak Cycling and time-varying rates). The largest savings came from commercial lighting efficiency measures and residential demand response. The pilot tested the role that energy efficiency and demand response programs can play—as potential lower-cost solutions—in managing load and deferring distribution capacity-related investments when targeting specific capacity-constrained geographies.

Sources: Consumers Energy Electric Distribution Infrastructure Investment Plan, April 13, 2018.
Chew, Brenda et al. *Non-Wires Alternatives: Case Studies From Leading U.S. Projects*. Smart Electric Power Alliance, Peak Load Management Alliance (PLMA), and E4TheFuture. November 2018.
Luoma, Mark, and Steve Fine. *Consumers Energy*. "Non-Wires Alternatives Lessons and Insights from the Front Lines," presentation for PLMA, Nov. 14, 2017.

California—SMUD PowerDirect® AutoDR program

Grid services: generation capacity, contingency reserves, ramping

Sacramento Municipal Utility District (SMUD) has offered its PowerDirect® AutoDR program for C&I customers since 2013.* When the utility needs bulk power system capacity, the program uses automated demand response (AutoDR) to provide reliable, predictable, and sustainable load reduction during the summer. A demand response management system communicates with an AutoDR controller at each participating facility or to an aggregator that manages the control strategy and signal communication to its customers.

During a peak event, the utility signals that a demand response event is initiating. The AutoDR controller at each building, or the aggregator, responds accordingly. The controller works with the building's lighting and HVAC systems to provide demand flexibility, communicating with the utility system every few minutes. Using AutoDR allows for automated notification, dispatch, and settlement. Participants are able to set their own parameters and strategy for how they will shed load during a peak event. The program is typically used about 10 times per year. There is no limit to the number of events that can be called lasting two hours or less. Events over two hours are limited to 12 per season. Participants receive a minimum 30-minute advance notice before the event begins.

Participants can receive $5 per kW per month during the summer if they achieve at least half of their average load reduction across event hours. In addition to the performance incentive, SMUD also provides technical assistance and technology incentives for participants.

**A 2002 SMUD pilot PowerDirect® program was the forerunner to the current program.*

Sources: https://aceee.org/files/proceedings/2014/data/papers/3-420.pdf
https://drrc.lbl.gov/openadr
https://www.smud.org/en/Business-Solutions-and-Rebates/PowerDirect-Technology

California—Pacific Gas & Electric, Home Energy Optimization

Grid services: generation capacity, avoid renewable curtailment, non-wires solutions

Pacific Gas and Electric's Home Energy Optimization program uses innovative technologies to optimize participants' energy use and help meet bulk power system capacity needs through demand flexibility. Under the program, customers buy a smart thermostat for their home, and Pacific Gas & Electric installs it at no charge. The utility also provides free air-conditioning system tune-ups and other energy-saving measures at no charge.

Participants also are eligible for up to $2,000 worth of incentives for energy efficiency measures (pipe insulation, a power strip, LED bulbs, and sink aerators), as well as additional smart technologies for energy management at no charge. These include a weather optimization protocol (software that adjusts the thermostat according to weather in the participant's neighborhood), a smart water heater controller that customizes heating based on the participant's preferences, a diagnostic detection device for HVAC systems that provides notifications of potential repair needs, and temperature control valves that save hot water by turning off water flow once it reaches a target temperature.

Source: https://www.homeenergyoptimization.com/get

New York—Consolidated Edison and Orange & Rockland Smart Home Rate

Grid services: generation capacity, contingency reserves

A demonstration project by Consolidated Edison and Orange & Rockland utilities, the Smart Home Rate, is examining how tariff rate structures can use demand flexibility to optimize value for customers and grid services.

The opt-in program offers two special rate structures. Both include time-varying energy supply charges (based on day-ahead, hourly locational marginal prices set by the New York Independent System Operator) and critical peak event charges. Demand charges for Rate I are based on the customer's peak demand during each day's designated peak period. Rate II participants "subscribe" for a specified number of kilowatts and are charged an overage rate for any incremental demand during the event period.* The utility notifies all program participants the day before a generation, transmission, or distribution peak event occurs.

The program also offers participants two technology tracks. Track 1 automates central air-conditioning loads with price-responsive home energy automation technology. These participants may opt into either of the two rate structures.

Track 2 automates home battery systems coupled with solar PV systems. These participants may take part only in Rate I but are eligible for a number of credits for exporting power to the grid during events.

**Participants can choose the default level calculated by the utility, or 75% or 125% of the default level.*

Sources: ConEd, O&R. (Jan. 31, 2019). REV Demonstration Project: Smart Home Rate, 2018 4Q Quarterly Progress Report.
NY PSC. (Feb. 7, 2019). Case 18-E-O548 and Case 18-E-0549. Order Approving Tariff Amendments with Modifications.

Appendix C: Detailed List of Actions to Advance Demand Flexibility

	Who can take action?							
	Gov. Office	PUC	SEO	Other Agencies*	City/County	Utilities	RTO/ISO	Bldg. Owners**
1. Gather Information and Identify Opportunities								
Consider how demand flexibility can support goals								
• Articulate ways demand flexibility can help achieve energy-related goals (e.g., resilience and reliability, energy affordability, emissions, energy efficiency, integrating variable renewable generation, electrification, energy security, grid modernization) and other aims (e.g., economic development, critical infrastructure)	●	●	●	●	●	●	●	●
• Establish team to consider how demand flexibility can contribute to achieving these goals	●	●	●	●	●	●	●	●
Inventory options and select opportunities for early action								
• Catalog existing pilots, standards, programs, procurements, policies, and regulations that address demand flexibility		●	●	●	●	●	●	●
• Consider ways to further integrate demand flexibility in these areas (e.g., lead by example, building operator training, energy savings performance contracting, benchmarking and transparency, DER incentives, smart cities, performance standards for existing buildings, state building energy codes and appliance standards)	●	●	●	●	●	●	●	●
• Identify planning processes that can address demand flexibility goals (e.g., integrated resource plans, efficiency and other DER plans, and plans for distribution systems, transmission expansion, grid modernization, transportation electrification, resilience, energy security) and initial integration steps		●	●	●	●	●		
• Identify DER requirements that may need updating (e.g., revising energy efficiency resource standards to also target peak demand savings, modernizing demand response requirements to better integrate variable renewable generation and EVs, requirements for participating in electricity markets)	●	●	●	●	●	●	●	
Participate in pilot projects and share best practices								
• Identify opportunities to collaborate on test beds for individual buildings, campuses, and commercial developments to gain experience, validate demand flexibility performance, and demonstrate value to the utility system, and building owners and operators		●	●	●	●	●		●
• Conduct pilots for public buildings and campuses to test demand flexibility technologies and microgrids		●	●	●	●	●		●
• Test approaches for hard to reach audiences, including low-income households and small and medium-size commercial buildings		●	●	●	●	●		●
• Share results across the jurisdiction and in regional and national forums		●	●	●	●	●		●

**For example, state departments of general services, codes, environment, economic development, and transportation and financing authorities.*

***Best opportunities for owners and operators of privately owned buildings to support state and local activities.*

	Who can take action?							
	Gov. Office	PUC	SEO	Other Agencies	City/County	Utilities	RTO/ISO	Bldg. Owners
2. Develop and Implement Strategies to Integrate Demand Flexibility								
Develop a roadmap to advance demand flexibility								
• Engage key stakeholders (e.g., third-party program administrators, DER service providers, DER aggregators, contractors, consumer representatives, trade associations for building owners and operators, energy service companies) and use public meetings to discuss strategies	●	●	●	●	●	●	●	●
• Establish principles (e.g., related to cost-effectiveness, consumer and utility system benefits, equity, resilience)	●	●	●	●	●	●		
• Create a comprehensive and collaborative approach with steps to advance demand flexibility through programs, planning processes, standards, policies, and regulations (e.g., through a Governor's executive order, memorandum of understanding across agencies, multistate partnership)	●	●	●	●	●	●	●	
• Estimate benefits and costs to determine cost-effective achievable potential of demand flexibility for residential and commercial buildings and best opportunities for action		●	●	●	●	●	●	●
• Make a public commitment toward achieving this potential with specific multiyear targets	●	●	●	●	●	●		
• Develop interim and long-term metrics for measuring progress	●	●	●	●	●	●	●	
• Update roadmap on a regular schedule (e.g., every three years)	●	●	●	●	●	●	●	●
Develop mechanisms to allow building owners, operators, and occupants to earn compensation for providing grid services								
• Establish multiyear funding assurances for utility programs, and establish payment methods for DER aggregators and customers		●				●		●
• Consider performance-based incentives for utilities to encourage use of buildings as energy assets toward meeting generation and delivery needs		●				●		●
• Review retail electric rates for embedded incentives and disincentives for demand flexibility in residential and commercial buildings		●				●		●
• Work across states to encourage wholesale electricity markets to enable buildings to provide a broader suite of grid services by updating participation requirements and compensation methods		●	●				●	●
Conduct outreach and education about opportunities and benefits								
• Partner with utilities, utility consumer groups, energy services companies, DER aggregators, building owner and management organizations, trade associations, and other stakeholders to develop and disseminate educational materials		●	●	●	●	●	●	●
• Create user-friendly, online resources such as how-to guides and establish online forums that answer common questions			●	●	●	●	●	●
• Organize webinars and in-person trainings with utilities and stakeholder groups			●	●	●	●	●	●

	Who can take action?							
	Gov. Office	PUC	SEO	Other Agencies	City/County	Utilities	RTO/ISO	Bldg. Owners
3. Accelerate Adoption								
Assess and remove barriers to advancing demand flexibility in buildings for grid services*								
• Technical (e.g., requisite building technologies and utility systems, cybersecurity, lack of integrated design and system approaches)		●	●	●	●	●	●	●
• Financial (e.g., cost-effectiveness, inadequate compensation through utilities or markets, upfront cost)	●	●	●	●	●	●	●	●
• Regulatory, market and other institutional barriers (e.g., restrictions on DER aggregation and participation, lack of compensation mechanisms, data access provisions and data privacy concerns, siloed DER programs, procurement provisions)	●	●	●	●	●	●	●	●
• Other (e.g., split incentives for building owners and tenants, lack of motivation and energy focus for building operators, workforce training needs)	●	●	●	●	●	●	●	●
• Determine which barriers are critical to address and develop strategies to overcome them	●	●	●	●	●	●	●	●
Update economic valuation methods for DERs as energy assets for utility programs, plans and procurements to address:**								
• All economic impacts for the electric utility system across all asset types (generation, T&D), including value of risk reduction and increased reliability and resilience		●				●		
• Time-sensitive economic value of savings		●				●		
• Locational economic value of savings for T&D systems		●				●		
• Interaction between DERs when deployed collectively (e.g., combined impact of energy efficiency and demand response, or demand response with and without storage)		●				●		
• Interaction between DERs and existing and future grid resources supplying comparable services		●				●		
• Potential variations in the timing and amount of grid services that DERs provide over their expected life		●				●		
Establish practices for robust and cost-effective assessments of demand flexibility performance for utility programs and electricity markets**								
• Catalog existing foundational approaches for determining demand flexibility impacts (e.g., for demand response)		●	●	●	●	●	●	
• Establish new assessment strategies for determining the quantity, quality, and value of grid services provided by integrated DERs, multiple flexibility modes, and potential continuous demand flexibility (e.g., data collection and validation protocols, system interoperability, baseline definitions, analytical methods, cybersecurity, and privacy)		●	●	●	●	●	●	
• Use assessment results to further optimize demand flexibility to provide grid services		●	●	●	●	●	●	●
• Expand implementation of building energy management systems and AMI with real-time metering capability and built-in, two-way		●	●	●	●	●		●

communication capable of recording and transmitting instantaneous data								
• Update performance metrics consistent with grid services needed by utilities and centrally-organized wholesale electricity markets		●	●		●	●	●	
• Update building service impact metrics (e.g., affordability, comfort, and indoor air quality) and strategies to assess them			●	●	●	●		
Regularly assess and report on progress								
• Track and report to stakeholders annually on metrics identified in the roadmap		●	●	●	●	●	●	
• Identify new opportunities to improve demand flexibility implementation and performance and update the roadmap		●	●	●	●	●	●	●
• Use a variety of channels to share information, such as presentations at established events, social media, and online dashboards and maps		●	●	●	●	●	●	●
• Provide recognition for building owners and operators, government agencies, utilities, and regional grid operators for outstanding projects and programs that advance demand flexibility	●	●	●	●	●	●	●	●

**Overcoming some barriers may require state legislative action.*

***Subject of other SEE Action reports in this series.*