GET SMART

THE BUSINESS CASE FOR GRID-INTERACTIVE, EFFICIENT BUILDINGS

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ULI's interdisciplinary membership represents all aspects of the industry, including developers, property owners, investors, architects, urban planners, public officials, real estate brokers, appraisers, attorneys, engineers, financiers, and academics. Established in 1936, the Institute has a presence in the Americas, Europe, and Asia Pacific regions, with members in 84 countries

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ABOUT THIS REPORT

With buildings accounting for 39 percent of global emissions, and trillions of dollars of real estate assets at risk due to climate hazards, there is a strong imperative for constructing and retrofitting buildings to be more resilient, responsive, and energy efficient. Achieving grid interactivity and improving energy efficiency will be key considerations in real estate's journey toward this paradigm.

This report outlines the value of grid-interactive efficient buildings, namely carbon and utility bill cost reductions, business continuity and asset resilience, improved occupant comfort, and long-term asset viability. The report also describes considerations for implementation including physical features, automation, stakeholder buy-in, climate resilience, cybersecurity, and scalability, coupled with project profiles highlighting exemplars of grid interactivity and efficiency.

CONTENTS

INTRODUCTION: DEFINING GRID INTERACTIVITY EMPIRICALLY AND ANECDOTALLY

In view of increasing concerns over emissions reductions, worsening climate conditions, and growing public support for adaptation and mitigation, grid interactivity and energy efficiency pose a tremendous opportunity for more sustainable, high-performance, and resilient buildings.

A **grid-interactive efficient building** is a building with smart technologies characterized by the active use of energy efficiency, solar, storage, and load flexibility to optimize energy use for grid services, occupant needs and preferences, and cost reductions (see Figure 1).[1]

Elements of Grid Interactivity

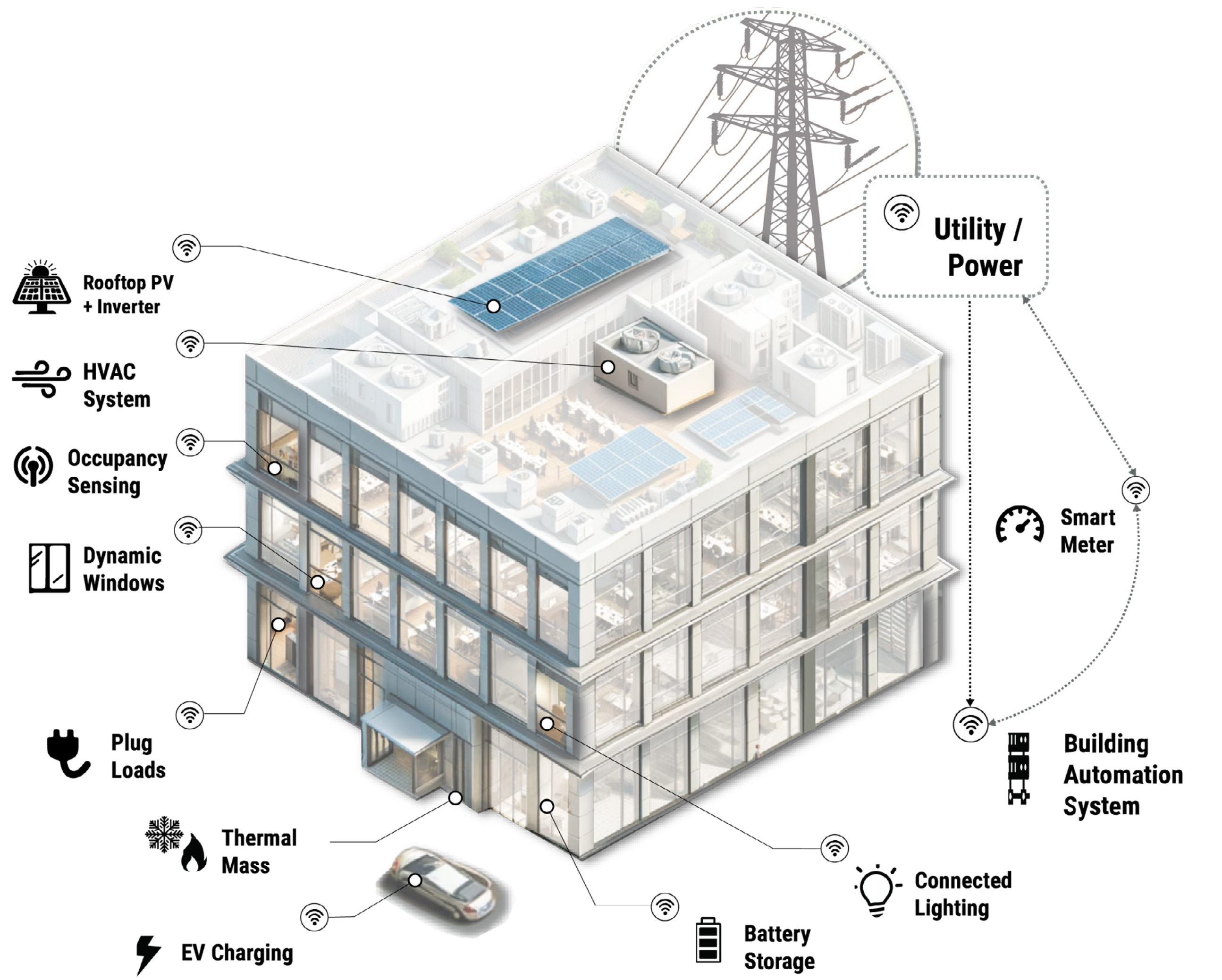


FIGURE 1 U.S. Department of Energy example of a grid-interactive, energy-efficient building. (Derived from Navigant Consulting, base image generated using Midjourney)

In 2019, the World Green Building Council reported that 39 percent of global energy-related carbon emissions originated from buildings (see Figure 2).[2] In addition, according to the U.S. Department of Energy, the U.S. electric power system could benefit from $8 billion to $18 billion in annual savings by 2030 from grid-interactive efficient buildings. By 2040, cumulative power system benefits are projected to be in the $100 billion to $200 billion range.[3]

This report, focused on new and existing structures, helps building owners and developers understand the growing business case for grid interactivity and identify paths toward implementation. The report also outlines methods for financing, designing, and constructing structures that can both interface with the electrical grid and enable fine control over building systems. The report pulls from leading scholarship and subject matter expert interviews with individuals from public agencies, ULI Greenprint Center real estate members, technology investors and vendors, and nongovernmental organizations.

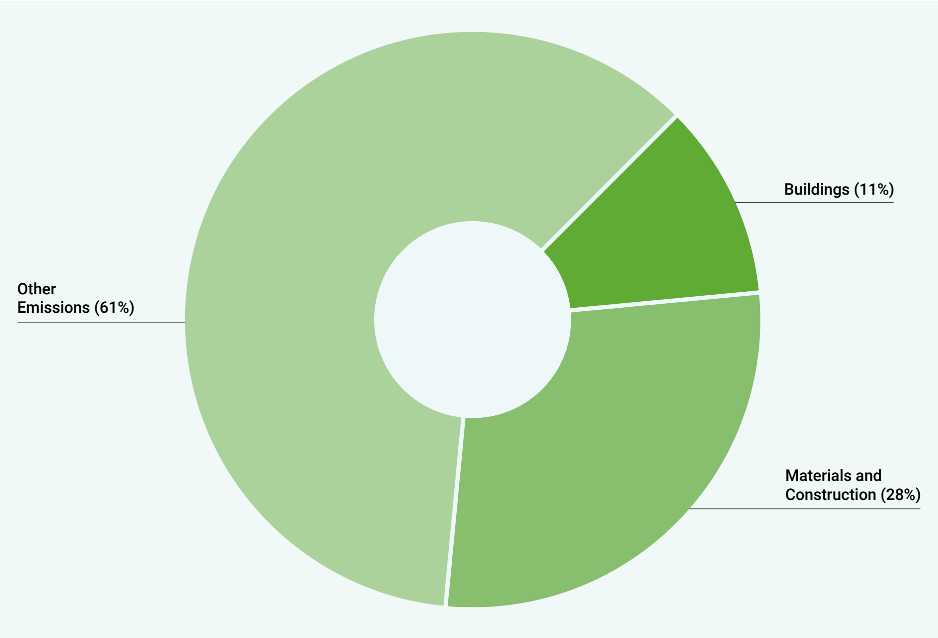
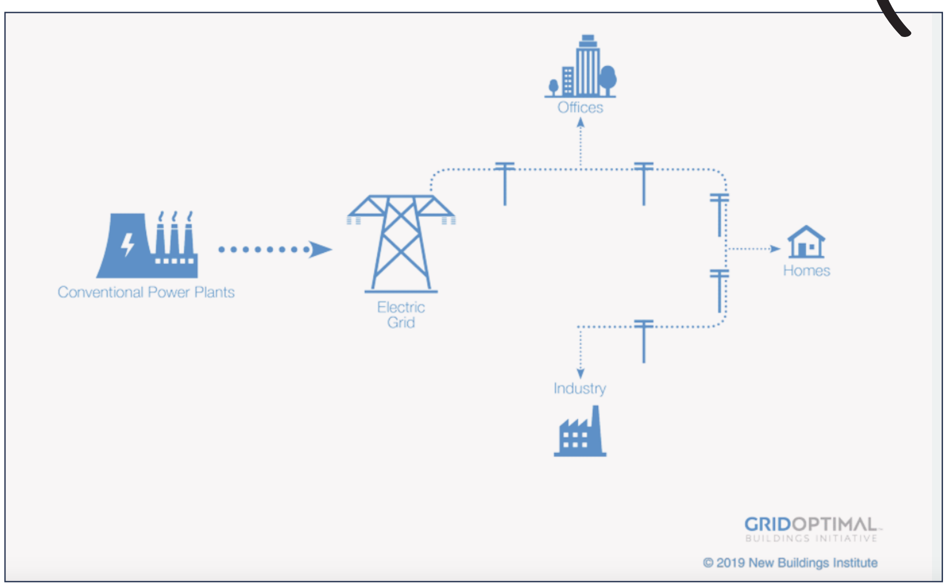


FIGURE 2 Global energy-related carbon emissions sources. (World Green Building Council)

The concept of grid interactivity involves the integration of smart technologies into buildings to enhance their energy efficiency while maintaining occupant comfort. These technologies enable two-way communication with the grid and building operators, which facilitates analytics-supported optimization of energy use (see Figure 3). Through flexible loads, distributed generation, energy storage, and other techniques and features, buildings can reduce, shift, or modulate energy consumption to align with the demands of the grid. Interactivity produces many benefits for building owners and operators, including emissions reductions, utility bill cost reductions, business continuity and resilience enhancements, improved occupant comfort, and long-term asset viability. When implemented at scale across asset portfolios, these benefits hold promise to pay even greater dividends.

Past one-way electricity grid



Future grid

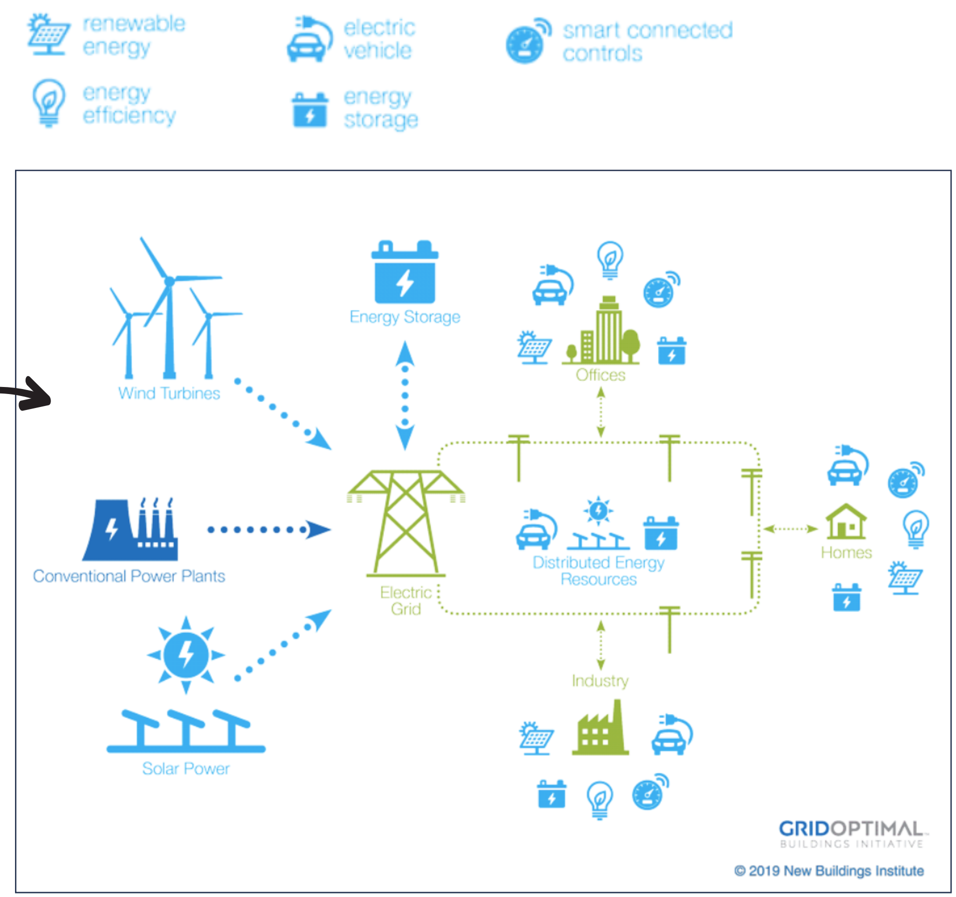


FIGURE 3 Grid conditions and strategies for better integrating buildings into utility grid management strategies as part of the New Buildings Institute's GridOptimal Buildings Initiative. (New Buildings Institute)

EXECUTIVE SUMMARY

A significant business opportunity exists for buildings to ***get smart*** with grid-interactive efficient features that not only support the bottom line, but also accelerate the real estate industry's journey to net zero.

PART I: THE BUSINESS CASE FOR GRID INTERACTIVITY

Part I of this report highlights the value proposition of grid-interactive efficient buildings, emphasizing five key areas:

1 UTILITY BILL COST REDUCTION

Grid interactivity allows for more efficient energy management, which leads to lower energy costs from reduced use and reduced peak demand, as well as participation in utility demand and response incentive programs for further utility cost reductions.

2 BUSINESS CONTINUITY AND ASSET RESILIENCE

Grid-interactive efficient buildings that employ distributed energy resources designed to maintain operations during utility grid disruptions can offer a competitive advantage during normal conditions and in times of emergency.

3 IMPROVED OCCUPANT COMFORT

Grid interactivity and energy efficiency increase occupant comfort through use of smart controls and sensors.

4 CARBON REDUCTION

Grid-interactive efficient buildings mitigate greenhouse gas emissions by optimizing energy efficiency and timing, increasing the share of low-carbon energy consumed.

5 LONG-TERM ASSET VIABILITY

Grid-interactive efficient buildings are better prepared for regulatory changes, stakeholder sustainability demands, and technological advancements, ensuring their long-term value and sustainability.

PART II: CONSIDERATIONS FOR IMPLEMENTATION OF GRID INTERACTIVITY

Part II of this report discusses strategizing an approach to grid interactivity in the private sector, including an examination of the factors that facilitate or hinder the adoption of grid-interactive buildings.

Strategizing an Approach to Grid Interactivity

- **Shape** loads to respond to tariffs
- **Shift** to cleanest-available sources of electricity and move consumption to the cleanest time of day
- **Shed** load through traditional demand response
- **Shimmy** with fast-acting ancillary services like battery storage

MARY ANN PIETTE, LAWRENCE BERKELEY NATIONAL LABORATORY

Part II also covers important considerations regarding the following factors:

- Physical features of structures permitting increased control over energy consumption and generation
- Automation of building systems' response to internal and external environmental factors
- Operational priorities and occupant expectations in balancing human needs with new, connected building systems
- Climate resilience of assets and grid infrastructure for utility providers and building owners
- Asset and grid resilience against cybersecurity threats
- Scaling of asset-level improvements at the portfolio level for comprehensive insight and control

PART I: THE BUSINESS CASE FOR GRID INTERACTIVITY

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FIGURE 4 Five tenets of the value proposition of grid-interactive, high-performance buildings.

UTILITY BILL COST REDUCTION

Energy consumption by residential and commercial sector operations was equal to approximately 28 percent of the U.S. total in 2021.[4] Grid-interactive efficient buildings reduce utility costs by lowering overall energy use, reducing peak demand charges, and optimizing time-of-use energy pricing.

"The utility sector is undergoing a remarkable transformation as power companies look to decarbonize their existing grid while building the equivalent of one to two more [facilities] to account for electrification and industrial growth. As a result of this gauntlet, utilities are increasingly willing to partner with the real estate sector to manage the demands of electrification. It's no longer just about turning your thermostat down a couple of times a year; we're seeing utilities willing to pay customers to use their own generators or on-site batteries during peak conditions. This can fundamentally change the economics of these investments for real estate operators—providing them with decarbonized, resilient power when needed while sharing it with the grid when it's not."

—Jake Elder, vice president, Energy Impact Partners

In general, three types of charges compose energy bills:

- **Baseline:** fees to connect to the grid (includes transmission and distribution charges)
- **Energy or use:** charges based on quantity (and sometimes varied based on the time) of energy used; accounts can be divided by utilities into tiers based on quantity of energy consumed
- **Demand:** charges based on peak quantity of electricity used and rate of consumption[5]

Both the emissions reduction and the utility bill cost reduction aspects of grid-interactive buildings' value proposition can depend on the quantity of energy drawn from the grid in addition to the time of use.

MAREK ŚLUSARCZYK

Time-of-use pricing refers to variation in the rate paid for electricity based on the time of day when it is drawn.[6] Most utilities will adjust their rates according to demand to balance the grid's load. For example, the adjustment can be seasonal: the cost of energy during the peak of winter or the middle of summer may be higher due to greater demand from heating or cooling mechanical equipment versus other times of the year when the weather is more temperate. It can also be hourly: the cost of energy can vary during certain hours of the day, giving building owners a vested interest in real-time energy management to optimize energy use and energy costs. Time-of-use pricing incentivizes building owners and operators to mitigate building energy consumption during peak demand through a practice referred to as peak shaving (see Figure 5).

Demand response entails reducing electricity use during peak periods in response to time-based rates or other forms of financial incentives. Some utilities offer demand response program incentives, and some localities offer incentives to customers that generate electricity on site. Demand response programs are already being implemented in jurisdictions across the United States, including in Massachusetts, New Hampshire, New York, Rhode Island, and Texas.[7] The advantages of participating in demand response programs include lower utility bills and thus lower operating expenses, which translates to higher net operating income—and higher asset value.

Both peak shaving and demand response programs help minimize the cost and quantity of energy purchased from utilities, thereby reducing overall utility bills. Specific interventions for participating in peak shaving or demand response might include operational interventions, use of energy storage technologies, and on-site generation.[8] At the operations and maintenance level, staff might also manually adjust building equipment or use a building automation system with presets for particular grid conditions.

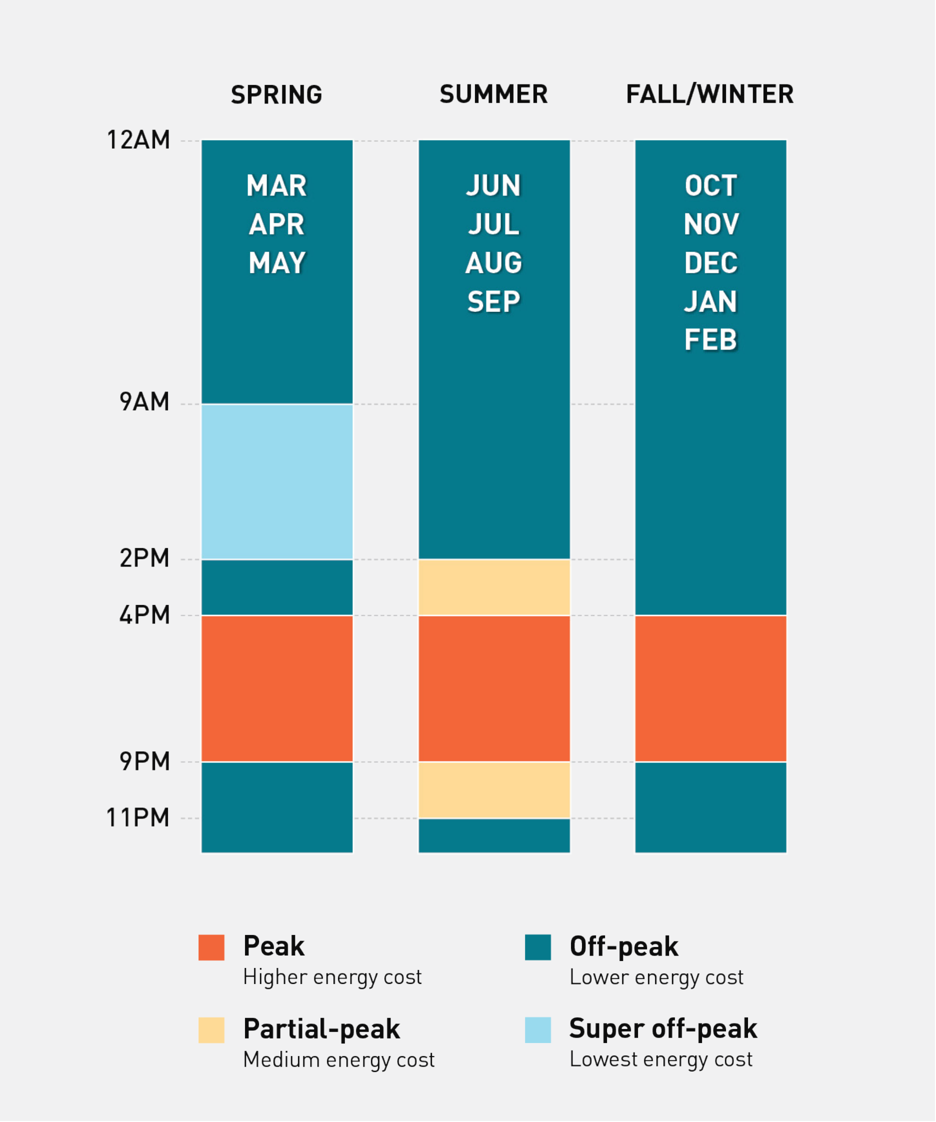


FIGURE 5 Sample utility time-of-use pricing. (Pacific Gas & Electric)

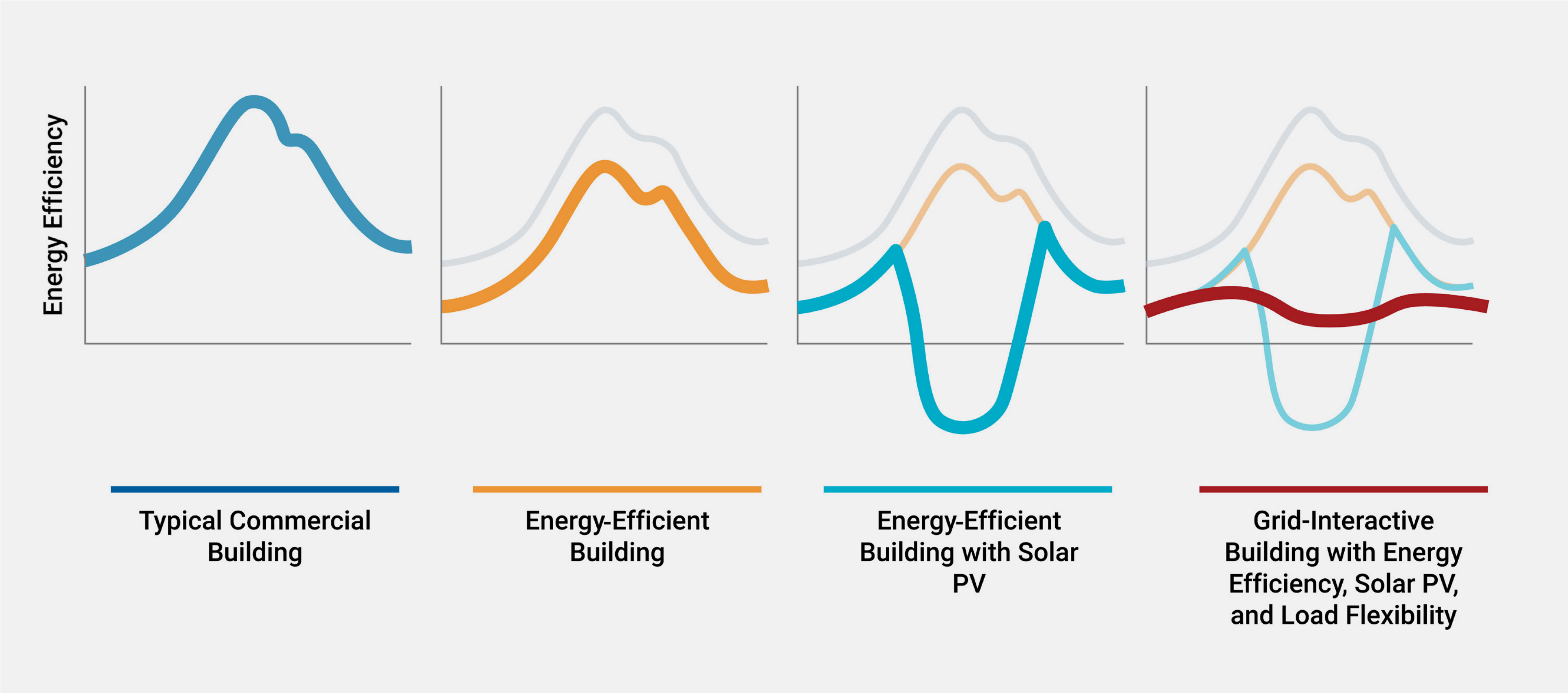


FIGURE 6 Load profiles for grid-integrated buildings. By incorporating energy efficiency, distributed energy resources like solar photovoltaic, and grid-interactive load flexibility, a building can significantly reduce its energy demand. (Rocky Mountain Institute)

In addition to benefiting building operators and property owners, there is also incentive for utility providers to support grid-connected buildings. A 2021 report by the U.S. Department of Energy estimated a $100 billion to $200 billion value proposition to the U.S. power sector from implementing grid-interactive, energy-efficient buildings.[9] Despite having insight into some aspects of customers' energy consumption, utility providers' understanding of the energy consumption of individual buildings often stops at the property line. The missing building information, such as building startup schedules, electric vehicle energy consumption, and insights from smart devices, can introduce an extra layer of complication—especially at times when demand is highest and supply is limited (see Figure 6). Failure to plan accurately for peak demand can lead to widespread blackouts and brownouts. Programs like demand response allow utilities to reliably provide power to customers during peak hours.

BUSINESS CONTINUITY AND ASSET RESILIENCE

Beyond carbon emissions reductions and utility bill cost savings, grid-interactive efficient buildings also help owners and operators ensure occupants' business continuity and bolster asset resilience through environmental shocks and stresses. Although the benefits to building owners may be captured mainly in terms of long- and short-term operating cost and energy use reductions, maintaining reliable systems for building occupants is yet another value-add. For commercial property owners, buildings unable to remain operational through adverse conditions present a challenge to business continuity. For both residential and commercial tenants, reliable access to building features such as functioning air conditioning, lighting, phone and internet connectivity, and running water can affect tenants' overall satisfaction and rate of turnover.

Productivity inevitably declines when occupants are unable to use office and retail amenities that are crucial to conducting daily business, or, in the case of residential buildings, when residents are unable to work in comfortable environments (e.g., without air conditioning) or are unable to access the internet to work remotely. Support for business continuity is a compounding concern: extreme weather events such as storms, wildfires, or heatwaves disconnect homes and businesses or place intense demand on power grids, resulting in power interruptions and threatening lives, livelihoods, and business operations.[10] Grid-interactive structures can help address the emergent challenge posed by climate shocks. Moreover, grid-interactive efficient structures can lift some of utility providers' burden in supplying continuous and reliable power through long-term and unprecedented temperature extremes. As such, there is an incentive for utility providers to move beyond traditional demand response and to collaborate more extensively with owners and operators to improve building energy efficiency and capacity for grid interactivity.

"Some of the measures that grid-interactive, energy-efficient buildings incorporate are very traditional and known energy-saving measures, such as passive measures like more efficient building envelopes, [which] improve or increase passive survivability of buildings so even if they are down for a period of time, the buildings [are] thermally comfortable without heating or cooling.

We are already looking at smart controls to address behavioral shifts for improving existing building energy performance. [The grid-interactive efficient buildings] roadmap to take this beyond building efficiency and address grid efficiency is the right way to scale up for decarbonization, especially in existing cities and neighborhoods like Battery Park City."

—Varun Kohli, assistant vice president, real property, Battery Park City Authority

The U.S. Department of Energy requires that electric emergency incidents and disturbances be reported to the Office of Cybersecurity, Energy Security, and Emergency Response. In 2022, 321 incidents were recorded, with nine incidents attributed to fuel-supply deficiency or generation inadequacy and 76 attributed to severe weather and severe weather-related disruptions. Many of these disruptions are unplanned due to a variety of factors, but some, such as the month-long outages that occurred in Shasta County, California, in September 2022, were planned as part of a "public appeal to reduce the use of electricity for purposes of maintaining the continuity of the Bulk Electric System" (see Figure 7).

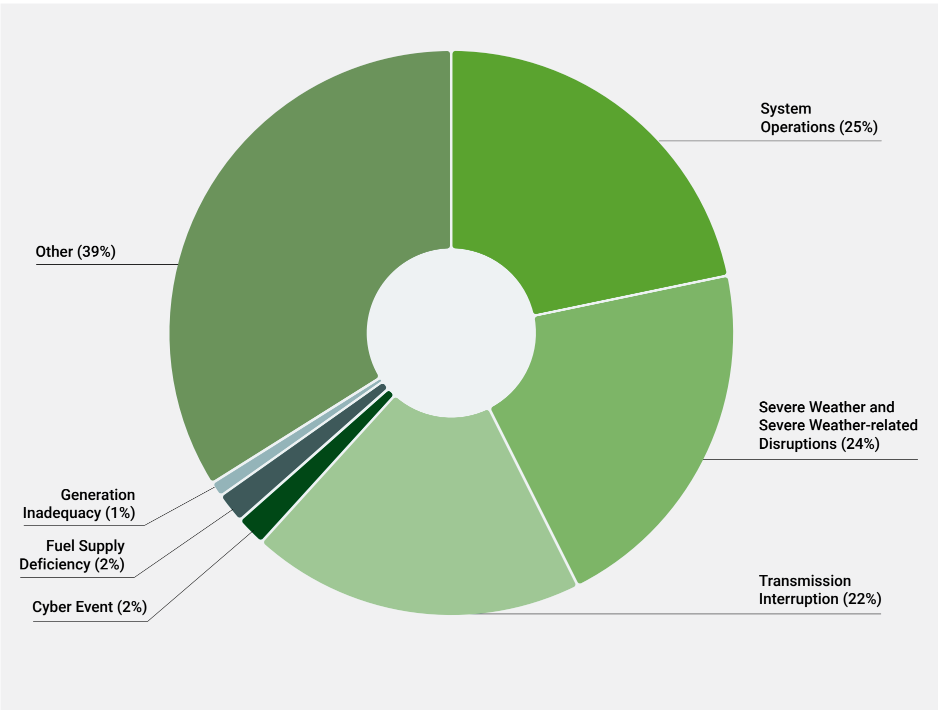


FIGURE 7 Annual summary of electric disturbance events in the United States in 2022. (Office of Cybersecurity, Energy Security, and Emergency Response)

Even in regulated markets like the state of Florida, where utilities are controlled by the Florida Public Service Commission, utility providers have begun to explore partnerships with developers and local jurisdictions to develop microgrids—ensuring localities can continue operations in times of emergency. One notable collaboration between the city of Orlando and its utilities is the Florida Municipal Solar project, which is headed by the Florida Municipal Power Agency.[11] This project is a joint initiative involving 16 municipal electric utilities that contemplates the installation of 1.5 million solar panels across five sites. Once completed, the project will consist of five solar farms that add 375 megawatts of generation capacity for both residential and commercial customers.[12]

As microgrids develop through different public and private partnerships, they include myriad configurations of components and connections with the main power grid. To meet localized energy demand, microgrids may employ on-site generation and storage including solar arrays and wind turbines; they may also use combined heat and power systems.[13]

Microgrids are a localized energy system that can operate independently or in conjunction with the larger grid, providing enhanced resilience, flexibility, and control over energy supply and consumption.

Wood Mackenzie, a leading energy resource consultant, reports that microgrids have been growing in number throughout the United States for the past decade, and that they produced more than 10 gigawatts of power in the third quarter of 2022.[14] The firm estimates that in 2023, the U.S. microgrid market will surpass $2 billion in investments, and it notes that most of the power generated originated from industrial and commercial operations, with a smaller share from residential uses (see Figure 8).

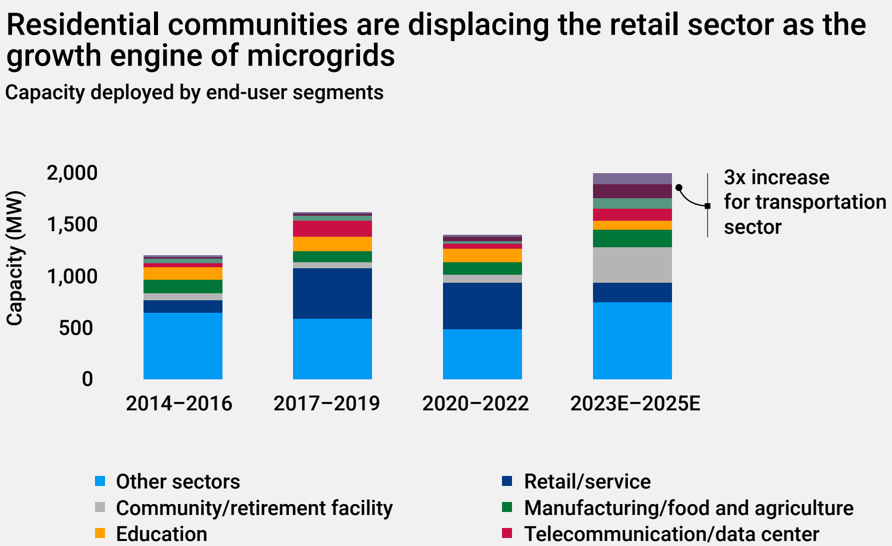


FIGURE 8 U.S. microgrid generation capacity from 2014 to 2025 by industry sector. (Wood Mackenzie)

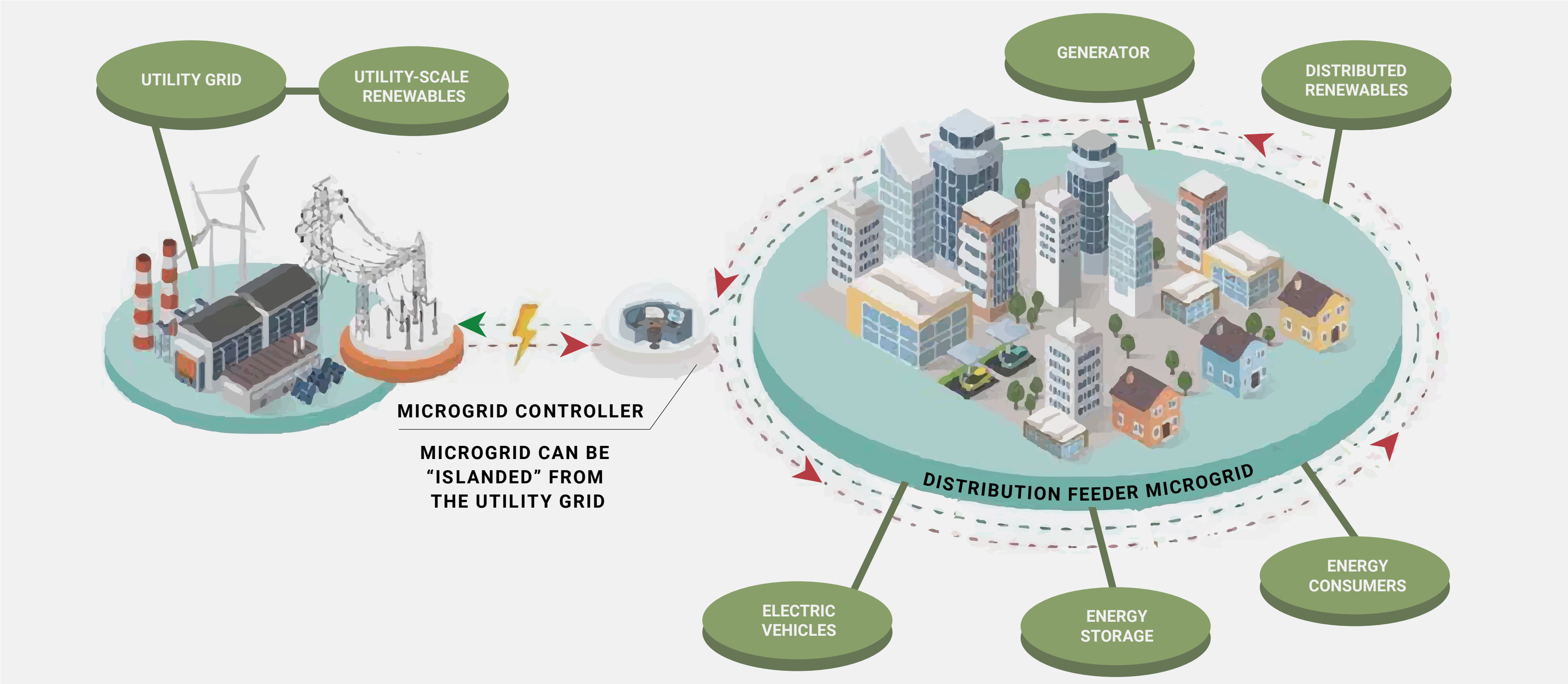


FIGURE 9 Mesa del Sol microgrid system components. ([University of New Mexico School of Engineering](#))

The microgrid system at the University of New Mexico in Albuquerque illustrates this concept of mixed and varied partnerships and features in microgrids. The Mesa del Sol microgrid system was constructed in 2012 by Japan's New Energy and Industrial Technology Development Organization (NEDO) and enabled by partnerships among governments, education and research-focused institutions, and numerous industry partners including El Paso Electric, PNM, Siemens, the National Renewable Energy Laboratory, and the Electric Power Research Institute (EPRI). The Mesa del Sol system integrates information about human activity with energy input and output from electric vehicles, on-site energy storage, and generation equipment and transacts power with the utility grid while retaining the ability to operate independently ("islanding") if necessary (see Figure 9).

Although microgrids pose one of many options for grid operators and private interests to manage demand, building owners and operators should also examine the feasibility of safely integrating features such as backup energy storage and on-site generation on individual properties to enhance low-power building performance into vulnerable assets. Doing so brings value to both owners and occupants in the form of resilience against current and future outage-causing events, such as record high and record low temperatures alongside more frequent and intense wildfires and storms.

Renewable Energy Transformations Reshape Utility Strategies and Infrastructure Resilience

Demand management through energy efficiency may also ease the grid's transition to more sustainable energy sources; a grid with distributed energy resources (DERs) offers more options for sourcing and supplying power, as well as alternatives to high-emitting energy generation facilities that are typically only brought online at peak times.

Partly spurred by federal policies governing emissions, some states have adopted Renewable Portfolio Standards, driving some utilities to plan to decommission high-emitting plants and to bring online more utility-scale renewable energy generation facilities over time.[15] However, at present, many utilities are unable to meet 100 percent of demand through renewables and frequently fall back on, or rely entirely on, conventional energy sources such as coal, petroleum, and natural gas.[16] Utility providers committed to supplying energy from renewables can do so more effectively with better insight into building energy consumption. On the demand side, grid interactivity can also contribute to lower purchase prices for power purchase agreements (PPAs) in jurisdictions where such agreements are permitted.[17]

Furthermore, the notion that utility providers should be the exclusive or primary suppliers of electricity to the grid is changing. On-site renewable energy systems, like solar photovoltaic arrays, geothermal, and wind turbines, are types of DERs that can generate enough energy to power buildings and even contribute excess capacity back to the grid. The spread of on-site power generation and construction of community microgrids is creating an unfamiliar but potentially beneficial landscape for overburdened utilities. Although the specific mechanisms for operationalizing this additional DER capacity are still in their nascent stages, both states and utilities are crafting creative means of capitalizing on the additional capacity and incentivizing consumers' switch to renewables. For example, the state of California offers rebates to customers that install generation equipment on site.[18]

According to the Lawrence Berkeley National Lab, the potential benefits to owners using DERs are as follows:[19]

1. **Energy bill savings**
   - Reduction of peak demand charges
   - Energy cost savings: Use stored energy when energy rates are high, charge storage when rates are low
2. **Resiliency**
   - Microgrid serves building loads during grid momentary and sustained outages
   - Protection of critical loads
3. **Revenue opportunities**
   - Participation in demand response programs or wholesale capacity markets
   - Provision of other grid services
4. **Carbon reduction**
   - Integration of intermittent renewables
   - Storage of renewable energy when there is excess production

Outside of the conventional building owner–occupant relationship, utility grid operators and managers of critical infrastructure (including hospitals, fire stations, and evacuation shelters) can leverage adaptive buildings capable of operating autonomously to operate when there are limited energy resources available. The downstream benefits of reliable critical infrastructure feed back into broad benefits to local businesses and communities, enabling them to recover quickly from natural disasters.

IMPROVED OCCUPANT COMFORT

"When talking about energy use in the building, there is a lot of energy that goes into maintaining thermal comfort and lighting the office, but there might only be a few people at their desks. People advocate for having localized controls: heated and cooled chairs, and task lighting. That allows the building to adjust for automated controls . . . those are strong ways to reduce energy use and have demand-flexible buildings."

—Anish Tilak, manager, carbon-free buildings, Rocky Mountain Institute

There is a common misconception that grid-interactive efficient buildings compromise occupant comfort. Contrary to this belief, features like automated building controls that enable grid interactivity can actually improve both energy efficiency and occupant comfort, benefitting property owners, operators, and tenants alike. Comfortable tenants reduce facility engineers' busywork (fewer "hot and cold calls" to answer), and those tenants are more likely to renew their leases. Results from post-occupancy and employee health studies indicate that factors affecting occupant wellness, such as temperature, lighting, and indoor air quality, are primary drivers in decisions to renew or end commercial leases. Moreover, 70 percent of commercial tenants would pay a premium to occupy sustainable, energy-efficient properties, with those properties seeing a 10 percent decrease in vacancy and 10 to 25 percent increase in property value.[20]

Historically, better occupant comfort has been linked to inefficiency, as meeting occupants' lighting, temperature, and air-quality needs on an individual basis can compete with efficiency measures that reduce energy use. That notion is quickly fading as the industry identifies more innovative and holistic approaches to building design. There are now many ways for occupants to exercise control over the spaces they inhabit that still enable buildings to function efficiently. From heated chairs to tenant polling apps and from high-efficiency heating, ventilation, and air conditioning (HVAC) technologies to daylighting sensors, solutions are bridging the gap between efficient buildings and happy occupants.

Attaining Smart, Efficient Buildings and Ensuring Happy Occupants through Occupant Comfort Controls

Although building owners play a significant role in guaranteeing the comfort of occupants through system-wide adjustments, occupants themselves can exert additional influence on their immediate environments through zonal controls. Giving occupants the agency to make adjustments to their immediate environments gives building owners and operators more leeway to make macro adjustments to building systems. Giving building occupants access to zonal controls can also improve personal comfort, which translates to cobenefits in tenant retention and increased productivity (see Figure 10).

FIGURE 10

Examples of Occupant Comfort Controls

While appropriate strategies may vary between building type and use, the following are examples of controls that may benefit occupants of office and residential buildings, allowing operators to minimize "cold and hot calls" and to better optimize for environmental and grid conditions.

- Ergonomic chairs
- Movable worktables, desks, and files
- Adjustable, movable task lamps
- Ventilation controls at workstations (e.g., operable windows, underfloor air distribution vents, operable ceiling vents)
- Adjustable blinds and other sunlight control devices
- Meeting spaces (for six or more people) with ventilation and temperature controls
- Conference rooms with adjustable lighting
- Printers and copiers centralized and centrally ventilated
- Paper management that reduces dust and particles
- Regular assessment of occupant comfort through survey
- Occupant education about facility sustainability goals
- Energy performance feedback readily available to occupants

CARBON REDUCTION

"The ability to program a building's energy use to maximize the use of zero-carbon emissions source generated electricity lowers our carbon emissions from electricity consumption (Scope 2) and helps us drive toward achieving our net zero carbon goal."

—Tim Hewer, director, energy and sustainability, Brookfield Properties

According to the U.S. Environmental Protection Agency, in the United States, emissions from commercial and residential sector operations contributed to 30 percent of total U.S. greenhouse gas emissions in 2021 (see Figure 11).

Many major real estate firms and real estate–adjacent markets have adopted environmental, social, and governance (ESG) goals that include a commitment to reduce corporate carbon emissions to net zero. Commitments include pledges and participation in voluntary and compulsory reporting frameworks such as those created by the Task Force on Climate-related Financial Disclosures (TCFD), GRESB, and the United Nations–supported Principles for Responsible Investment (UNPRI). These commitments require companies to assess their emissions, both direct and indirect, and identify pathways for mitigation. Adoption of these goals are forward-looking decisions made in part to reduce both physical and transition risk to assets.[21] With such a large share of emissions from residential and commercial real estate originating from energy consumption, addressing all aspects of emissions from portfolio assets will continue to be a key component of transition risk mitigation through emissions reduction. Such risk mitigation involves regulation of both direct fuel consumption and grid electricity consumption.[22]

Implementing energy efficiency programs in tandem with grid interactivity can aid efforts to reduce carbon emissions. At the asset level, a traditional building is transformed into a grid-interactive efficient building by, at a minimum, using insights from separate building energy systems to adjust energy use based on signals from the electric grid. Establishing this connection makes it easier for asset owners to track energy use, mitigate consumption of less-sustainable energy resources by grid operators, and reduce carbon emissions–associated electricity generation. More specifically, building operations and maintenance staff or automated systems might adjust mechanical equipment to minimize the amount of energy consumed during peak hours in addition to source and time of energy use.

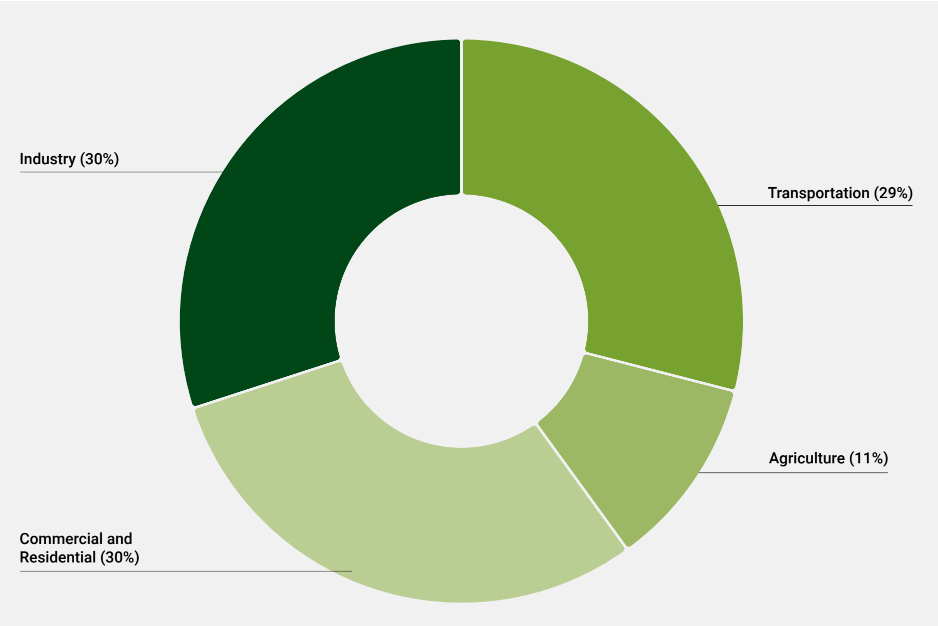


FIGURE 11 Total direct U.S. greenhouse gas emissions by sector with electricity distributed (2021). ([U.S. Environmental Protection Agency](#))

Electric Vehicles and Grid Interactivity

Power grid benefits of grid interactivity extend beyond buildings and are closely linked with other sectors, including transportation, which has the second highest carbon emissions of any sector after real estate. The connection between transportation and real estate emissions is an important one. There is major debate concerning the viability and sustainability of electric vehicles (EVs) and their power sources, as well as the inclusion of EV charging in totals for building electricity use. In addition, the real estate industry is grappling with the question of whether a building ought to exercise control over the charging of resident/tenant EVs on site.

Regarding EV viability, if an EV is charged via a building charging connection during peak demand, it introduces an extra burden of energy use and carbon emissions. A grid-interactive building may be able to dynamically modulate charging of EVs (i.e., slow down EV charging stations during peak demand) and therefore mitigate overall transportation-sector emissions while minimizing burden on utilities and the grid. For multifamily and commercial property owners, the ability to optimize when and how much EVs are charged (especially as they become more abundant) could translate into lower utility costs at the building level and carbon emissions reductions across portfolios. Whether EV owners approve of buildings modulating their charging for grid optimization is another quandary.

Regarding whether or not EV charging should be included in the accounting of building electricity use for green building certifications and for benchmarking ordinances, ESG reporting managers may omit some or all EV charging from emissions totals—particularly from nonfleet vehicles.[23] Although some reporting frameworks allow for certain types of EV charging to be overlooked, both building owners and grid operators benefit substantially from optimizing charging infrastructure in buildings because doing so enables the spread of bulk charging over time to lower peak demand and to front-load charging during off-peak hours or during hours when the "cleanest" power is available. As such, while grid interactivity through EV chargers may not support carbon emissions reductions for buildings, it still supports decarbonization and grid reliability overall.

New technologies are advancing the technical possibilities of grid interactivity and EV charging. For example, one startup firm, ev.energy, is building an EV charging platform that allows utilities to manage charging directly, minimizing emissions and cost for both utilities and users. Through this firm's software, a utility can control recharge of particular vehicles, ensuring, for example, that all vehicles in a lot are not charging at 6 p.m. (at the end of the workday), thereby lowering peak demand.[24]

The Role of Publicly Funded Research and Development

Publicly funded research and development initiatives, such as those led by the U.S. Department of Energy, are improving grid interactivity and renewables in jurisdictions across the country.

New innovations are driving opportunities for measuring and reducing energy consumption and carbon emissions thanks to grid-interactive optimization. For example, Benchmark 8760 seeks to change the way building performance is assessed by evaluating energy use timings, greenhouse gas intensity of power, and the associated building occupancy. This initiative, funded by a $1 million investment from the New York State Energy Research and Development Authority, aims to help building owners, developers, and government officials find opportunities for investment in load shifting, demand management, and occupant-responsive building operations by providing better insight into building energy consumption. Currently, the initiative is focused on developing a pilot benchmarking platform to incorporate hourly data into benchmarking through the collaborative efforts of real estate owners, nonprofit thought leaders, government stakeholders, and academics.[25]

"The existing performance metrics don't account for how well buildings are used. Were we to add occupancy counting, we could link building energy consumption with space utilization and community engagement. We want buildings to use energy at night because they are full of people, opening their doors to community groups and meetings, not because they have systems that do not turn down as people vacate the building."

—Charlotte Matthews, owner, CMat Advising LLC

LONG-TERM ASSET VIABILITY

"Where sustainability is heading now is about how you think about your own operations, how you are impacting the larger system, and how the built environment can help enable a massive change that needs to happen—that you aren't the only one in control of."

—Sarah King, senior vice president, sustainability, Kilroy Realty Corporation

Current global trends in voluntary and required carbon reporting are creating impetus for the adoption of grid interactivity. In 2019, the European Union introduced the Sustainable Finance Disclosure Regulation to require financial institutions to disclose climate-related risk to assets; the regulation went into effect in 2021. Canada introduced similar legislation in 2022 (effective 2024), and the United States and other global powers have either announced their intent to adopt similar disclosure requirements or have already adopted them.[26] The impetus for grid-interactive structures in this regulatory landscape is that, when implemented at scale, grid interactivity offers pathways for achieving widespread carbon reduction goals. Local and state government policies are also driving the value proposition of shifting to grid interactivity. For example, many states, including California, Connecticut, New Jersey, New York, and Oregon have passed laws to curb building emissions and to support utility planning and programs toward interactivity.[27]

Given current trends in regulation and growing support for achieving net zero emissions in the real estate sector, it is unlikely that, over time, major firms' asset portfolios will continue to rely on carbon intensive sources of electricity or to operate within siloed energy markets, making connectivity all the more important. Some energy markets are already diverging from business-as-usual practices with the help of regulators, property owners, and the utilities themselves. In competitive markets, like those in the northeastern United States and Pacific Northwest, property owners have some flexibility in sourcing and trading energy in real time (see Figure 12).[28]

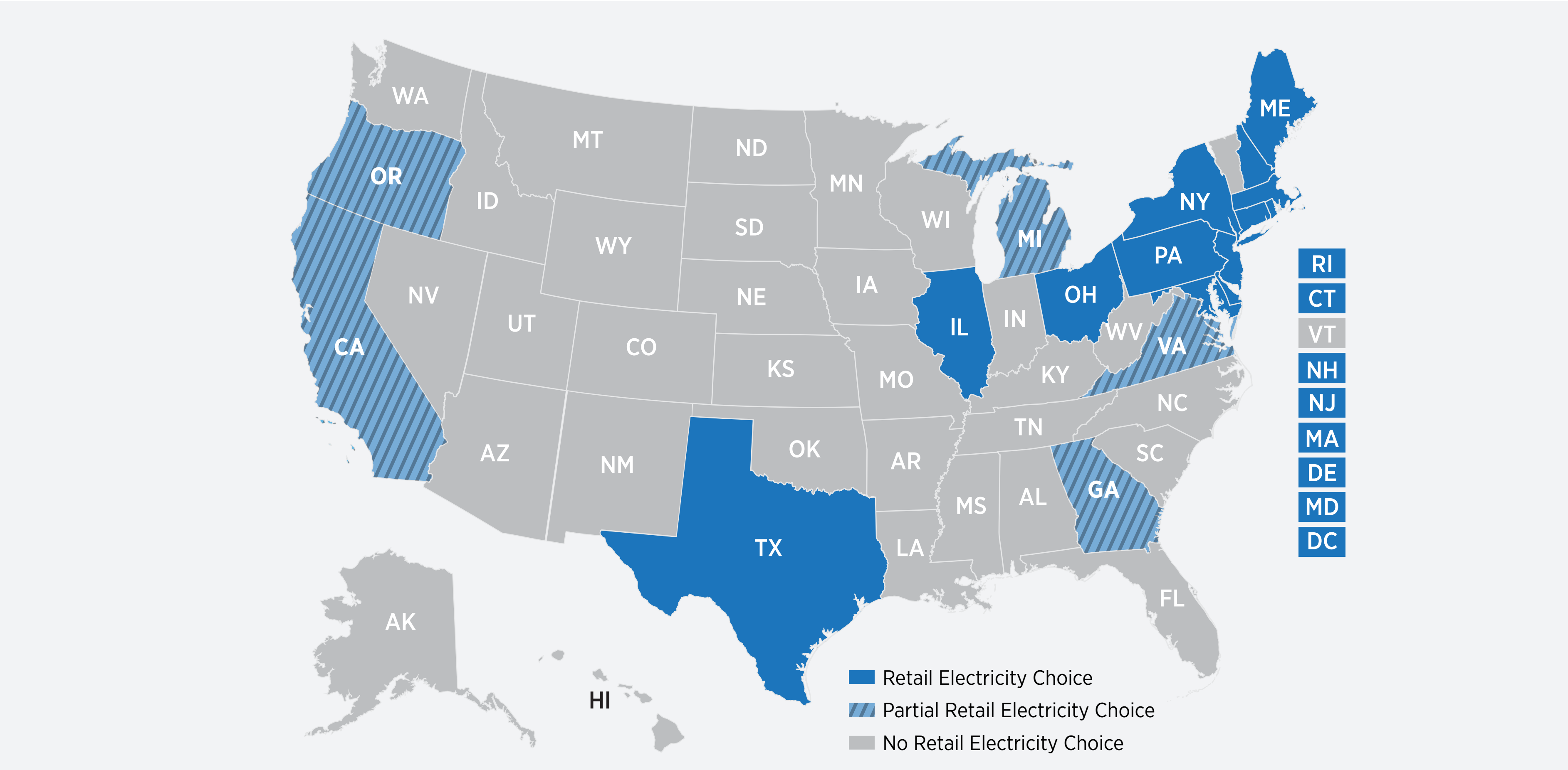


FIGURE 12 Map displaying regulated and competitive retail electric power markets. (NREL)

Eventually, private capital requirements, public incentive opportunities, projected revenue from on-site generation, and savings from reduced consumption costs for grid-interactive and energy-efficient buildings may become standard considerations when developing pro formas for new buildings and costing ongoing maintenance. In addition to costs associated with noncompliance with local regulations, there are also costs associated with remaining disengaged from the energy trading market. In cases where individual properties are already participating in net metering and supplying energy to the grid, there is competitive advantage in designing and retrofitting for grid interactivity.[29] Grid-interactive efficient buildings capable of maximizing revenue streams afforded by interfacing with the local utility grid may ultimately be more profitable. With higher profit margins from grid interactivity a forgone conclusion, developers, for example, may find it easier to scope and execute more innovative designs and to offer buyers and prospective tenants enhanced and expanded amenity options.

PART II: CONSIDERATIONS FOR IMPLEMENTATION

Savvy real estate leaders are already integrating smart building technologies and grid interactivity into their properties and throughout their portfolios. Even though adoption is not yet widespread, one can anticipate that market pressures will drive growth over time. It bears mention, however, that many buildings are heavily dependent on manual/pneumatic operations and maintenance, and even though owners and operators are actively trying to incorporate technology like smart access, smart thermostats, building automation systems, smart leak detection, and occupancy sensors to ensure systems run efficiently, there are barriers to achieving system-wide insights at the property and portfolio scale, as well as between property owners and grid operators.

The following sections explore the major barriers, potential solutions, and initial actions that can be taken toward the rollout of grid-interactive structures, according to the following topic areas:

- **Physical features** of structures permitting increased control over energy consumption and generation
- **Automation** of building systems' response to internal and external environmental factors
- **Operational priorities and occupant expectations** in balancing human needs with new, connected building systems
- **Climate resilience** of assets and grid infrastructure for utility providers and building owners
- Asset and grid resilience against **cybersecurity** threats
- **Scalability** of asset-level improvements at the portfolio level for comprehensive insight and control

For key terminology used in supply side and demand side interventions for grid-interactive buildings, see the Appendixes. The Supply Side Glossary (Appendix I) addresses interventions for structures that generate energy on site and the Demand Side Glossary (Appendix II) outlines interventions for any connected structure. Some redundancy exists between the glossaries as some interventions can be applied in both cases regardless of whether energy is being generated or consumed. Specific implications of these interventions are discussed further in the report.

Despite the challenges, the are myriad paths forward. To begin, consider the following high-level points of guidance when crafting an approach to grid interactivity:

Strategizing an Approach to Grid Interactivity

- **Shape** loads to respond to tariffs
- **Shift** to cleanest-available sources of electricity and move consumption to the cleanest time of day
- **Shed** load through traditional demand response
- **Shimmy** with fast-acting ancillary services like battery storage

MARY ANN PIETTE, LAWRENCE BERKELEY NATIONAL LABORATORY

MAKING THE CONNECTION THROUGH PHYSICAL FEATURES

Understanding the feasibility of grid interactivity begins with understanding the range of physical aspects of a building that allow for more control over, and insight into, energy consumption and generation. Such features might include on-site renewables and smart sensors or internet of things (IoT) devices that allow buildings to adjust to projected and current environmental or grid conditions. The range of possibilities is vast, but there are similar limitations for many types of energy-generating equipment or smart building technologies. The following section outlines the characteristics and limitations of such features and the pathways to take to roll them out. The section also addresses the integration of distributed energy resources and energy saving improvements into structures, and it explores the elements and the significance of the interplay between physical features and building control systems to grid interactivity.

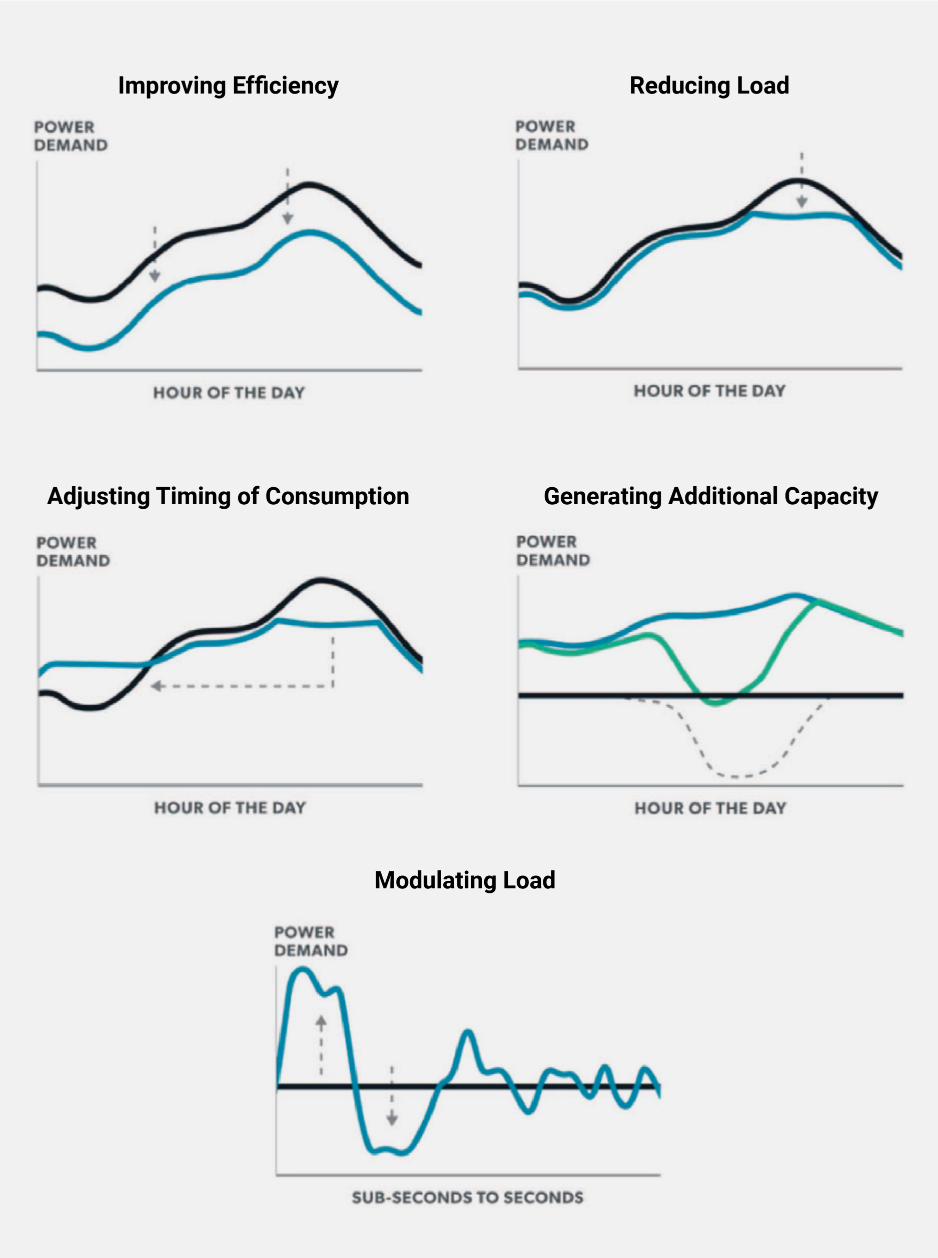


FIGURE 13 Grid-interactive building load profile comparisons and example measures. (Lawrence Berkeley National Laboratory)

INTEGRATING DISTRIBUTED ENERGY RESOURCES AND ENERGY-SAVING IMPROVEMENTS

Increasingly, buildings are being designed or retrofitted for energy efficiency, on-site renewable generation, and battery storage. In addition to producing different load profiles, such improvements may also have varying degrees of efficacy across asset types (see Figure 13 for an illustration of load impacts). Figure 14, adapted from the New Buildings Institute's GridOptimal factsheets, details high-impact strategies that can be implemented to "deliver time-of-use energy efficiency and demand flexibility while minimizing or avoiding occupant disruption" for specific building types, offering a solid foundation for grid interactivity.

It should be noted that the approach to implementing these strategies will vary among new and existing buildings. Although some features, such as lighting, appliances, and certain fixtures, can be replaced with minimal impact to tenants, other features, such as central controls, cannot. Most notably, in existing buildings, some strategies (such as "smart HVAC controls," as shown in Figure 14), may require owners to coordinate improvements with current tenants whose lease requirements could slow owners' recommissioning processes.[30] In the long term, the adoption of green leases, which seek to align owner and tenant goals and to maximize tenant space energy efficiency, may be the solution. In the short term, operators can conduct systems and equipment inventories, treasure hunts, building tune-ups, and audits, and install energy management and monitoring systems (see Figure 15).

FIGURE 14

High-Impact Strategies for Grid Interactivity

	Office	Education	Multifamily	Single-family	Retail	Warehouse
On-site renewable energy	✔	✔	✔	✔	✔	✔
Energy efficiency	✔	✔	✔	✔	✔	✔
Energy storage	✔	✔	✔	✔	✔	✔
Smart HVAC controls	✔	✔	✔	✔	✔	✔
Managed EV charging	✔		✔	✔		
Windows and shading		✔	✔		✔	
Grid-connected appliances				✔		
Equipment and process loads						✔
Plug load management	✔	✔				

Source: Adapted from New Buildings Institute.

For properties with existing or planned DERs, several factors could stymie efforts to construct and integrate them into existing grid infrastructure. Specifically, high upfront cost, inconsistent and inflexible regulatory and policy environments, technical challenges to integration with existing infrastructure, and cultural and organizational misalignment of priorities among utilities, developers, and property managers pose obstacles for implementation. Although these challenges are significant, numerous solutions and workarounds can be employed to overcome them.

FIGURE 15

Short-term Opportunities for Grid-Interactive Efficiency Improvements in Existing Buildings

Opportunity	What is it?	Why is it important?
Systems and equipment inventory	Inventory of major building systems (heating, cooling, lighting, ventilation, roof), and rollout of portfolio upgrades based on age and efficiency of current equipment	Allows facilities managers to proactively replace or upgrade aging or inefficient components to ensure alignment with industry standards and best practices, enabling or priming buildings to transition to grid interactivity.
"Energy Star Treasure Hunts" and building tune-ups*	Searches by teams that walk around a facility at varied times of the day, looking for quick ways to save energy	Allows building operators to quickly conduct regular reviews with minimal cost and in varied conditions and to initiate conversations about energy savings and real-time response to conditions contributing to structures' energy consumption.
Audits	Reviews of building equipment and use; multiple types of audits are available	Identifies areas for improvement as well as anticipated costs and savings, which may include evaluation of suitability for piloting features that enable grid interactivity and further energy efficiency priorities.
Energy management/monitoring systems	Systems that assist with monitoring and managing energy use in real time	Ensures that building equipment functions properly, which reduces maintenance needs and energy waste. Provides initial insights that, when leveraged in tandem with additional layers of data around environmental and grid conditions, can further optimize building systems and initiate progress toward grid interactivity.

Source: Adapted from "How to Identify Opportunities for Efficiency" from *The ULI Blueprint for Green Real Estate*. *Energy Star.

Pivoting to a more granular examination of these challenges and solutions, the issue of **high upfront cost** relates to the installation of renewable energy generation systems, deployment of advanced metering systems, energy storage, and other smart grid technologies. These can be particularly expensive, which makes it challenging to finance them because there is not a quick return on investment. Governments or utilities can offer tax credits, subsidies, or grants to reduce the required initial investment. Various financing options are also available. Green loans, green bonds, commercial property-assessed clean energy (C-PACE) financing,[31] and other public programs provide loans with favorable terms to lower upfront costs for individuals or businesses. Third-party ownership models, where an entity such as a utility installs, owns, and maintains the on-site system, are another solution; this solution can include energy-efficiency-as-a-service or microgrid-as-a-service options. Similarly, cost-sharing partnerships, where utilities collaborate with developers or property managers to co-invest in DER installations, can be beneficial.

There is wide variability in the type and breadth of programs and policies concerning grid interactivity between state and local governments. As such, **inconsistent and inflexible regulatory and policy environments** tend to pose a problem not only by potentially stalling innovation and uptake of new technologies for individual projects, but also by slowing or preventing scaling of solutions across portfolios. Addressing this issue requires clear, long-term renewable energy goals and supportive policies from governments, as well as the introduction of more consistent regulations and standards. Stakeholder engagement is also critical—regular dialogues and forums allow utilities, governments, developers, and other stakeholders to collaborate on policy formation and address specific concerns.

Technical challenges also arise when integrating structures into the electrical grid. The infrastructure required to maintain grid stability and reliability for transmission and distribution infrastructure might be too costly for utilities, owners, or developers. Solutions include:

- Investment in grid modernization, which incorporates new technologies for integrating DERs, such as new meters, analytics, and automation software and sensors;[32]
- Community microgrids constructed and maintained in collaboration with local interests that can operate independently or alongside the main grid; and
- Energy storage solutions that can help counteract the intermittency issues associated with on-site renewables and bolster grid stability.

In addition, setting clear standards for achieving connectivity and fostering collaborative research and development among various stakeholders can pave the way for more streamlined integration.

Embracing new technologies and implementing new processes often demands organizational change, which makes **cultural and organizational misalignment** a hurdle in implementing grid-interactive efficient buildings. Such change can be hard to address, especially within and between large, complex organizations or in smaller entities, where change comes with high costs. To navigate these issues, education and engagement are crucial. Training sessions and workshops to familiarize operations and maintenance staff about the importance of DERs and their role in the energy sector's future, adjusting management approaches based on feedback, and collaborative pilot projects can all further this goal. Intersectoral collaboration may occur as utilities partner with developers and property owners to test new technologies or business models, fostering mutual understanding and progress.

In addition to the foregoing challenge, a commonly cited concern with adopting on-site renewables is the intermittency of renewables and availability of battery storage to compensate for instances when "the wind isn't blowing or the sun isn't shining." But this concern is quickly becoming outdated with the advent of new building information management systems, advancements in storage technology, and in some markets, advancements in smart grid technology.[33] However, there are emerging concerns about future climate conditions and their implications for today's assessments of renewable energy generating capacity on site. For instance, 15 years in the future, peak hours and amount of on-site renewable energy generation could be wildly different from today's projections given unpredictable changes in climate conditions.

Defining Building Automation and Control System Protocols and Data Interoperability Standards

Building automation and control system (BACS) protocols are communication standards used by building automation systems to control and monitor conditions in a building. These protocols allow different components of a building's infrastructure, such as HVAC systems, lighting, and security systems, to communicate with each other and with a central control system, and they enable devices from different manufacturers to communicate with each other. Some examples of BACS protocols commonly used in building automation systems include BACnet, LonWorks, and Modbus.

In addition, data interoperability standards such as Project Haystack and the Brick schema allow building operators to crosswalk information outputted by BACSs by assigning data outputs to a common schematic (see Figure 16). Organizing data in this fashion makes it possible for building and portfolio-wide monitoring and automation systems to derive insights and make recommendations for operations that are informed by a wider variety of building system outputs.[34]

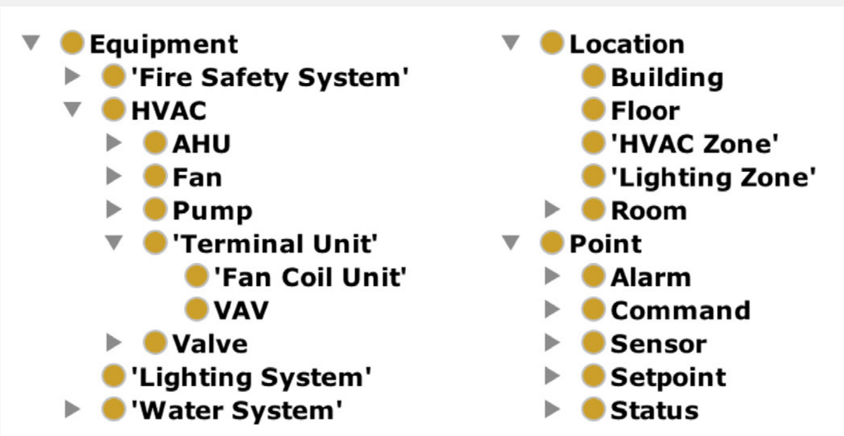


Figure 16 Example of the Brick schema's class hierarchy. (Balaji, Bhattacharya, et al.)

INTEGRATING CENTRALIZED CONTROLS, ZONAL CONTROLS, AND EXTERNAL DATA TO OPTIMIZE BUILDING SYSTEMS

Because they determine how and when energy-consuming equipment operates, building controls are a piece of the physical feature puzzle that allows building owners to shape, shift, shed, and shimmy their way to grid interactivity and ultimately, to net zero emissions. Centralized controls that cover electricity, water, and plumbing and zonal controls like thermostats, occupancy sensors, ventilation controls, and window shades create opportunities for optimization.

A building automation and control system (BACS) can integrate data from sensors and make adjustments to mitigate inefficiency. In theory, this would enable utility account holders to earn dividends on investment in energy-efficient buildings by reducing energy consumption and costs. Although it can take time—and in the case of centralized control systems, some initial investment—to install the necessary equipment to track data, the long-term benefits can outweigh the upfront costs. For example, in portfolio-wide recommissioning, zonal controls constitute a comparatively nominal cost with the potential to yield immediate returns from energy efficiency and occupant comfort benefits.

In general, economies of scale have made zonal controls more affordable. Because they are easier to procure, install, and physically access, zonal controls have greater opportunities for refinement, which allows them to be used more effectively. In addition, for existing structures, it is generally easier to phase out inefficient zonal controls than it is to phase out centralized controls. Zonal controls are also equipped to measure and monitor conditions in the same space and in many cases they are also capable of responding to commands from building automation systems. The versatility and location of zonal controls in building systems make them early targets for recommissioning. Thermostat setbacks, through an automated function to respond to occupancy or peak load hours, are one common manifestation of zonal controls at play in BACSs.

FIGURE 17

Building Control System Comparison Chart

	Flexibility	Energy Efficiency	Ease of Use	Scalability	Cost	Maintenance	Integrarion with Other Systems
Manual Building Zonal Controls	★★	★	★★	★	★	★★	★
Automated Building Zonal Controls	★★★	★★★	★★	★★	★★	★★	★★
Manual Central Controls	★	★★	★★	★★	★	★★	★
Automated Central Controls	★★ to ★★★	★★★	★★★	★★★	★★★	★★	★★
Fully Manual Building Control System	★	★	★	★	★	★★	★
Comprehensive Building Automation Control System	★★★	★★★	★★★	★★★	★★★	★★★	★★★

Flexibility: Measures the system's adaptability to accommodate varying use cases and to adjust to changing occupancy patterns and needs.

Energy efficiency: Represents the system's capability to optimize energy use, thereby reducing energy consumption and costs.

Ease of use: Indicates how intuitive and straightforward the system is for users, especially for building managers and maintenance staff.

Scalability: Evaluates the ability of a control system to scale across asset portfolios.

Cost: A rough assessment of the financial investment required for the system's setup, operation, and potential savings.

Maintenance: The ease of upkeep—more stars indicate a system that is easier to maintain.

Integration with other systems: Demonstrates how seamlessly the control system can be integrated with other building systems or technologies; more stars indicate a system that can work across a wider range of building systems or technologies.

By contrast, centralized controls, which are tied to buildings' main mechanical equipment, cannot be added and removed as easily; but they are more closely linked to BACSs. The communication protocols of centralized controls are generally standardized and immutable. In some instances, such as the extensive process of electrifying structures, outright replacement of centralized controls may be more feasible.

BACSs must reconcile input data from a variety of sources, such as external environmental data in addition to data from both zonal and central controls. The integrity of the data and the degree of interoperability between devices are material to the ability of BACSs to conserve resources and ultimately to the ability of BACSs to interact with the grid.

Figure 17 provides an in-depth comparison of six prevalent building control systems. Each system is evaluated on seven criteria, with an eye toward capacity for enabling grid interactivity, which provides insight into each system's adaptability, energy-saving potential, user experience, scalability, cost-effectiveness, maintenance requirements, and ability to integrate with other systems.

AVOIDING OVERDEPENDENCE ON INDIVIDUAL PROVIDERS' PROPRIETARY ECOSYSTEMS

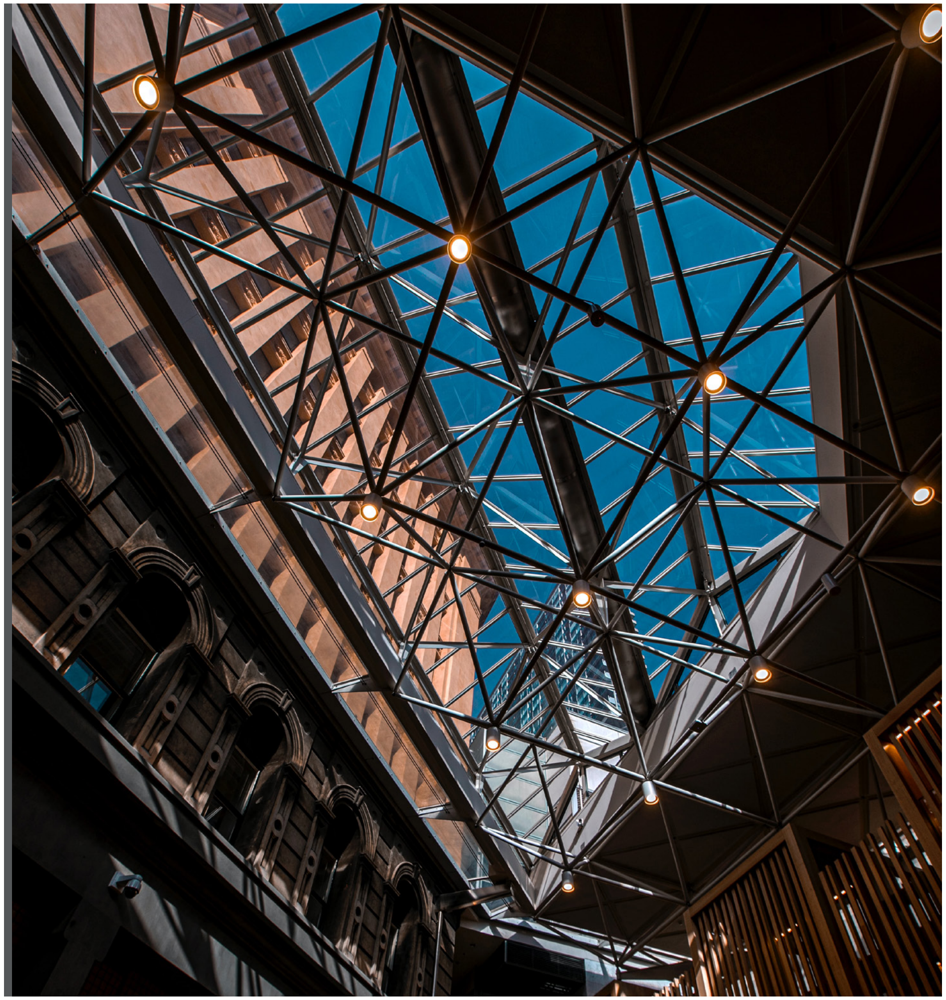
There is a market need for smart building technologies to communicate with each other as opposed to operating in proprietary siloes.

Imagine a smart home system that includes various IoT devices, such as a smart thermostat, smart lighting, and a smart lock. Each of these devices is made by a different manufacturer and comes with its own mobile app and cloud platform. If an occupant wants to integrate all of these devices into a system controlled by a single mobile application, such as Google Home or Amazon Alexa, they must ensure that all devices are compatible with the application. If, for example, the smart lock can only be controlled through its own proprietary application, then, unless the app allows it, the smart lock cannot be integrated with any other device or the mobile application that the occupant intends to use.

The need to use a separate application to control smart locks seems like a minor hindrance at first, but it can quickly become a major source of frustration, especially if there are guests or family members who need access to the home but do not have access to the smart lock app. In that scenario, the smart lock manufacturer has effectively rendered the device useless in the context of the larger smart home system.

Other devices and platforms used throughout multifamily and commercial structures, including electric vehicle charging stations and lighting, pose similar interoperability challenges. Not only is there a need for products that can to talk to each other and interface with BACSs, but there is also a need for these products to easily interface with performance tracking platforms such as ESG data management and benchmarking platforms such as Energy Star Portfolio Manager. However, this imperative is hard to meet because software tools that can "talk to" all other systems (e.g., battery, HVAC) are few and far between and the integration of all these tools has been a major stumbling block for asset managers, building owners, and grid operators alike.

Even hardware and software that do not currently pose interoperability challenges may pose them in the future as devices are updated or discontinued, protocols are introduced or phased out, and manufacturers and software developers create their own proprietary device ecosystems. In this fashion, the growing internet of things does not guarantee more efficient building controls. However, developers and property managers still have a great deal of agency in the market for connected devices. To avoid being locked into provider ecosystems, developers and property managers must anticipate obsolescence, monitor trends in IoT device specifications, and develop procurement standards for connected devices.



PROJECT PROFILE

Tishman Speyer Employs Thermal Energy Storage for Demand Response at Rockefeller Center in New York City

FIGURE 18 Exterior of 45 Rockefeller Plaza in New York City.

Rockefeller Center, located in Midtown Manhattan, is one of the most prominent commercial complexes in the world. Spanning 22 acres and encompassing 19 commercial buildings with approximately 17 million square feet of office space, its iconic art deco envelope hosts tenants such as NBCUniversal, Deloitte, Meriwether Capital, Lazard, and co-owner and operator, Tishman Speyer.

Rockefeller Center faces the same major challenge that other commercial buildings in urban centers face, namely high utility costs. In New York City and other high-density areas, it is difficult for utilities to supply sufficient energy at peak hours, which creates a strong incentive for more efficient, and where possible, self-sufficient buildings. To minimize the cost of heating and cooling, some owners in New York City, including Tishman Speyer, are turning to battery and thermal storage to minimize peak energy consumption.

At Rockefeller Center, demand response is made possible with a combination of battery storage and thermal energy storage for 12 buildings in the complex (see Figure 19). On-site battery storage in tandem with thermal storage fills gaps in energy needs during peak hours for non-HVAC uses and ensures the complex can continue operations when an outage occurs. In addition to redundancy, thermal storage also offers energy efficiency and carbon reduction benefits: the system yields an estimated reduction of 314 metric tons of carbon dioxide per year (a 30 percent carbon emission reduction per kilowatt-hour). Moreover, both storage options benefit from special pricing incentives through the [Con Edison Demand Management Program].

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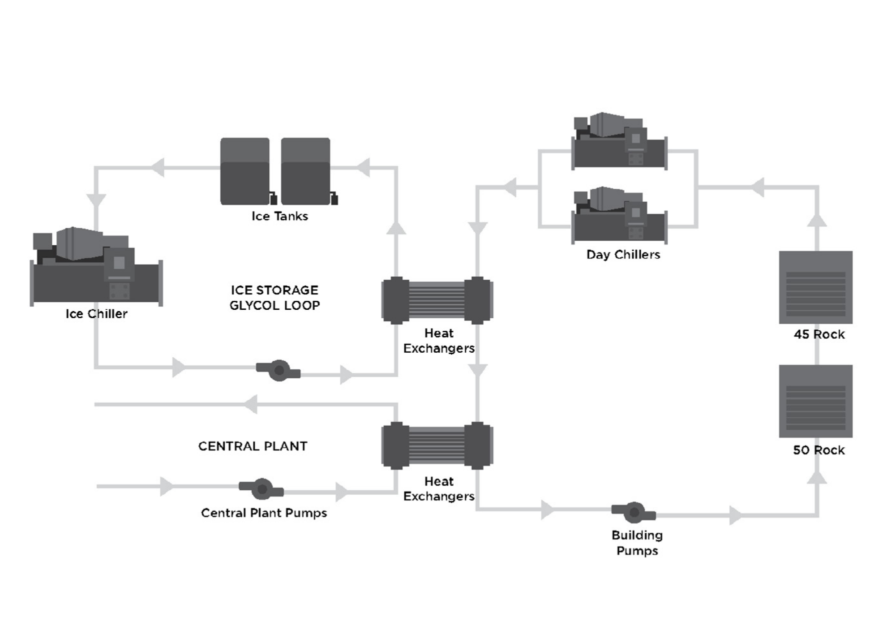

FIGURE 19 Overview of Rockefeller Center's thermal storage system. (Tishman Speyer)

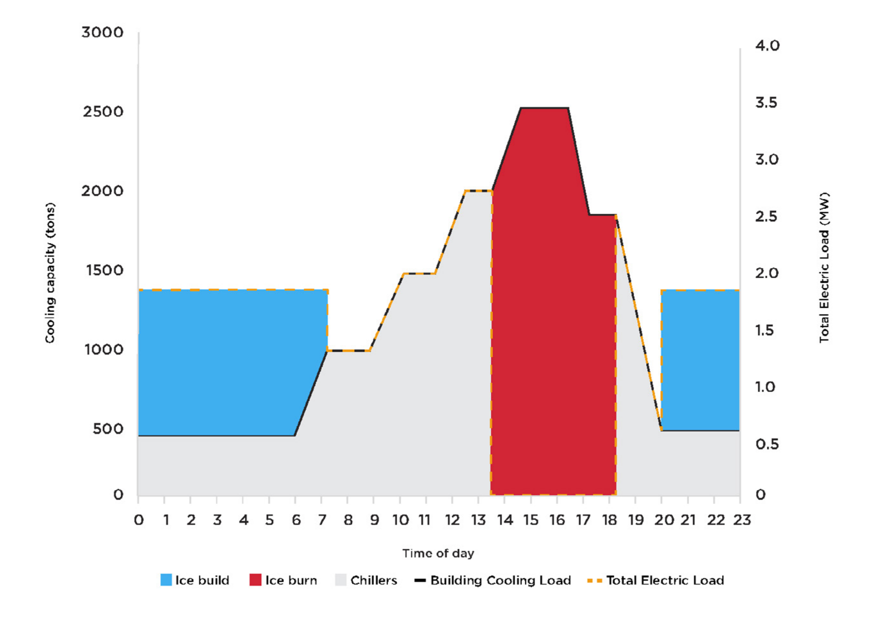

FIGURE 20 Peak demand shifting for Rockefeller Center post-facility upgrade. (Tishman Speyer)

Ice-based thermal cooling systems use electricity during off-peak hours to freeze water in storage tanks. Then, during the day, when the demand for air conditioning is high, the system melts ice to cool the building (see Figure 19). This process uses electricity to create ice when demand and prices are low, and reduces the need for central plant air conditioning when demand and prices are high. An estimated 43 metric tons of carbon dioxide emissions per year are avoided thanks to demand shifting from the thermal cooling system. The system itself was partly funded by the Con Edison Demand Management Program.

Though Rockefeller Center's storage systems yield tremendous benefits to the commercial complex, they also come with some important lessons learned. In addition to fire code–related permitting concerns related to battery storage, ice storage has significant weight, installation, and space requirements (Rockefeller Center's system requires 61 ice storage tanks) that may cause such projects to become infeasible on sites with little square footage to spare.[35]

PROJECT PROFILE

Brookfield Properties’ Digital Twins for Creation and Predictive Analysis

FIGURE 21 1 Manhattan West, site of Brookfield Properties’ first full-scale digital twin launch. (Brookfield Properties)

“We are increasingly using AI-enabled building management systems to help us program our building systems around certain grid conditions, occupancy, and weather, which is exciting. We’re also rolling out a digital twin platform pilot that will help us understand the building’s individual systems contributions to our overall energy performance on a much more granular level.”

—Tim Hewer, vice president, energy and sustainability, Brookfield Properties

Digital twins, or real-time virtual models of objects—ranging from buildings to entire cities—represent a new frontier for capturing, analyzing, and operationalizing new streams of data produced by increasingly connected common devices in buildings. Specifically, a building-scale digital twin might improve day-to-day operations and forecast maintenance needs or contribute to demand response, energy conservation, and physical climate risk mitigation by consolidating and analyzing data from building sensors, grid providers, public agencies, and other contextually relevant sources.

Real estate firms are beginning to explore integration of digital twins into their buildings and across their portfolios. Brookfield Properties, a global asset management firm, is currently piloting a mix of digital twin and automated demand response products to respond to grid conditions in real time (see 1 Manhattan West pictured in Figure 21).

Brookfield’s platforms of choice for its pilots include Nantum OS, developed by Prescriptive Data for automated demand response, and Willow and Brainbox AI for digital twin real-time analysis and insights. These tools are currently undergoing trial phases in select North American markets, informing operations on site. For grid interactivity, it is worth noting that Brookfield’s engineers remain at the helm, taking on the critical task of initiating the response process.

AUTOMATING BUILDING CONTROL SYSTEMS

The real estate sector is not moving toward a paradigm of fully automated building systems. Instead, it is discovering what aspects of buildings can be automated and adopting technology for automation where it is feasible, while benefitting from algorithmically generated recommendations where it is not. The following section discusses the applications, limitations, and pathways to roll out automation systems at the building and portfolio scale to support grid interactivity.

"With the Automated Demand Response program incentives, we were able to improve operating flexibility at four facilities. The installed systems overlaid existing facility controls and allowed for additional capabilities over our existing equipment."

—Sara Neff, former senior vice president, sustainability, Kilroy Realty Corporation, via Pacific Gas & Electric[36]

AUTOMATING DEMAND RESPONSE

By using demand response and efficient building technologies, structures can optimize their energy use and minimize costs. Automated demand response consists of adjusting peak loads and implementing grid-interactive strategies. By aligning energy consumption with periods of increased renewable energy availability, both cost and carbon emissions can be reduced simultaneously. The U.S. Department of Defense outlines three basic components of automated demand response technology:

1. A cloud-based server to distribute market signals from an energy provider according to a standard format;
2. Facility-side endpoints to convey market signals to facility energy management systems or assets; and
3. Firewall technology to perform inspection of all signals.

Each of these components integrated into a sophisticated building automation system can actively manage the electric loads transmitted by way of connection to utility provider data in real time.

Demonstrated by industry leaders and further elucidated by government agencies, the move toward automating demand response has yielded both practical and technological advantages.

Kilroy Realty Corporation sees automated demand response as an opportunity to demonstrate positive collaboration with utilities. That goodwill between developers and utilities can be important, for example, when developing new construction projects that require a certain electric capacity. When taking a systems approach to the challenge, the owner, utility, and other local interests can come together to achieve cobenefits, with the building serving as the "battery" needed for the grid to transition to 100 percent renewable electricity while managing renewables' intermittency.

EMPLOYING ALGORITHM-BASED SYSTEM RECOMMENDATIONS

Recommender systems are algorithms that make relevant suggestions to users. A commonly cited example of such a system is the Netflix recommender algorithm, which offers media suggestions to users of the platform based on their prior activity.[37] Examples of property technology (proptech) applications of algorithm-based system recommendations include the following:

- **Zillow's** Zestimate, which is used to estimate property value based on public records and user-submitted data;
- **CoStar's** market analysis functionality, which analyzes data such as transaction history, property characteristics, and economic indicators to help identify investment opportunities; and
- **SmartRent**, which employs algorithms that analyze data from IoT devices in rental properties and offers insights into tenant behavior and preferences. Based on the data, it recommends adjustments to rent rates and amenities, among other things, to improve tenant satisfaction and increase property owners' return on investment.

Some proptech firms specialize in developing similar systems for BACSs, ingesting data about current environmental conditions (including outdoor temperature, humidity, annual average daily temperature) alongside data from building systems (such as measures of air quality, indoor temperature, operating status of various mechanical equipment including EV chargers, batteries for on-site storage, or generating capacity for on-site renewables). These firms' utilities synthesize building information, sometimes taking into account historical data, and churn out recommendations for configuration of building systems for operators.

Brookfield Properties, specifically, is using one such building management system to help program building systems to respond to certain grid conditions, building occupancy, and weather, and is rolling out an extensive digital twin platform to gain detailed insight into buildings' individual systems' contributions to overall energy performance.

PROJECT PROFILE

AvalonBay Communities Launches Demand Response and Battery Storage for Residential Development in White Plains, New York

FIGURE 22 Apartments at Avalon White Plains in White Plains, New York. (AvalonBay Communities)

The advantages of battery storage are many and include load shifting, renewable integration, and increased reliability and resilience. According to reports by the U.S. Energy Information Administration, battery storage capacity is also increasing from year to year throughout the United States in tandem with uptake of renewable energy generation, indicating increasing interest in including such features in both private development and utility-scale projects.[38] However, growth in on-site battery storage for commercial and residential real estate development is a new frontier for many U.S. jurisdictions, requiring developers to clear more regulatory hurdles to implement.

Owners and developers that are seeking to scale such on-site storage systems will need to be prepared to negotiate local jurisdictions' permitting processes, but as these systems become increasingly common, the process will also become less onerous. Consider, for example, the first grid-interactive indoor lithium-ion battery storage system at Avalon White Plains. Developed by AvalonBay Communities in 2009, this 407-unit apartment complex, located at 27 Barker Avenue in White Plains, New York, was retrofitted with a battery with a 144-kilowatt capacity to assist with peak shaving.

Continued on next page

"Retrofitting an existing building with an indoor lithiumion battery was a challenge given the maturity of the market at the time, former building codes, and lack of education amongst contractors, AHJs, and owners. With the projects like ours complete, as well as continuously rising utility costs and demand response opportunities, it's soon to become much easier, and possibly a standard in major metropolitan areas."

—Alexander Heckman, senior building systems engineer, AvalonBay Communities

As a master-metered building, the Avalon White Plains apartment complex serves as an ideal candidate for implementing demand response and battery storage solutions to enhance energy efficiency, reduce peak demand, and ensure a reliable power supply. The project involved coordination with various stakeholders and regulatory bodies to integrate systems, setting a precedent for similar installations in high-density areas throughout the state.

The successful implementation of demand response and battery storage at Avalon White Plains required coordination with state and local officials, general contractors, electricians, plumbers, and utility providers. The project team specifically had to address fire safety concerns by modifying the sprinkler system, installing additional control safety devices, and building ingress and egress, among other things. The city of White Plains, the New York State Energy Research and Development Authority, and the local utility Con Edison all contributed to the project by updating building codes to accommodate the proposed improvements, conducting technical reviews, and providing assistance with locating funding support as well as with expediting permitting.

Identifying a site that met the project's return on investment criteria and pioneering development was a challenging task because it was among the first of its kind in the state.

This project and others like it help pave the way for future indoor battery installations in other high-density areas, like New York City.[39]

PROJECT PROFILE

Jamestown Applies Energy Management Technologies to Waterfront Plaza Project in San Francisco

FIGURE 23 Waterfront Plaza development. (Jamestown)

Located in San Francisco, California, the Waterfront Plaza office complex, owned and managed by global real estate investment and management firm Jamestown, employs an automated scheduling system that leverages building system performance and occupancy data alongside weather predictions to optimize building operations and energy efficiency while prioritizing tenant comfort.

The complex consists of five buildings designed to meet the firm's portfolio-wide net zero carbon operations target by 2050.[40] Buildings on site are fully electric and make use of energy management technologies, including Nantum OS, an automated demand management product by Prescriptive Data. In addition to automated scheduling for energy conservation at Waterfront Plaza, Nantum OS enables automatic adjustment of building systems according to internal and external conditions, such as occupancy and weather. For instance, when building occupancy fluctuates and demand for cooling and heating shifts, the buildings use air handler ramps to adjust air handler fan speeds for energy savings during times of low occupancy.

The Waterfront Plaza development project presented some familiar challenges to Jamestown in the design and construction documents approval phases. For example, many fire codes are not well equipped to deal with projects that specify battery storage, which makes it difficult to obtain approvals. In this case, due to a special district requirement, the approval process for

Continued on next page

on-site battery storage was particularly onerous. Becca Timms, director of ESG at Jamestown, remarked that “for projected and actual savings, owners can kind of estimate what the savings are, but there aren’t guarantees from vendors.” She emphasized that to ensure “the juice is worth the squeeze” from smart building technologies, it is important for developers to have a thorough understanding of the structure’s system, data dependencies, and any manual input requirements.

There is often consternation about the feasibility of retrofitting older structures with technology that enables real-time monitoring and automation of building systems. The Waterfront Plaza complex, which includes buildings constructed in the 1970s, demonstrates that both new and existing buildings can be primed for grid interactivity. Surprisingly, the process of integrating these connected building systems with the Nantum OS platform was “straightforward,” according to Timms. Jamestown is currently working with Prescriptive Data to implement its offering at an additional building in downtown San Francisco and at a campus in Washington, D.C.

According to Cindy Zhu, director of grid services at Prescriptive Data, Nantum OS also draws from partnerships with several utility providers to demonstrate an automated demand response product that allows for more effective peak shaving and the alleviation of stress on regional grids. The Rudin Management Company’s portfolio of commercial properties in New York City is using Nantum’s automated demand response products to participate in local demand response programs from Con Edison and the New York Independent System Operator.

CREATING STAKEHOLDER BUY-IN: OPERATIONAL PRIORITIES AND OCCUPANT EXPECTATIONS

Stakeholder buy-in from operations staff and building occupants is necessary to enable grid interactivity.

However, operations and maintenance staff may be hesitant to change time-tested practices, and occupants may be similarly resistant to change. Once smart building systems are coordinated with operations staff buy-in, and tenants are educated about and tacitly agree to participate in measures that will improve efficiency and respond to grid demand, then new grid-interactive, efficient building features may see wider uptake and acceptance by both groups.

Building operations and maintenance personnel are characterized by an aging workforce with established workflows. To become adopters of smart building technology, owners must open lines of communication with operations staff to discuss expectations for systems' adoption, function, and maintenance. Further workforce considerations include the need for additional resources and development of a training program that "considers both the type of skills required and the available labor pool in the geographic area."[41] Topics that such a training program might address include the following:

- Safety/OSHA regulations and guidelines
- Equipment operational startup and shutdown procedures
- Normal operating parameters
- Emergency procedures
- Equipment preventative maintenance plans
- Use of proper tools and materials, including personal protective equipment

Anish Tilak, manager of carbon-free buildings at the Rocky Mountain Institute, notes that participatory governance of building systems through the use of polling platforms and the compartmentalization of aspects of building operations helps create comfortable living and working environments.[42]

"As we get buildings to be more dynamic and engaged with the grid, we will need to figure out how to educate and inform the building engineers who have been doing this one way for a long time, and the building's occupants about their involvement and effects of building automation."

—Sarah King, senior vice president, sustainability, Kilroy Realty Corporation

PROJECT PROFILE

AvalonBay Communities Administers a Portfolio-Wide Grid Rewards Program

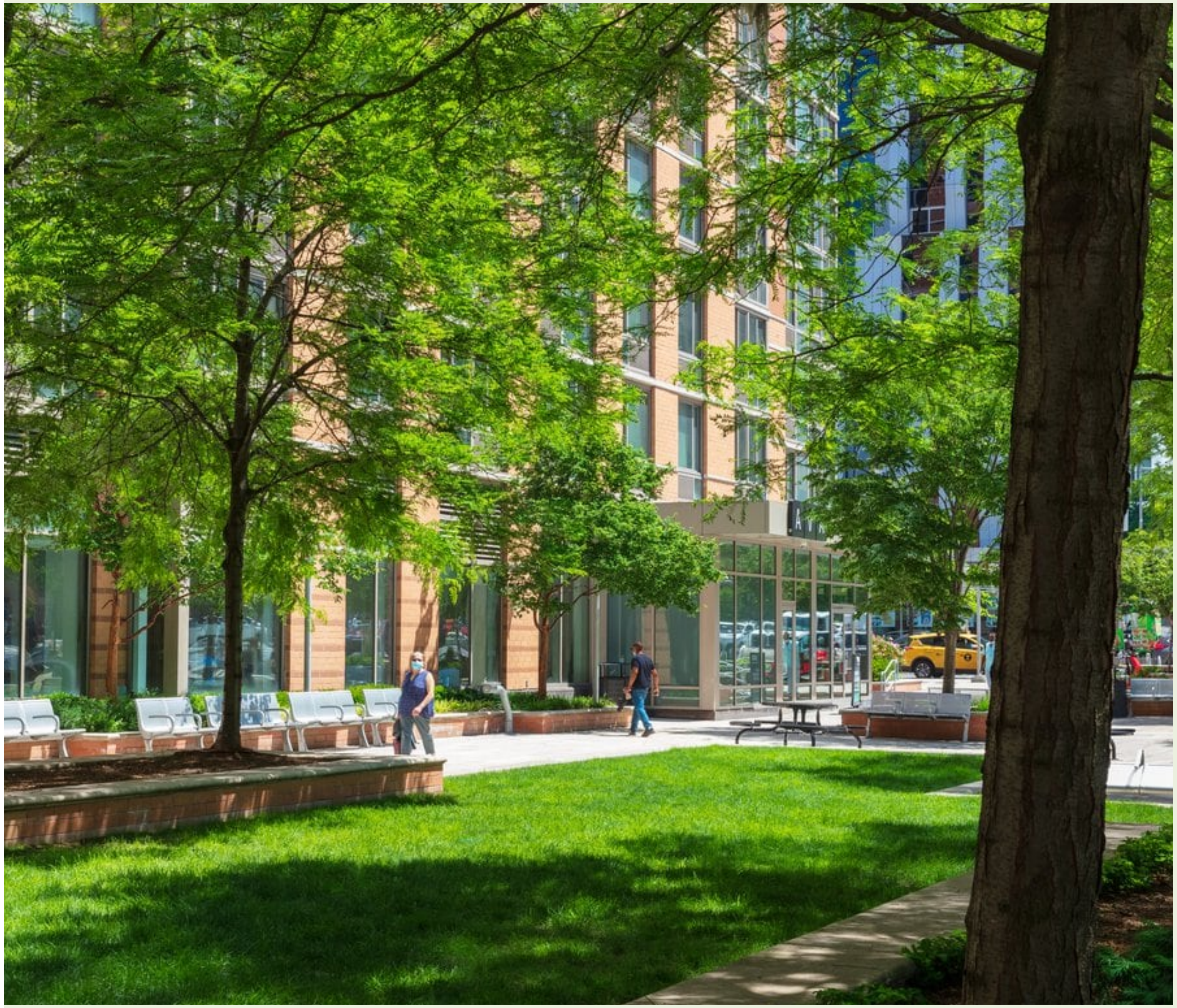

FIGURE 24 Avalon Fort Greene, a multifamily structure with 631 Grid Rewards program–eligible units and 11 percent program enrollment. (AvalonBay Communities)

Owner-led incentive-based programs have proven effective in getting occupants comfortable with aspects of new building energy efficiency and grid interactivity programs. For example, AvalonBay Communities' Grid Rewards program allows residents to benefit directly from the firm's efforts to reduce peak demand. By taking actions like turning off air-conditioning units on certain dates and at specific times, residents receive lower utility bills and program participants save $300 to $500 annually. Figure 25 offers additional insight into the performance of the Grid Rewards program in 2023.

The Grid Rewards program is part of AvalonBay Communities' ESG-focused plan for occupant engagement with the aim of educating occupants about direct impacts of energy consumption. Outreach efforts for this initiative extend into many laterals across the firm and include distribution of both digital and physical media (specifically email and social media outreach, elevator signs, and door hangers).

The program has seen increasing uptake, which AvalonBay attributes in part to a changing residential base to a younger, more sustainability-focused demographic.

Continued on next page

Total Eligible Units	Total Active Accounts	Enrollment	Sample CSRP Event Building Average kW Reduction
5,312	358	7%	7.16

FIGURE 25 Summary of AvalonBay Communities' Grid Rewards program participation across properties engaged in Con Edison's Commercial System Relief Program (CSRP). (Logical Buildings)

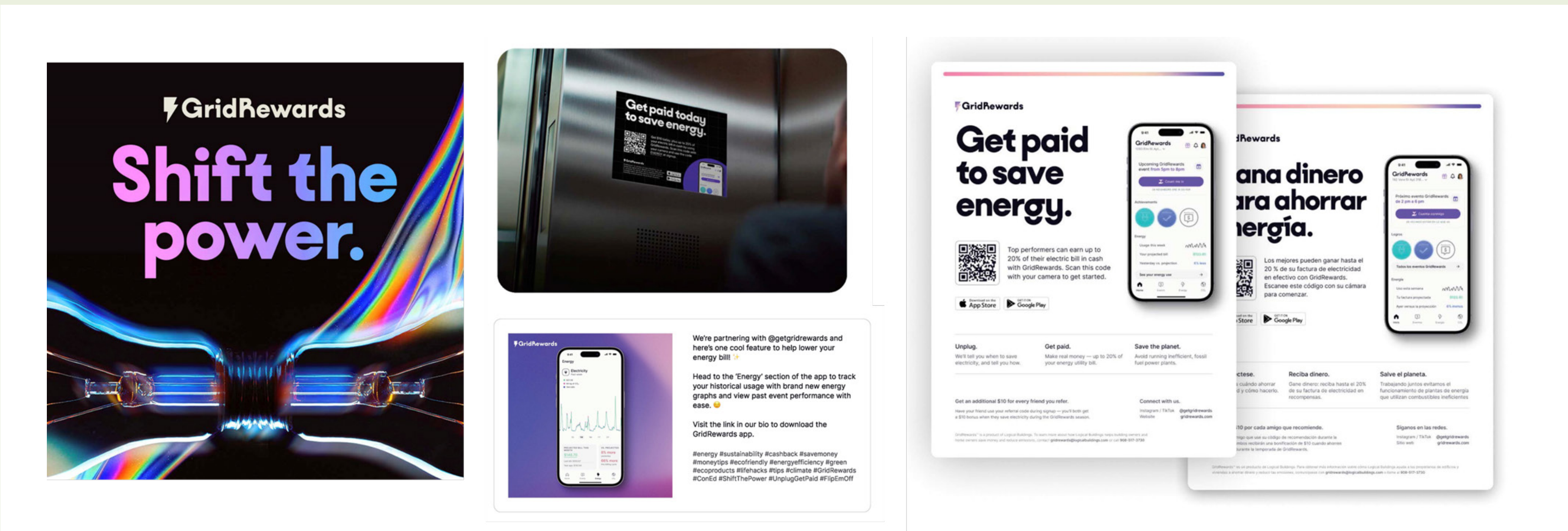

FIGURE 26 Educational and promotional collateral for the Grid Rewards program. From left to right, sample Grid Rewards Instagram post, elevator signage, social media post, and informational one-pager. (Logical Buildings)

ACHIEVING GRID RESILIENCE AT THE PROPERTY AND UTILITY SCALES

Owners and developers are already using combinations of grid interactivity and energy efficiency to enhance resilience against the effects of climate change. Such features allow occupants to resume their daily operations more expeditiously or continue their operations uninterrupted when faced with intensifying or increasing weather events. Grid-interactive efficient buildings to help occupants quickly bounce back after shocks and endure long-term stresses in many ways. However, some of the same ways that grid interactivity and energy efficiency can make structures and communities more resilient can also generate concerns about cost, tradeoffs, and overall capacity.

In reference to concerns around cost, as of 2023, the costs of community, commercial, and industrial solar and wind generation systems have declined, with combined capital and fixed and variable operations and maintenance costs now comparable with that of conventional sources (e.g., natural gas and coal; see Figure 27). With less upfront capital needed to finance these systems and numerous incentive programs available to further offset upfront cost, buildout of such systems is now more feasible.

Among the foremost concerns of building owners and operators about DERs aside from cost is agency over energy supply to on-site building systems for microgrids "embedded" into the broader utility infrastructure.[43] This concern is particularly relevant for microgrids financed through the increasingly popular Microgrid as a Service (MaaS) scheme, in which the utility provider or other public interest partners with property owners to build distributed energy generation capacity—often for institutional uses. Being able to access at all times the energy needed for operations is of paramount importance for owners, operators, and tenants.

Passive design features are helpful in cutting energy use and they can help reduce the amount of power needed to keep buildings up and running while keeping occupants safe and comfortable. At the same time, some energy is still needed to keep building systems online.

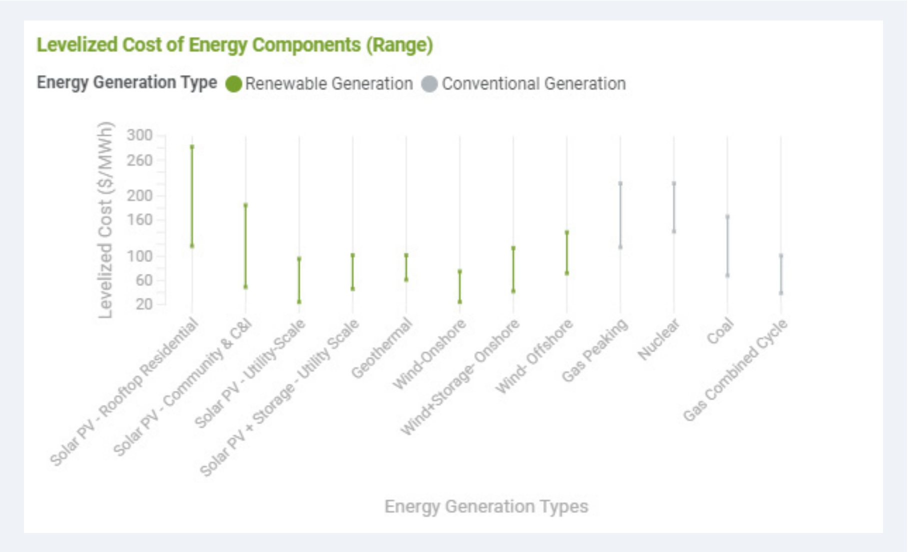

FIGURE 27 Range of levelized cost of energy components (as of 2023), illustrating cost per megawatt-hour of common DERs at commercial/industrial and utility scale. It should be noted that the cost of systems with storage can be significantly higher without subsidization. (Lazard)

Passive features may also hold answers to bridging that final gap of minimum energy input needed for on-site building operations during peak hours while retaining the option to island during widespread outages. In markets that are vulnerable to outages, developers are incorporating community-scale microgrids into development pro formas to enhance resilience, allowing the site to operate even when the utility is down using redundant and/or on-site fuel sources.

Among the challenges to widespread rollout of more resilient grid-connected efficient buildings are the cost and rollout of baseline energy efficiency upgrades and features. Some asset managers are actively struggling to replace single-pane glass windows and install insulation or implement framing construction and waterproofing—let alone install backup power and on-site generation capacity for outages caused by weather disasters. In addition, many developers and owners are hesitant to integrate DERs for some of the same reasons they are hesitant to recommission centralized control systems: upfront cost and uncertainty over return on investment.

OVERCOMING CONNECTIVITY CONCERNS FOR RESILIENCE AGAINST CYBERATTACKS

Carving out a pathway for grid interactivity will require collaboration for asset cybersecurity among tenants, building management information technology teams, building operations staff, and risk management teams.[44]

There is a fine line between an asset and a liability when it comes to grid-interactive equipment in buildings without robust cybersecurity infrastructure. At one time, it was thought that structures were secure because they had the privilege of an "air gap," meaning they were secure because they were disconnected from the internet. The possibility of remote attacks on physical structures entered the knowledge of the public realm as early as 2000 with the Maroochy Shire attack in New Zealand, which affected the local water authority's supervisory control and data acquisition system. The attack, perpetrated by a single disgruntled employee, led to the release of 265,000 gallons of untreated sewage into residential areas and coastal waters.[45]

Vulnerable building systems threaten tenants as well. While a building may perfectly suit the physical needs of occupants, consistently performing with efficiency and precision from day to day, a single misconfigured endpoint or unmonitored account can cause building systems to fail or inflict irreparable damage to tenant businesses once they are compromised. For example, in 2013, the department store Target suffered a loss of $309 million because the HVAC system of just one of almost 1,800 stores was compromised. Thieves were able to "jump" from the building's HVAC system into Target's business network through the building controls system, install malicious software on cash registers in stores across the country, and expose 40 million credit card accounts, causing an additional $200 million of collateral damage to financial institutions.[46]

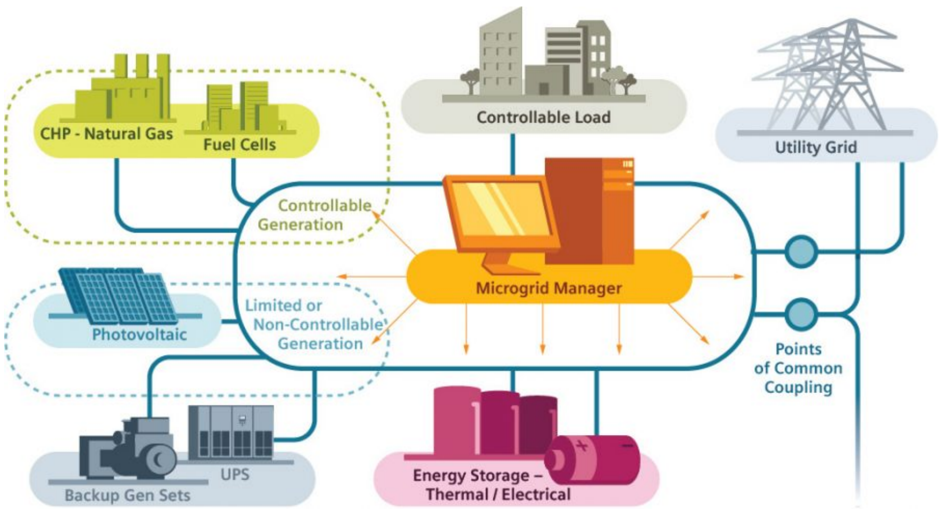

FIGURE 28 An example of a community microgrid. (Siemens)

In today's market, savvy real estate owners are requiring proptech providers to fill out data and governance questionnaires to protect assets from cyberattacks. On the development side, funders are also vetting proptech manufacturers and developers by screening products for known vulnerabilities to ensure software and hardware maintain minimum standards for security. Providers like Prescriptive Data (maker of Nantum OS) are responding in kind by creating built-in alerts for automated smart building hardware notifying building operators and information technology teams of compromised systems and potential intrusions.[47] Venture capitalist firms like Energy Impact Partners are also investing in firms like Dragos that specialize in assessing the vulnerability of IoT and operational technology (OT) devices as well as in monitoring industrial control systems for signatures of known threats.[48]

PROJECT PROFILE

Grid Interactivity Supports Resilience of Babcock Ranch, Charlotte County, Florida

FIGURE 29 Drone photo of Babcock Ranch community facilities and solar arrays. (Babcock Ranch)

When Hurricane Ian tore through central Florida in September 2022, it left a trail of destruction resulting in $12.6 billion in insured losses.[49] In the wake of the storm, many residents in Charlotte County, Florida, found themselves without power or access to other key resources such as potable water and roadways.

The Babcock Ranch planned development, located east of Punta Gorda, was one of the few communities that experienced only minor impacts stemming from the devastating storm. In addition to ensuring the development plan minimized impacts on existing wetlands and ecological systems, which supported nature-based resilience, developers had made investments in community resilience, including many grid-interactive measures, to ensure Babcock Ranch would be well-equipped to deal with storms like Ian. The investments in community resilience included the following features:

- Grid redundancy from additional on-site solar generation capacity and battery systems[50]
- Community microgrid through 74.5 megawatt solar facilities and solar "trees"[51]
- Rooftop solar and energy-efficient buildings

Continued on next page

Some of these features, including the stormwater facilities, grid redundancy, and community microgrids were made possible through partnerships between the developers, Kitson & Partners, the state of Florida, and the utility provider Florida Power & Light. In 2016, a 75-megawatt solar array was constructed on site in partnership with the utility through the donation of more than 400 acres of land nearby. In tandem with rooftop solar, the community is intended to generate more electricity than it consumes. Residential solar is paired with other smart home technologies that optimize buildings' energy use that is all connected to the broader community grid.

The key to the success of this project was developers' focus on capturing the value of community resilience improvements to demonstrate their return on investment. Kitson & Partners attributes the success of the project to this thorough tracking of return on investment, noting that not a lot of subsidies or other incentives contributed to the financing of the development.

In recent years, the term "prosumer" has grown in popularity, tied to the idea that those who originally consumed energy can now play an active role in the energy marketplace. However, in view of the liability posed by vulnerable building control systems, and for building systems to interact with critical infrastructure like that of the power grid, grid-interactive building control systems must first demonstrate their resilience against cyberattacks to grid operators. To this point, Anish Tilak, manager of carbon-free buildings at the Rocky Mountain Institute, remarks the importance of cybersecurity in grid interactivity for both the utility and the building: "Utilities are operating critical infrastructure, and if they are going to get into the business of using your structure as a battery and powerplant then it could have a ripple effect in bringing their systems down. From a building owner's perspective, it's more about privacy, but those concerns can be more easily mitigated."

SCALING GRID INTERACTIVITY AND ENERGY EFFICIENCY ACROSS ASSET PORTFOLIOS

Asset managers and developers are performing audits and deploying pilot studies for physical improvements to facilitate grid interactivity, and occupant engagement programs, with portfolio-wide scaling in mind.

The National Renewable Energy Laboratory offers some considerations for building-site characteristics to identify sites that would be well-suited for piloting grid interactivity in its 2022 ACEEE Summer Study on Energy Efficiency in Buildings conference paper "Quantifying the Value of Grid-Interactive Efficient Buildings through Field Study." The characteristics, both at the building scale and utility scale, may be particularly helpful in selecting and implementing software-based grid interactivity pilots; they are as follows:[52]

Building Scale Considerations

- Location
- Year built
- Building floor area that will be affected by controls
- Building energy use intensity
- HVAC system description (system type, configuration, number of units, etc.)
- Description of controlled end-use systems, such as lighting
- Primary/secondary building use
- Occupancy schedule
- Retro-commissioning projects in the past five years
- Description of building automation system
- Key site selection attributes

Utility Scale Considerations

- Utility rate structure
- Description of any customer sited DERs
- Energy improvements or capital projects within the past two years

Moving from pilot programs to portfolio-wide implementation requires meeting many conditions. For instance, the utility must be willing to share information about energy demand in real time with property owners, and it must have the ability to draw and analyze prosumer energy generating capacity and demand; building owners must be able to prove that the cost of investment in technologies to interface with grid operators' systems will yield a sufficient return.

Property owners and asset managers have greater control over these aspects of structures and, depending on the type of improvement, the cost of recommissioning or updating design specifications for new construction can be nominal, with cost savings more easily articulated. In addition, the use of grid-interactive investments to support overarching building decarbonization will become increasingly valued, as climate risk reporting requirements begin to demand consideration of transition risk and organizations continue to press for attainment of net zero emissions commitments.

Grid-Interactive Buildings for Decarbonization: Design and Operation Resource Guide

This guide, published by ASHRAE's Task Force for Building Decarbonization, outlines practices and guidance to increase building value by reducing carbon emissions, increasing cost savings, and improving resilience. The publication's focus is on commercial and multifamily buildings, however, guidance may also apply to other asset types. Learn more.

Capacity for grid interactivity will vary between jurisdictions. Further efforts to drive adoption of grid-interactive efficient buildings at scale are coming from conversations between utility providers and local authorities undertaken concurrently across jurisdictions and service areas.[53] Moreover, regulatory requirements supporting grid interactivity across the United States and other jurisdictions worldwide are forthcoming, but quite a few already exist (see Figure 30).

FIGURE 30

U.S. State Laws Furthering Grid Interactivity and Demand Response

Examples of laws across the United States requiring grid-interactive building capabilities:

- **Washington State House Bill 1444** requires that electric storage water heaters sold in the state be "grid ready."
- **Oregon Executive Order 20-04** imparts the Oregon Department of Energy with efficiency standards rulemaking authority resulting in appliance standards that promote grid interactivity.
- **California Senate Bill 49** requires the California Energy Commission to encourage grid-interactive appliance development.
- **California Title 24 Building Energy Efficiency Standards** promote demand response measures including demand responsive controls, demand responsive zonal HVAC controls, demand responsive lighting controls, and demand responsive electric message center controls.

Source: NEEP. See also *How to Build a Connected Community: Policies to Promote Grid-Interactive Efficient Buildings and Demand Flexibility*.

FIGURE 31 As part of its move toward net zero energy, Marine Corps Air Station Miramar installed a 250-kilowatt solar carport in April 2010. ([MCAS Miramar](#))

Analysis of Interactivity and Efficiency Benefits in the U.S. Federal Government Portfolio

In 2021, the U.S. General Services Administration published its report [Grid-Interactive Efficient Building Case Studies in the Federal Portfolio](#), which highlights successes, shortcomings, and lessons learned for nine federally owned properties that implement aspects of grid interactivity and energy efficiency. While the report is concerned with assets of the U.S. federal government, the report also offers some broad insight into the challenges of achieving grid interactivity and energy efficiency in structures throughout the United States. To this point, one particularly prescient idea found among the lessons learned for the Marine Corps Air Station Miramar project was that even though projects such as this one, involving the construction of a microgrid system at a military base, do not always result in positive financial returns from the perspective of economic savings, there is still unquantified avoided cost from prevented outages. Overall, the report offers a more nuanced view that has broad applicability for institution and community-scale projects to facilitate on-site energy generation and grid interactivity, namely that such improvements should be made after assessing site physical conditions and operations requirements in order for them to pay dividends.

FIGURE 32 A Marine inspects the solar carport at Marine Corps Air Station Miramar. ([MCAS Miramar](#))

CONCLUSION

Grid-interactive efficient buildings are not just the future—they represent a present need. Owners, developers, and asset managers are currently navigating complex and evolving operational challenges, environmental responsibilities, and financial objectives. Thankfully, there are many ways for the real estate industry to work with utility providers and other stakeholders to shape a new paradigm and **get smart** to enable grid-interactive efficient buildings.

Today, the U.S. Department of Energy and other state and local jurisdictions across the country are also collaborating with the real estate industry to deploy community-scale microgrid projects that not only include on-site generation from renewables, but also supply residents with equitable access to affordable power and energy-efficient buildings.[54] Although there are programs nationwide, such as the Inflation Reduction Act's Weatherization Assistance Program and the Low-Income Home Energy Assistance Program (LIHEAP) of Washington, D.C., that seek to lower low-income residents' utility bills and as a result remove a major financial burden that comes from living in older, inefficient buildings, this collaborative effort is particularly innovative because it contemplates the installation of technologies that enable both grid interactivity and energy efficiency.[55] **In this fashion, the real estate industry is making major strides toward a future where grid-interactive buildings are no longer an unattainable ideal but rather a minimum standard for all**.

"Grid-interactive efficient buildings are a critical piece of decarbonization because they enable flexible demand, improve our use of clean renewable energy, and reduce utility bills while providing high performance, comfortable, and resilient commercial and residential environments. They can save hundreds of billions of dollars in power system costs, reduce carbon emissions, and relieve stress on the grid by 2030."

—Mary Ann Piette,
associate lab director, energy technologies area, Lawrence Berkeley National Laboratory

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NOTES

INTRODUCTION: DEFINING GRID INTERACTIVITY EMPIRICALLY AND ANECDOTALLY

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PART I: THE BUSINESS CASE FOR GRID INTERACTIVITY

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PART II: CONSIDERATIONS FOR IMPLEMENTATION

Integrating Distributed Energy Resources and Energy-Saving Improvements

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APPENDIXES

APPENDIX I

Supply Side Glossary

Asset Resilience

The ability of a system or building to adapt, recover, and maintain function despite external stressors or shocks, such as climate change or cyberattacks.

Climate resilience
The capacity of a building to adapt to climate-related hazards and to maintain functionality under changing environmental conditions.

Cybersecurity
The practice of protecting computer systems, networks, and information from unauthorized access, theft, or damage.[56]

Backup Generation

Alternative energy sources or systems that provide power during an outage or when the primary energy source is unavailable.[57]

Energy Storage

The practice of storing excess energy to be used later when needed, improving the efficiency and reliability of the energy system.[58]

Battery storage
Using batteries to store electrical energy in the form of chemical energy, which can be discharged as electricity when required. Specific grid-interactive battery storage strategies might include frequency response.

Flywheel storage
Flywheels are a type of rotor that is accelerated with electricity to store kinetic rotational energy. When the energy is needed, the spinning force of the flywheel is used to turn a generator.[59]

Frequency response
An ancillary service that maintains grid frequency around a particular threshold (60 Hz) that can be facilitated through optimization of buildings' charging or discharging batteries.

Heat pump water heaters
A heating device produces hot water outside or inside an insulated tank. Hot-water heaters serve the dual function of heating water and storing energy, and the water can be heated with renewables and used in tandem with generation systems to address intermittency.[60]

Ice or chilled water storage
During times of low demand, electricity is used to produce chilled water or ice; during periods of peak electricity consumption, the stored water or ice is used for cooling.[61]

Off-peak supercooling
This practice shifts load from cooling buildings during peak hours to off-peak hours by preemptively pumping in cooler-than-normal air. This method may ultimately consume more total energy, but it is beneficial from a demand management standpoint.

Superconducting magnetic energy storage
Systems store energy in a magnetic field generated by a current traveling through a superconducting coil. Because the electric current is able to pass through the coil with no resistance, it can be stored within the system until it is discharged. These systems are still uncommon even at the utility scale.[62]

Thermal energy storage
Electricity is used to produce thermal energy, which can be stored until it is needed (see also *heat pump water heaters, ice or chilled water storage, and off-peak supercooling*).[63]

Distributed Energy Resources

Small-scale energy resources usually situated near sites of electricity use, such as rooftop solar panels and battery storage.

Hybrid Systems

Combinations of energy generation and storage technologies.

Microgrid

A localized energy system that can operate independently or in conjunction with the larger grid and provides enhanced resilience, flexibility, and control over energy supply and consumption.

On-site Generation

The production of energy at the location where it is consumed, using various energy sources and technologies, which minimizes the need for transmission and distribution infrastructure.

Combined heat and power systems

A type of distributed generation involving concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy including fuel cells, gas turbines, microturbines, absorption chillers, and steam turbines.[64]

Fuel cells

Fuel cell power systems are efficient on-site generators that use electrochemical processes instead of combustion to produce electricity. These systems can also provide thermal energy for heating or cooling. Demonstrations have shown they can cut energy costs by 20 to 40 percent compared with traditional sources.[65]

Geothermal

Tapping into the Earth's heat to produce electricity or for heating and cooling purposes

On-site renewables

Renewable energy sources—such as solar, wind, and geothermal—that are generated on the premises of a grid-interactive efficient building.

Photovoltaic systems

Harnessing sunlight using photovoltaic (PV) panels to produce electricity or to generate heat for water or space heating.

Wind turbine systems

Generating electricity using wind turbines that convert the kinetic energy in wind into electrical power.

Weatherization and Efficiency

Measures implemented to improve a building's thermal performance, reduce energy consumption, and increase comfort by protecting it from the elements.

APPENDIX II

Demand Side Glossary

Asset Resilience

The ability of a system or building to adapt, recover, and maintain function despite external stressors or shocks, such as climate change or cyberattacks.

Climate resilience

The capacity of a building to adapt to climate-related hazards and to maintain functionality under changing environmental conditions.

Cybersecurity

The practice of protecting computer systems, networks, and information from unauthorized access, theft, or damage.

Automated Controls Systems

Technology that automatically adjusts energy consumption based on predefined parameters, such as time of day, building occupancy, or temperature.

Automated demand-limiting

Systems that automatically reduce energy consumption during periods of high demand, helping to reduce peak loads on the grid.

Automated lighting

Systems that control lighting operation based on factors like occupancy, time of day, or task requirements.

Automated precooling, preheating

Systems that adjust temperature settings in advance of periods with high energy demand or fluctuating outdoor temperatures to reduce peak energy consumption.

Optimized airflow controls

Systems that automatically adjust airflow to maintain comfort and indoor air quality while minimizing energy consumption.

Daylight Sensors

Devices that automatically adjust artificial lighting levels based on the amount of natural light available.

Demand Response

A program or strategy that enables electricity consumers to reduce their demand during peak periods, which provides flexibility and reduces the burden on the grid.

Energy Efficiency

Measures and technologies that reduce the amount of energy required to perform a given task, which results in lower energy consumption and costs.

Efficient HVAC systems

Heating, ventilation, and air conditioning (HVAC) systems that are designed to consume less energy while maintaining comfort and indoor air quality.

Efficient lighting fixtures

Lighting technologies that provide the same or better illumination using less energy than traditional fixtures.

Weatherization

Measures that improve a building's thermal performance, reduce energy consumption, and increase comfort by protecting it from the elements.

Energy Storage

The practice of storing excess energy to be used later when needed, improving the efficiency and reliability of the energy system.

Battery storage

Using batteries to store electrical energy in the form of chemical energy, which can be discharged as electricity when required. Specific grid-interactive battery storage strategies might include frequency response.

Flywheel storage

Flywheels are a type of rotor that is accelerated with electricity to store kinetic rotational energy. When the energy is needed, the spinning force of the flywheel is used to turn a generator.[66]

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Systems store energy in a magnetic field generated by a current traveling through a superconducting coil. Because the electric current is able to pass through the the coil with no resistance, it can be stored within the system until it is discharged. These systems are still uncommon even at the utility scale.

Thermal energy storage
Electricity is used to produce thermal energy, which can be stored until it is needed (*see also heat pump water heaters, ice or chilled water storage, and off-peak supercooling*).[69]

HVAC Performance Data

Information on the energy consumption and efficiency of an HVAC system that is used for analysis and optimization.

Microgrid

A localized energy system that can operate independently or in conjunction with the larger grid and provides enhanced resilience, flexibility, and control over energy supply and consumption.

Whole-Building System Power Meters

Devices that measure and report the total energy consumption of a building, enabling energy management and conservation efforts.

Submeters for Chillers and Air-Handling Unit Fans

Devices that monitor and report energy use for specific HVAC components.

Temperature Sensors

Devices that monitor indoor and outdoor temperatures.

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