The Business Case for Investment in Upgrades and Features to Support Grid interactivity in New and Existing Buildings

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ABSTRACT

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. To that end, achieving grid-interactivity and improving energy efficiency will be integral to the market transformation that must occur for the built environment's movement toward this paradigm.

This paper outlines the value of grid interactive, efficient buildings to the real estate sector in the form of carbon and utility bill cost reductions, business continuity and asset resilience, improved occupant comfort, and long-term asset viability. Drawing from case studies across various regions, this paper provides tangible evidence of successful implementations and the myriad benefits they bring to address key considerations around implementation associated with physical features, automation, stakeholder buy-in, resilience, and scalability. Though primarily focused on U.S. markets, the paper poses universally applicable solutions to overcoming challenges associated with grid-interactivity and energy efficiency, and emphasizes the urgency with which the buildings industry can (and must) act to plan and build for grid interactivity and energy efficiency.

Introduction

The World Green Building Council notes that buildings are currently responsible for over 39 percent of global energy-related carbon emissions (WGBC, 2019). As awareness about the massive contribution made by buildings to global CO_2 emissions grows, the real estate industry is challenged to address emissions throughout building lifecycles. Some real estate firms have risen to this challenge in recent years and made pledges to reduce building and portfolio carbon emissions to a net zero standard. Some examples of real estate companies have made such commitments to net zero goals and science-based decarbonization targets include:

- **Equinix Inc. (Real Estate Investment Trust)**. 50% reduction in absolute Scope 1 and 2 greenhouse gas emissions and 50% reduction in absolute Scope 3 greenhouse gas emissions from fuel- and energy-related activities by 2030 from a 2019 fiscal year baseline (Rosacia, 2021),
- **Cushman and Wakefield**. 50% reduction in absolute Scope 1 and 2 greenhouse gas emissions by 2030 from 2019 baseline (Rosacia, 2021), and
- **Empire State Realty Trust, Inc**. Committed to achieve net-zero across portfolio by 2035 and for the Empire State Building in New York City by 2030 (Rosacia, 2021).

Meeting ambitious targets for emissions reduction set by firms and regulators requires widespread and collaborative action between private real estate interests and public entities.

In addition to mitigating emissions, the real estate industry is also forced to contend with new adaptation imperatives stemming from damage already wrought by past emissions. The financial outlook for real estate in areas vulnerable to climate hazards is bleak, with the International Renewable Energy Agency (IREA) reporting that $7.5 trillion of real estate assets are at risk of becoming "stranded" assets, cementing the need for transformational change in the sector toward more resilient buildings and emissions reductions (IREA, 2017).

These new imperatives for adaptation and mitigation can be achieved in part by seizing on new opportunities for improved optimization and responsiveness through energy efficiency measures facilitated in part through grid interactivity. Accomplishing this in turn requires the industry to embrace a shift in approach to design, construction, management, and operations of buildings.

The Urban Land Institute poses a six-step approach for real estate's journey to net zero across portfolios (see Figure 1):

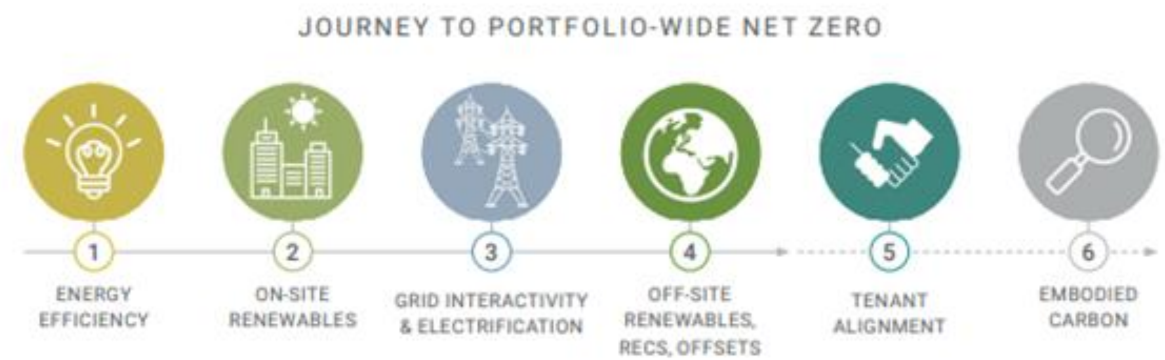

Figure 1. Real Estate's Journey to Portfolio-wide Net Zero by 2050. *Source*: ULI Net Zero Compendium.

The process begins by focusing on energy efficiency, recognized as the most economical means for reducing carbon emissions. Following this, emphasis shifts to implementing on-site renewable energy sources, enhancing the building's interaction with the energy grid in conjunction with its electrification, and addressing any residual emissions through investments in off-site renewable energy, Renewable Energy Credits (RECs), and carbon offsets.

Grid interactive, energy efficient buildings, defined as buildings that integrate 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 are key players in this process (Carmichael, et. al., 2019).

Grid interactivity Through a Real Estate Industry Lens

The real estate industry is a unique segment of the built environment in that it is the only sector for which the buildings are the business. This is compared to retail malls, schools, or hospitals, for example, where the business is selling widgets, teaching students, or healing people.

The expression "buildings as a business" reflects a perspective that views buildings not just as physical structures but as entities that generate revenue, provide value, and contribute to a business's overall financial strategy (BOMA). This concept has gained traction with the advent of new technologies and sustainability practices, which have expanded the ways in which buildings can contribute to a business model.

Further, buildings are increasingly viewed as a means of generating revenue beyond traditional leasing. When it comes to communicating the value-add of grid interactivity to building owners, developers, and other key players in the real estate industry (see Table 1), features that contribute to revenue streams or quantifiable avoided costs are often most compelling. Guidehouse Insights' latest data indicates that buildings equipped for utility demand response programs, which also incorporate solar generation and energy storage, are expected to see a global annual growth rate of nearly 13% from 2022 to 2031(Walton, 2023). These developments indicate declining opportunity costs for adoption by owners and developers and demonstrate increasing uptake and interest.

Table 1. Key real estate sector stakeholders in grid interactivity

Owners	Owners may be individuals or companies that own income-generating real estate across a range of property sectors. Owners seek to optimize energy usage, reduce costs, and increase resilience of properties to increase asset value and returns.
REITs	REITs are a subset of owners with a particular non-taxable trust structure.
Developers	Developers specialize in developing new real estate projects, including residential, commercial, and mixed-use developments. Developers seek to maximize value to prospective buyers who are increasingly concerned with sustainability and efficiency while balancing cost.
Construction	Construction firms are responsible for the building real estate projects including handling procurement for building systems. While they seek to minimize cost, they are also incentivized to procure systems that are well integrated and easy to manage. Legacy building systems lack such functionality, which incentivizes procurement of smart building technology.
Property managers	Property managers handle day-to-day operations of real estate properties, including maintenance, tenant relations, and financial management. In addition to bringing value to owners, property managers benefit from smart building systems through increased agency over energy consumption as well as from grid interactivity through reduced utility costs.
Facility managers	Facility managers oversee the daily operations of building equipment, including elevators, HVAC systems, and lighting, in real estate properties. They typically maintain long-term positions and possess extensive expertise in building systems.
Private equity and investment firms	Private equity and investment firms in real estate directly, or at scale through various types of real estate funds, benefit from the value-add of efficiency and sustainability in a similar fashion as owners and REITs.
Architects and Designers	Architects and designers are involved in designing new buildings and refurbishing existing ones. They can incorporate smart building systems in their designs to enhance functionality and energy efficiency, providing future-ready solutions.

Engineers	Engineers provide the engineering expertise needed for construction and development projects, including structural, mechanical, electrical, and civil engineering services. They may advise on the integration of smart technologies in building projects to improve performance and sustainability.
Sustainability consultants	Sustainability consultants advocate for sustainable and resilient building practices, including the potential use of smart technologies, to help clients achieve environmental and operational goals.
Technology Providers	Technology providers offer smart building technologies, property management software, and other technology solutions for the real estate sector.
Government and regulatory bodies	Government and regulatory bodies create regulations that can require or incentivize adoption of smart building technologies, influencing sustainable development practices across the real estate industry.

Participation in demand response programs alone can unlock significant revenue streams such as energy bill reduction, demand charge reduction, and revenue from sale of electricity back to the grid (Carmichael, 2018; DOE 2018). A 2023 report by the National Renewable Energy Laboratory outlines potential utility bill savings from state to state from participation in various demand response activities. While potential emissions and cost savings vary significantly by jurisdiction and geography, building owners in some states can recoup thousands of dollars per year for cooling energy efficiency and precooling activities as well as lighting efficiency and demand flexibility measures. Consider, for example, one study by the National Renewable Energy Labs demonstrating the savings and emissions reduction potential of energy-efficiency measures in large office buildings, particularly through improvements in lighting efficiency, demand flexibility, and cooling measures (see Table 2).

Table 2. Top 10 States for annual customer bill savings (Single Building, $/yr) and carbon emissions reductions (kg CO2 per Building/yr) for large office buildings (>50,000 sf) throughout the United States

		Median Annual Potential Bill Savings (Single Building, $/yr)				Carbon Emissions Reductions (kg CO_2 per Building/yr)			
Rank	State	Lighting Efficiency, Demand Flexibility	Cooling Measure Energy-Efficiency and Load Shedding	Cooling Energy Efficiency and Precooling	Total	Lighting Efficiency, Demand Flexibility	Cooling Measure Energy-Efficiency and Load Shedding	Cooling Energy Efficiency and Precooling	Total
1	MS	$8,840	$2,580	$710	$12,130	28,140	9,190	4,900	42,230
2	TX	$7,760	$2,460	$580	$10,800	22,160	7,650	4,100	33,910
3	ME	$3,800	$3,940	$3,040	$10,780	3,880	680	200	4,760

4	AL	$8,150	$2,380	($160)	$10,370	27,180	8,070	1,850	37,100
5	FL	$7,180	$2,020	$1,040	$10,240	20,020	9,360	6,560	35,940
6	WV	$6,220	$2,580	$1,320	$10,120	31,930	5,170	1,300	38,400
7	MN	$8,620	$1,320	$100	$10,040	24,840	3,630	1,410	29,880
8	GA	$8,200	$2,360	($590)	$9,970	25,310	7,820	1,710	34,840
9	AR	$7,990	$2,280	($350)	$9,920	27,520	9,460	4,210	41,190
10	LA	$7,090	$2,250	$440	$9,780	21,990	7,860	3,850	33,700

Source: McLaren et.al., 2023.

Grid interactive efficient buildings incorporate energy efficiency, energy storage, renewable energy, and load flexibility technologies enabled through smart controls. By optimizing these elements, buildings can reduce operating costs, optimize investments, and provide access to new revenue streams (RMI, n.d.; Schwartz and Leventis, 2020). For a sector characterized by the acquisition, ownership, operation management, construction, refurbishment, development, and provision of services relate to land and buildings as a business (Wechsler and Edwards, 2013), the real estate industry should naturally be interested in grid interactivity as a potential source of revenue, particularly given the strong business case posed by potential benefits, namely, utility bill cost reduction, business continuity and asset resilience benefits, improved occupant comfort, long-term asset viability, and carbon reduction.

Each of the tenets of the business case for grid interactivity directly contributes to the overarching achievement of decarbonization and the associated carbon reduction benefits, ultimately enabling firms to manage emissions more effectively. Upgrades and features for grid interactivity at the property scale for new and existing buildings can be justified to real estate professionals more easily when viewed through this lens.

Understanding the benefits that grid interactivity offers to real estate sector actors is key to motivating the transition towards more sustainable practices. However, translating these benefits into implementation within the real estate sector requires knowledge of the physical and digital infrastructure components that enable grid interactivity. Figure 2 offers a high-level view of the many elements that facilitate this transition.

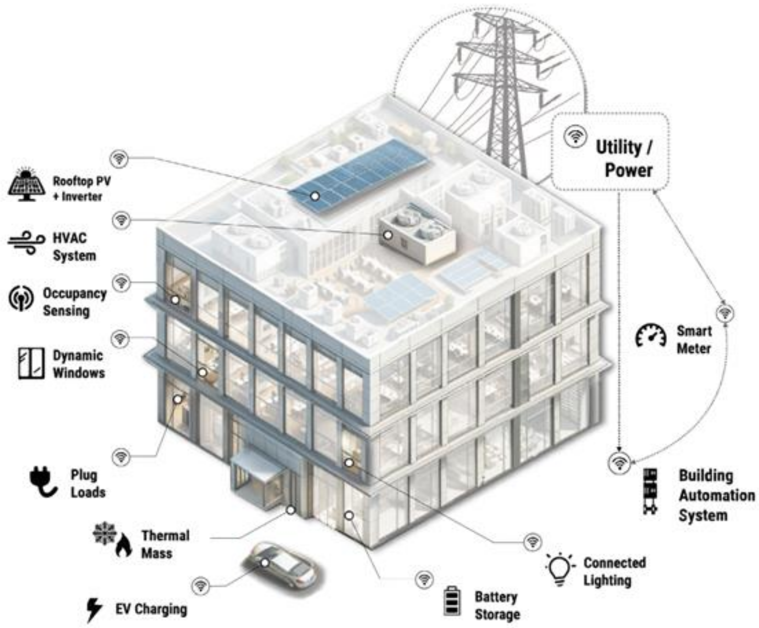

Figure 2.- Example of a grid interactive, energy-efficient building derived from Navigant Consulting figure featured in US DOE Grid-interactive Efficient Buildings factsheet; base image generated using Midjourney. *Source*: Plass, Kokernak and Shantz, 2024.

Subsequent sections of this paper address the connection between these physical improvements and five tenets of the real estate industry's business case for constructing and retrofitting for grid interactivity and energy efficiency.

Outlining A Business Case for Investment in Technological and Physical Improvements for Grid interactivity

The following section addresses the business case for enhancing grid interactivity through technological and physical upgrades such as rooftop solar, HVAC, dynamic windows, and more. It examines how these components can support strategic investment in grid interactivity, guided by five key business case tenets:

- **Utility bill cost reduction.** Grid interactivity allows for more efficient energy management, which leads to lower energy costs from reduced energy usage and reduced peak demand, as well as participation in utility demand response incentive programs for further utility cost reductions.
- **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.
- **Improved occupant comfort.** Grid interactivity and energy efficiency increase occupant comfort through use of smart controls and sensors.

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

Utility Bill Cost Reduction

> "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." - Jake Elder, vice president, Energy Impact Partners

Across all asset classes, implementing physical and digital grid interactive efficient infrastructure on-site can generate cost savings in addition to new revenue streams. Depending on the asset class and utility provider there can be substantial differences between rates between single family residential and commercial real estate properties. For instance, rates may be lower for commercial real estate properties versus single family residential properties, but commercial rates often have different pricing schemes. Utility providers may also apply demand charges in addition to standard rates depending on grid conditions.

There are many possible features that support utility bill cost reduction at the asset level. "Smart" buildings sporting integrated building controls systems can realize 30-50% savings in existing buildings that are otherwise inefficient (King, 2017). Basic interventions such as installing digital devices and systems that monitor and control usage in small appliances such as air conditioners and water heaters can yield energy savings of up to 40% for little or no cost, with demand optimization techniques offering further benefits (Chadwick, et.al, 2023).

Business Continuity and Asset Resilience

> "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

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Extreme weather events, including storms and heatwaves, present significant challenges to electrical infrastructure, often overloading or damaging it and resulting in grid failures. It's estimated that approximately 83% of reported major power outages between 2000 and 2021 in the United States can be attributed to weather-related events, resulting in profound losses impacts on business activities (DOE, 2023). These outages not only disrupt communication systems but also pose public health risks by compromising the functionality of critical infrastructure, in addition to causing severe economic consequences (Zamuda et.al., 2018). In response to these challenges, integration of smart grid systems, distributed energy resources (DERs), microgrids, and enhanced weather forecasting and early warning systems have been shown to mitigate the impacts of weather-related power disruptions (DOE, 2023).

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

Despite perceptions that grid-interactivity results in unhappy occupants, it actually can result in improved occupant comfort. Research indicates that indoor environmental quality, including factors like thermal comfort, noise, light, and air quality, contribute to occupant health, comfort, and productivity (Al horr, et.al., 2016; Bueno et.al., 2021). Real estate owners of buildings with features that prioritize occupant comfort also benefit from higher tenant satisfaction and retention (Wallin, 2023).

Features such as blinds that can be adjusted automatically and heating and cooling that responds to internal and external environmental conditions also contribute to optimizing energy consumption and balancing load. According to one article on occupants and grid interactive efficient buildings by the Lawrence Berkeley National Laboratory, "Depending on the building type, climate, and degree of automation in operation and controls, occupants could increase or decrease energy use by a factor of up to three for residential buildings [Andersen 2012], and increase by up to 80% or reduce by up to 50% for single-occupancy offices [Lin and Hong 2012]. One simulation study…also estimated occupant behavior measures have a 41% energy savings potential for office buildings"(LBL, 2018).

Although past sentiment among tenants and facilities managers alike has been that automated controls would achieve energy efficiency at the expense of occupant comfort, modern systems, when installed in tandem with zonal controls that allow occupants to make adjustments to their immediate surroundings, defy these assumptions.

Long-term Asset Viability

Addressing transition risk at the asset level through grid interactivity can mitigate a significant amount of risk and support long-term asset viability. By leveraging asset management for risk mitigation, businesses can reap benefits such as enhanced efficiency and passive cost savings (Hock, 2021). At the same time, implementing asset management strategies, including those related to grid-interactivity, allows businesses to ensure continuity and lower maintenance and repair costs (Hock, 2021).

The U.S. Environmental Protection Agency's Renewable Systems Interconnection (RSI) study identifies grid-integration issues as, "a necessary prerequisite for the long-term viability of the distributed renewable energy industry." The study notes that such integration is necessary to addressing the constraints or requirements that arise from the need to maintain a reliable electricity grid (McGranaghan, et.al., 2008). Thus, by helping the grid, grid interactive buildings are helping themselves by supporting a low-risk power supply.

Laws, policies, and programs adopted in recent years contribute to the ability of owners and developers to capitalize on grid interactive buildings. Although there is variability in government and organizational priorities when it comes to defining the role of grid interactivity in decarbonization, that has not stopped progress in recent years toward grid interactive, efficient buildings. For instance, in early 2024, the U.S. Department of Energy part 1 of a draft definition for zero emissions buildings, targeting non-federal structures, specifies high energy efficiency, no on-site emissions from energy use, and exclusive use of clean energy but conspicuously omits grid interactivity (Federal Register, 2024).

To wit, the U.S. Department of Energy (DOE) released a National Roadmap for Grid interactive Efficient Buildings (GEBs) in 2018, outlining 14 recommendations to address the top barriers to GEB adoption and deployment (DOE, 2021). These recommendations cover areas such as expanding funding and financing options, developing GEB design and operation decision-making tools, and supporting GEB deployment through federal, state, and local enabling programs and policies.

Furthermore, federal agencies including the US DOE Building Technologies Office (BTO) are also making a foray into grid interactivity for federal assets through the Grid interactive Efficient Buildings Initiative (DOE, 2021). States are also adopting building energy codes and appliance standards that require grid interactive functionality for appliances, homes, and buildings. For instance, Western states like Oregon, California, and Washington are leading the charge while regional stakeholders in the Northeast and Mid-Atlantic regions adopt similar approaches (Salvatore, 2021).

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

Grid interactivity in buildings can significantly reduce carbon emissions by allowing buildings to interact with electrical power grids in a dynamic, two-way relationship. This interaction enables buildings to respond to changing grid conditions and time-varying carbon emission rates, thereby reducing overall demand and greenhouse gas emissions (Burns, 2023;

Mandel and Stone, 2019). By optimizing energy consumption and generation through smart technologies, renewable energy sources, and energy storage systems, grid interactive buildings can actively engage with the energy grid, leading to a more sustainable, resilient, and energy-efficient built environment (Mandel and Stone, 2019). Initiatives such as load shedding, shifting major loads to different times, and employing on-site distributed energy resources contribute to reducing demand on the grid, lowering building operating costs, and supporting load flexibility initiatives (IFMA, 2023). Ultimately, integrating grid interactivity in buildings is a critical component in the decarbonization process and plays a key role in achieving significant reductions in carbon emissions (Burns, 2023; Radoff, 2023).

For general reference, see Table 3 which categorizes various technologies and measures into typologies based on their impact on grid interactivity and business case benefits. Typologies include appliances, fixtures, and equipment, building envelope features, distributed energy resources (DER), energy optimization and management tools, energy storage systems, HVAC, sensor systems, and systems for energy management. Each technology is evaluated against business case criteria, namely, utility bill cost reduction, business continuity and asset resilience, improved occupant comfort, long-term asset viability, and carbon reduction.

Table 3. Example measures ordered by typology for grid interactivity and corresponding business case benefits

	Example Measures	Utility Bill Cost Reduction	Business Continuity and Asset Resilience	Improved Occupant Comfort	Long-term Asset Viability	Carbon Reduction
Appliances, Fixtures, and Equipment	Electric thermal storage heaters	X	X	X	X	X
	Dimmable lighting fixtures	X	X	X	X	X
	EPA ENERGY STAR connected products	X	X	X	X	X
	Electrochromatic window glass	X	X	X	X	X
	LED lighting	X		X	X	X
	Solar shading devices	X		X	X	X
	Automated window shades	X		X	X	X
	Dynamic glass	X		X	X	X
Distributed Energy Resources (DER)	Cogeneration Systems	X	X	X	X	X
	Building Integrated Photovoltaics	X	X		X	X
	Bi-directional inverters	X	X		X	X
	Community microgrids	X	X		X	X
	Onsite renewables (e.g., solar panels, wind turbines, geothermal)	X	X		X	X
	Smart transformers	X	X		X	X
	Solar-powered outdoor lighting	X			X	X
Energy Optimization and	Demand response software applications	X	X		X	X
	Plug load controls	X	X		X	X
	Building energy benchmarking platforms	X	X		X	X

	Real-time energy pricing platforms	X			X	X
	Power factor correction devices	X	X		X	
	Smart power strips	X			X	
Energy Storage Systems	Kinetic Energy Storage	X	X		X	X
	Hydroelectric Storage Systems	X	X		X	X
	Battery storage	X	X		X	X
	Thermal energy storage (i.e., chilled water, ice, hot water, PCMs)	X	X		X	X
HVAC	Rooftop unit (RTU) optimization technology	X	X	X	X	X
	Energy recovery ventilators	X	X	X	X	X
	Smart thermostats	X		X	X	X
	Demand-controlled ventilation	X		X	X	X
Sensor Systems	Smart ventilation controls	X	X	X	X	X
	Occupancy sensors	X		X	X	X
	Daylight sensors	X		X	X	X
Systems for Energy Management	Home energy management systems (HEMS)	X	X	X	X	X
	Building automation systems (BAS)	X	X	X	X	X
	Distributed Energy Resource (DER) Management Systems	X	X		X	X
	Energy monitoring software	X	X		X	X
	Smart meters	X	X		X	X
	Automated load management EV charging systems	X			X	X
	Bidirectional charging systems	X			X	X

Typologies and example measures z from Grid-interactive Buildings for Decarbonization: Design and Operation Resource Guide. Source: ASHRAE, 2023.

Overcoming Challenges To Achieving Grid interactivity

Achieving grid interactivity involves an approach that combines energy efficiency, the integration of distributed energy resources like solar photovoltaic systems, and grid interactive load flexibility. This integration allows buildings to reduce their energy demand, minimizing carbon emissions and ensuring more reliable service delivery.

However, transitioning to a grid interactive model is not a straightforward process. It necessitates a considerable amount of coordination and commitment from a variety of stakeholders, including building owners, operators, utilities, legislators, and public officials. This collaborative effort must address several key areas, namely physical features, automation, operational priorities and occupant expectations, climate resilience, and cybersecurity across enabling features implemented at the site level.

Physical Features of Structures Permitting Increased Control Over Energy Consumption and Generation

Ensuring connectivity of physical features including on-site renewables, smart sensors, or internet of things (IoT) devices is the foundation of grid interactivity. Scoping for interactivity and efficiency and retrofitting buildings to get the most out of connected equipment, however, is a task that must be prioritized and carefully coordinated throughout the project life cycle from procurement, installation, and connection of onsite renewables to negotiation of green lease agreements to support operations improvements and recommissioning. Owners should be prepared to address high upfront costs, regulatory and policy stumbling blocks, technical challenges, and cultural and organizational barriers.

The installation of renewable energy generation systems, deployment of advanced metering systems, energy storage, and other smart grid technologies is often associated with a high upfront cost (Nubbe, et.al., 2020). To overcome this barrier, owners and developers may leverage government and utility incentives such as tax credits, subsidies, or grants. Green loans, green bonds, and C-PACE financing may also help spread costs out over the course of a project's lifecycle.

Even in the most permissive jurisdictions served by the most progressive utility service providers it can be both difficult and time consuming to pilot development projects that incorporate grid interactivity. One of the most commonly-cited examples of this pertains to permitting of battery energy storage systems (BESSs), which often conflict with fire codes and require variances or special use permits to be approved for build-out (Williams, 2022). To overcome barriers to innovation and uptake of new technology as well as barriers to scaling of solutions across portfolios when faced with more common inconsistent and inflexible regulatory and policy environments, it's recommended that real estate sector actors establish long-term renewable energy goals, engage with utility providers governing authorities, and other key stakeholder to collaborate on policy formation and address specific concerns.

According to the US DOE, much of the U.S. electric grid was built in the 1960s and 1970s with limited upgrades and improvements to accommodate emerging technologies—including those that support grid interactivity (DOE, 2023). Consequently, technical challenges arise in the course of integrating individual properties into the grid for both load management and distributed generation purposes. Some solutions to these technical challenges include public and private investment in grid modernization, prioritization of development of community microgrids, and build-out of on-site energy storage capacity to compensate for intermittency.

Underlying all other challenges to necessary physical improvements is a need to address broad cultural and organizational misalignment to support system change. Grid interactivity will imposing new demands on and among large, complex organizations as well as on smaller entities, where change comes with high costs. Getting buy-in from and providing training to staff can help to address these challenges, as can collaborative pilot projects with utilities and civic institutions.

Automation of Building Systems' Response to Internal and External Environmental Factors

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 recommendation where it is not.

Automated demand response is one of several strategies being deployed to optimize buildings' energy use and minimize costs (Boch and Nawy, 2018). By integrating automated demand response technologies, building operators can manage electric loads in real time, aligning with renewable energy availability to reduce costs and emissions. Owners and asset managers are also employing algorithm-based recommender systems to manage building conditions and operations, using data to optimize settings. Some firms are also piloting digital twin platforms for detailed energy performance insights (Plass, Kokernak and Schantz, 2024).

Operational Priorities and Occupant Expectations in Balancing Human Needs with New, Connected Building Systems

To successfully implement grid interactive buildings, it's important to have the support of both operations staff and occupants. This can be achieved through staff and occupant education about the benefits and roles in building automation, and staff training programs focused on safety, equipment operations, and maintenance (Sapp, 2017). These constitute two measures that can help align staff's capabilities with new, smart building technologies and to engage occupants in energy-efficient measures, increasing acceptance and effectiveness of grid interactive building features.

Climate Resilience of Assets and Grid Infrastructure for Utility Providers and Building Owners

While in the past, owners and developers might have balked at the upfront cost and uncertainties of retrofitting systems for demand response and energy efficiency, owners and developers are now integrating grid interactivity and energy efficiency into buildings to combat the effects of climate change and facilitate faster recovery and service availability during events as a matter of course. To be sure, there are still major hurdles, including the fact that simple yet essential upgrades such as window replacements and insulation, which are crucial for enhancing building resilience, are still not commonplace throughout the industry.

However, as part of efforts to incentivize interactivity, property owners have begun to work together with utility providers through new Microgrid as a Service (MaaS) funding models to reduce energy needs, particularly during peak hours or outages (Venkataramanan and Marnay, 2008). Further, buildings may be designed with passive design features that make it possible for structures to island or require minimal power to operate with limited power.

Asset and Grid Resilience Against Cybersecurity Threats

Creating a successful pathway to grid interactivity in buildings requires the collaborative efforts of both owners and tenants' IT teams, building operations staff, and risk management teams. In grid interactive buildings, there is a thin line between asset and liability as the transition from traditional, isolated systems to grid interactive ones could potentially lead to more vulnerable systems. Past incidents—such as the Target hack of 2013, where a malicious actor accessed the company's network through an HVAC system, resulting in significant financial loss and data exposure—underscore a pressing need for secure building systems (Hemsley and Fisher, 2018).

Today, real estate owners and funders are increasingly scrutinizing property technology providers for cybersecurity standards. Companies are responding with solutions like built-in alerts for compromised systems and investment in cybersecurity firms specializing in IoT and operational technology, but there is still much work to be done (Plass, Kokernak and Schantz, 2024).

Conclusion

In conclusion, there is a necessity for the real estate sector to integrate grid interactivity and energy efficiency into the core of building design and retrofitting strategies to both address the challenges brought by climate change and improve their business' financial success. The implementation of grid interactive efficient technologies such as photovoltaic inverters, wireless energy management systems, high-efficiency windows, building-integrated photovoltaics, and occupancy sensors offers a pathway to reducing emissions, cutting utility costs, and improving occupant comfort. This shift calls for active participation from property owners, developers, asset managers, and occupants to recognize and leverage the economic, environmental, and social advantages of grid interactive, efficient buildings.

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