Energy Efficiency is Not Enough:
Rethinking Building Energy Performance for Good Times and Bad

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ABSTRACT

Energy efficiency policy has, naturally, focused on reducing the amount of energy needed to provide energy services. While this focus remains critical, it does not sufficiently address other objectives: minimizing costs, reducing adverse environmental impacts, and enhancing energy reliability and resilience. Achieving these objectives requires complementing energy efficiency with both grid and onsite energy resources, including generation, storage, and flexible load management, i.e., adjustment and control of energy use in response to real-time grid conditions.

While strides have been made to differentiate the value of saved energy by time of use or location, more attention is needed on valuing load flexibility and controllability. Energy efficiency's role in supporting grid reliability and helping buildings operate during power interruptions—particularly through implementing systems-level strategies—also remains underappreciated. More can be done in grid design and operation to integrate variable renewable resources and energy storage and improve reliability and resilience. The paradigm of adjusting supply to meet demand is shifting to one where supply and demand are adjusted together to optimize system performance. Integrating customer-side energy efficiency with generation and storage can enhance energy system performance (cost, reliability, and environmental) and help maintain essential building energy services during outages.

This paper discusses the growing linkages among efficiency, generation, storage, and load controllability. We consider how current energy efficiency policy tools sometimes conflict or compete with grid-level environmental, economic, reliability, and resilience objectives and how such tools can be updated to better support these broader goals.

Energy Efficiency: Necessary but No Longer Sufficient

Since the 1970s, the United States and other countries have achieved great success in advancing the energy efficiency and energy productivity of the economy. Buildings, equipment, vehicles, and industrial processes now deliver more and better service using less energy and with lower economic and environmental costs (ACNEEP 2013). This is due to improved technologies and practices, and various efficiency policies and programs that have supported those advances.

Energy efficiency policies have centered on reducing energy use, either total or per unit of service. Utility programs typically seek to meet absolute or percentage savings goals, in terms of energy (MWh) or peak demand (MW). Building energy codes have focused on reducing total annual energy use or energy costs. Appliance energy standards, labeling, and voluntary programs such as ENERGY STAR use varied units but all are oriented toward reducing total energy use.

While these approaches continue to be very important, wider systems thinking and increasing concern over energy reliability and resilience suggest that energy or peak demand savings are no longer sufficient goals. We are finding that systems-level strategies for improving energy efficiency can yield not only significantly greater energy savings but also offer many other benefits. The Alliance to Save Energy's Systems Efficiency Initiative (SEI) identified numerous examples of untapped energy savings opportunities that are missed by traditional device-specific or whole-building approaches to efficiency (ASE 2017). For example, integrated design processes, in which design teams collaborate to consider buildings and facilities holistically, can optimize interactions within and among building systems (e.g., lighting, heating, cooling, miscellaneous electric loads, and power distribution) and consider a building's interactions with its surroundings, other buildings, the electricity grid, and other energy infrastructure. System-level opportunities exist at multiple levels, from intra-building to large-scale regional and national interactions of energy supply, delivery, and use, including transportation and other components. The SEI reports illustrate numerous benefits of a systems approach—not just additional energy savings, but also improved building and grid resilience, i.e., ability to withstand and recover from energy supply disruptions due to weather, earthquake, accident, attack, or other damaging events.

These types of studies have brought about a growing recognition that the traditional focus on minimizing annual energy use can result in missed opportunities to optimize costs, reduce risks to energy reliability and security, and minimize adverse environmental impacts. The timing and location of energy use and savings—not just their magnitude—matter. In terms of pollutant emissions, for example, emission rates are affected by the generation mix, which varies with time. In an analysis of the Midcontinent Independent System Operator (MISO) region during 2007–2016, Thind et al. (2017) found that using average emission factors for carbon dioxide, sulfur dioxide, and nitrogen oxides would typically overstate the emission benefits from energy savings by about 20 percent relative to marginal emission rates. However, the study did not address how energy savings also vary with time; using annual or monthly savings does not yield the most accurate emission impact estimates. Available tools, such as the U.S. Environmental Protection Agency's AVoided Emissions and geneRation Tool (AVERT), allow users to go further in understanding marginal emission rates and more accurately translate time-differentiated electricity savings into avoided emissions (U.S. EPA nd).

A system-focused approach suggests a need for broader thinking about how energy management can enhance benefits and reduce costs and risks. This is underscored by continuing advances in renewable energy and storage technologies (both utility scale and distributed), along with information and communications technologies (ICT) that enable more precise and flexible control of both energy loads and other distributed energy resources (DERs).[1] As a result of these advancements, Blumstein (2011) suggests that "the old paradigm for system operation in which supply is continuously adjusted to meet demand will be replaced by a new paradigm in which supply and demand are adjusted together to optimize system performance."

Traditionally, utility service planning and regulation treat demand as a given and measure the quality of service in terms of supply. State utility regulators specify that supply must meet demand (plus a federally required reserve margin). With most electricity coming from generation

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[1] DERs include distributed power generation as well as demand-side resources such as end-use efficiency, demand response and other load management, and energy storage.

sources that can be run on demand, long-term demand forecasts signal the need for new capacity investment while short-term forecasts plus cost-optimization (and sometimes environmental criteria) determine how existing generation capacity is dispatched—either in a market or resource planning context. As more renewable generation is developed, these regulatory and cost structures are changing. With zero fuel costs, (non-biomass) renewables have very low marginal costs, so cost optimization pushes toward using as much renewable output as is available. This flips the traditional utility model from supply meeting demand to demand following supply.

As long as renewable generation levels are modest, fossil-fueled generators are sufficiently flexible to balance variable renewable supply. However, as renewable generation portfolios grow, the cost of maintaining what amounts to redundant generation capacity can exceed the economic benefits from renewables. Also, where dispatchable fossil-fueled resources provide spinning reserve and other ancillary grid services such as voltage and frequency regulation, their emissions offset some environmental benefits of renewables. Thus, an important alternative is to harness controllable loads to help provide these ancillary grid services.

Adding to the challenges and opportunities of new energy technologies is the increased salience of energy system reliability and resilience. Recent storms (e.g., Hurricane Maria, Superstorm Sandy), heatwaves, polar vortices, wildfires, and errors and accidents (e.g., the 2003 Northeast Blackout)—along with heightened sensitivity to physical and cyber-attack threats—have put a spotlight on energy system vulnerabilities. While more robust energy efficiency would likely not have prevented most of the energy system disruptions that have occurred, it could help reduce the risks and impacts of future disruptions and hasten recovery—particularly when combined with distributed generation, energy storage, and flexible energy management capabilities.

The following sections discuss ways that energy efficiency contributes to reliability at both the building and grid levels, and where efficiency alone falls short.

Energy Efficiency, Reliability and Resilience

Energy efficiency can support both energy reliability and resilience, which are related but distinguishable concepts. Energy reliability is often defined as the ability to deliver a consistent and expected quantity and quality of energy (Energy-101.org 2016), while resilience is "the ability to absorb, adapt to, and/or rapidly recover from a potentially disruptive event" (NIAC 2009).

This paper considers how energy efficiency can contribute to energy reliability and resilience at two levels: (a) the energy system, including the electricity grid and natural gas system, and (b) locally in buildings, facilities, campuses, and communities. The paper also suggests that a sole focus on energy savings without attention to other aspects of energy management, including load shifting and energy storage, is insufficient to optimize reliability and resilience as well as economic and environmental benefits.

How Energy Efficiency Contributes to Grid Reliability and Resilience

Energy efficiency can help lower peak power demand, reducing stresses to the electricity grid—including line losses and possible voltage reduction or outages triggered by supply side constraints, whether generation or transmission related. Energy efficiency also can reduce stresses on the natural gas system on high energy demand days, particularly during cold weather periods when high demand for heating fuels coincides with high demand for natural gas-fueled electricity generation. Finally, efficiency can ameliorate price spikes and availability shortages of delivered fuels such as propane and fuel oil.

Moderating demand through energy efficiency also reduces the potential impacts of energy infrastructure disruptions due to extreme weather events, accidents, physical or cyber-attacks, or extreme energy demand during heat waves and cold spells. Further, when damage does occur to the electric grid or natural gas infrastructure, it will be less expensive to rebuild or replace it to meet lower energy demand due to widespread end-use efficiency. As illustrated in the sections below, these reliability and resilience benefits of energy efficiency will be further enhanced when combined with DERs, including on-site generation and storage, and in conjunction with flexible management of end-use loads.

Where Energy Efficiency Falls Short

Where traditional energy efficiency programs fall short is in their effectiveness at reducing specific energy loads based on their relative value to both the grid and the consumer. The value to the grid of energy efficiency improvements depends on when the savings occur and the degree to which the load reductions can be flexibly dispatched. However, traditional energy savings accounting focuses on total annual savings, and to a lesser extent on peak demand reductions. Although some analytic frameworks—such as the Time Dependent Valuation (TDV) analysis used in California to evaluate the cost-effectiveness of building codes and appliance standards—have attempted to incorporate the time-differentiated value of efficiency improvements, in practice those frameworks are based on fixed load profiles and give special weight to “critical peak periods” (CEC 2017).

While time-differentiated valuation of energy savings is a step forward, the focus on avoided cost of energy supply remains mired in the supply-meets-load paradigm. To upend that perspective, a new approach would need to explicitly consider the relative value of loads—or rather, the services they provide—and “dispatch” those loads according to the cost and availability of supply. Most existing demand response (DR) programs, developed when automated controls were less sophisticated, fall well short of the full potential of real-time dispatch for both small and larger loads. These DR programs typically target large loads that often are the most valuable to customers: Industrial customers receive payments or discounts to accept non-zero risk of costly lost production, and air conditioning load control programs target residential air conditioning on the days it is needed most. Enormous potential exists—in this age of voice-controlled digital assistants that can learn your schedule and adjust lighting and temperature to your preferences—to use communications and control technologies to find loads that are least valuable *to the customer* at the particular time the grid needs to reduce load or add resources.

Presuming the continued expansion of the connected Internet of Things, one can imagine a meaningful percentage of loads being technically available to provide the kind of grid balancing services that high penetration of renewable generation will require. Large numbers of small loads responding to dynamic grid signals would eventually be highly predictable, under a wide range of circumstances and across all hours of the year. Such DR also would be much more robust and valuable than reliance on a small number of large loads that could individually fail to perform or simply not be available when needed.

Both electric and thermal energy storage are emerging as key resources to reduce expensive peak demand, to serve load when renewable output is low, and to serve as useful additional “load” when renewable output is high. Citing several utility demand flexibility programs that center on thermal storage and electric vehicle (EV) charging, Goldenberg, Dyson, and Masters (2018) conclude that demand flexibility can be important for achieving a low-carbon grid at low cost.

Load flexibility and energy storage linked to onsite generation via microgrids also support building or facility resilience by allowing “islanded” operation in the event of grid failure. And the same control systems that would optimize storage performance based on time-differentiated electricity prices could be expanded to include dispatchable end uses (Piette at al. 2016). Rather than requiring a choice of consume, store, or discharge, the energy system should optimize among the cost of grid-supplied electricity, the value of stored electricity (discounted for conversion and storage losses), and the value of consumption to the consumer on a time-specific and device-by-device basis. Such control systems could be on track to become standard features in buildings that include DERs if appropriate time-varying price signals are instituted.

One unanticipated benefit of this transition will be the attention that is paid—at least initially—to when loads occur, and how much value those loads provide at any particular moment. Herter, Wayland, and Rasin (2009) found that participants in a DR pilot were able to achieve energy savings of 20 percent in addition to shedding 14–20 percent of load during a DR event. The holy grail of more than 40 years of energy efficiency programs—how to get people to pay attention and care about the additive impacts of small loads and small savings—may end up being an ancillary benefit of demand response.

In a future with high renewable energy penetration, improvements that focus on minimizing end-use consumption during times when the wind isn’t blowing and the sun isn’t shining will have much greater value. If properly incentivized, flexible and controllable loads will have value equivalent to that of the flexible generation resources required to firm renewables. In a high-renewable, low carbon system, reliability will depend on some combination of load management and storage. And the key role of energy efficiency remains paramount: As the cost of serving load increases, the most effective reliability and cost-reduction strategy is reducing consumption in the first place.

Trade-off examples

The links among energy efficiency, renewables, and storage are growing, allowing them to work in concert but also setting up conflicts. For example, conflicts already have arisen between equipment-level energy efficiency and features said to support a cleaner, more economical, and reliable grid. In 2010 the U.S. Department of Energy (DOE) adopted an efficiency standard for large electric storage water heaters that would require heat pump technology, roughly doubling their efficiency over electric resistance water heaters (DOE 2010). In response, several utilities and others argued that the new standards would essentially preclude large electric water heaters from serving as load-leveling “batteries” that absorb surplus power (such as overnight wind power) by super-heating water off-peak and storing it to reduce demand during peak periods. Soon after the standard took effect in 2015, Congress amended it to exempt larger “grid enabled water heaters” from the heat pump water heater (HPWH) standard and to allow continued use of resistance heating for large water heaters enrolled in utility load control programs (Congress 2015).

Beyond load-leveling, with proper utility-connected controls, electric resistance water heaters can provide more precise, real-time grid services such as frequency control and grid stabilization (Poderson 2016; Trabash 2017). Despite an energy efficiency penalty, one study estimates that the potential dollar value of grid reliability and other ancillary services from grid-enabled water heaters could significantly exceed the energy cost savings of a HPWH (RMI 2016). Could the standard have advanced *both* energy efficiency in normal operation and grid integration potential? Although disputed by utilities arguing for relief from the heat-pump standard, others argued that efficient HPWHs can also be grid-integrated to absorb excess wind or solar power, though perhaps not provide ancillary grid-reliability services (Bronski et al. 2015; RMI 2016).

Conflict is also arising over potential tradeoffs between energy efficiency and photovoltaics (PV) in building energy codes (ASE nd), and the failure of today's codes to recognize the full role of efficiency and load control in supporting energy reliability and building resilience. With few exceptions, building energy codes and rating schemes such as ENERGY STAR and the Home Energy Rating System (HERS) focus on annual energy use per unit of floorspace. There is generally a "source energy" adjustment for electricity system losses but no requirement to account for differences in power generation costs or emission intensities by season or time of day, nor consideration for load flexibility or building resilience. Model energy codes and "stretch" codes (e.g., the International Energy Conservation Code (IECC), ASHRAE Standards 90.1 and 189.1) include a performance-based (energy cost budget) option for code compliance which allows, but does not require, use of time-of-use tariffs to calculate annual energy costs. California's Title 24 code goes further with its time-dependent valuation of energy use and savings (CEC 2017). However, these building codes, standards, and rating schemes only consider energy performance under "normal" operating conditions. They do not address building operational resilience when the electric grid (or gas distribution) is stressed or fails. Nor do they address real-time control of building loads to support efficient, clean, and reliable grid operation.

Further, the model building energy codes allow trade-offs between efficiency of the building envelope and the mechanical system, without regard to how these features will affect building performance during a grid outage. For example, thermal envelope improvements such as better windows, insulation, and passive-solar design may provide the same annual energy savings as high-efficiency HVAC equipment or improved distribution ducts. Yet only the former, load-reducing measures also help maintain occupant comfort, safety, and health when the power is out. The same is true for daylighting, which offsets electric lighting when power is available but is even more valuable during a power failure. While Leadership in Energy and Environmental Design (LEED), the IECC commercial model code, and some "stretch" codes (e.g., ASHRAE Standard 189.1 and CalGreen) allow performance credits for energy efficiency and on-site renewable energy, there is no recognition of how on-site renewables, especially when coupled with storage and dispatchable loads, can contribute to reliable grid operation and extend building operation during a grid outage.

California is beginning to address these complex issues, driven by its high penetration of solar generation leading to repeated instances when the grid cannot absorb and store excess renewable generation. The recent update of the state's Title 24 building energy code requires additional grid harmonization strategies (GHS) to maximize on-site use of PV power and minimize exports back to the grid via battery storage, thermal storage, load flexibility, and grid-integrated EV charging (Shirakh et al. 2017). Under Title 24, new homes built to the 2019 code will need to meet current energy efficiency requirements plus an additional requirement that can be met with a combination of efficiency and PV. Title 24 also includes provisions for right-sizing PV systems to take advantage of on-site storage and demand flexibility.

Energy Efficiency and Resilience of Buildings and Facilities

Energy efficiency can contribute to the resilience of individual buildings, facilities, campuses, and communities. Resilience is often described in terms of physical hardening, such as strengthening structures against wind or seismic damage, raising structures and barriers to mitigate flood damage, and installing fire suppression systems. However, resilience of energy services is also critical to protecting health and safety as well as to continuance of business and other operations in the face of energy disruptions.

To be sure, building energy efficiency cannot prevent damage from floods, earthquakes, ice storms, physical attack, or other catastrophes absent other resilience-reinforcing measures. However, energy efficiency—particularly when linked with other DERs, such as combined heat and power (CHP), other onsite generation, and energy storage—can reduce adverse impacts.

While not focused on end-use energy efficiency, case studies emerging from such events as the 2003 Northeast Blackout and Superstorm Sandy note that CHP installations allowed apartment buildings, college campuses, hospitals, and industrial plants to operate during wider electricity grid outages (ICF International 2013). During and after Superstorm Sandy, some of these locations became de facto refuges. Since then, some policymakers and energy officials have emphasized CHP and other distributed generation in microgrids as key resilience measures, particularly for critical facilities such as hospitals and wastewater treatment plants (NJEDA nd). The military and others are looking to microgrids to improve resilience and energy reliability over standalone backup generators (Marqusee, Schultz, and Robyn 2017). The National Renewable Energy Laboratory is examining energy resilience valuation, particularly of onsite solar energy and storage (NREL 2018).

To maximize the energy resilience of buildings and campuses during grid outages or other energy disruptions, however, it is critical to include energy efficiency measures. At the simplest level, an energy efficient home with a good building envelope will stay warm longer than a less efficient home should power fail on a freezing day. High efficiency buildings and equipment allow facilities to operate longer and/or provide better service when there is limited backup generation capacity and limited fuel. Energy efficiency (including passive solar and daylighting features) can enable facilities to better operate with onsite solar energy combined with energy storage.

Reduced loads also allow designers of onsite energy systems to reduce the size and cost of onsite generation (renewably or fossil fueled) and storage to meet facility needs, whether to provide minimum critical loads or higher levels of service. However, the role of energy efficiency in complementing other DERs to provide energy resilience (and reduce costs) remains underappreciated. In the context of military facilities, for example, Marqusee, Schultz, and Robyn (2017) noted that “The cost of providing energy security on a military base is a function of the peak power required for protected loads; thus, when the base reduces those power needs through energy conservation and efficiency, its energy security costs drop proportionately. To date, the Services have made only limited improvement in their energy efficiency, in large part because they view energy efficiency as a way to comply with statutory goals and executive orders rather than as an essential element of energy security.”

These principles also apply to non-building facilities. For instance, efficient light-emitting diodes (LEDs) enable solar-plus-batteries to operate traffic signals and outdoor lighting, which could not readily be done with incandescent or high-intensity discharge lamps. Another example is more-efficient pumps that allow water utilities to deliver water and maintain positive pressure in pipes (important for preventing contamination) longer on backup diesel generators or renewables-plus-storage during an extended power disruption.

While energy efficiency clearly is an under-recognized resilience asset, it is important to note that designing buildings and facilities for energy resilience—including storage, generation, and flexible controls—may not necessarily minimize energy use. Energy storage comes at an energy penalty. Onsite power generation may indeed support energy efficiency (a rationale for CHP) but can also compete with efficiency measures for design attention and investment.

Policy and Program Implications

Energy system vulnerabilities have become more salient in the face of increased severity of weather-related catastrophes, wildfires, cases of accident and error, and fears of physical and cyber-attack. Policymakers and regulators can improve the resilience of the energy system with the help of technological advances that enable more flexible management of energy loads as well as supplies, allowing energy efficiency, storage, and generation (both onsite and grid-provided) to work in concert. As discussed, however, policies and regulations will need to consider potential conflicts and tradeoffs between efficiency and other energy system approaches.

Metrics and Analytics

A critical prerequisite for policies that will promote building performance beyond energy consumption and energy use intensity (EUI) is metrics that measure progress toward broader energy system economic, environmental, reliability, and resilience goals.

An initiative of the New Buildings Institute and U.S. Green Building Council (USGBC), GridOptimal, is working to develop a metric to rate a building's "grid citizenship"—how well it "contributes to, rather than detracts from, the reliable, safe, and affordable operation of the grid" (NBI 2018). Development of such metrics, as well as those focusing on building or campus-level resilience, will be helpful for planning and constructing buildings and communities that are more energy resilient, environmentally friendly, and cost effective.

There is need for tools that actively manage and optimize system performance by continuously analyzing price signals—and perhaps emission rates and other parameters—against building or facility needs, along with capabilities to "dispatch" load as well as supply. Machine learning may provide solutions. Since utility tariffs and regulation will likely lag technological capabilities, investment decisions will have to be based first on internal operational needs.

Fortunately, when buildings are viewed as both energy producers and consumers (or prosumers), operational flexibility allows load management to work with onsite generation. As such systems become more mainstream, scale and experience will drive down costs.

Research, Development and Demonstration

As discussed, the efficacy of energy efficiency as a means of increasing resilience depends on a paradigm shift toward coordination of supply and demand to optimize system performance. This is happening, but progress is slow; research, development and demonstration (RD&D) can play a key role to accelerate change.

What is slowing down the paradigm shift? Existing technical tools seem adequate to the task, but there are significant social and institutional impediments, including:

- <u>Utility culture</u>. Paradigm shifts are hard, especially if work practices and thinking patterns are tied to the old paradigm.
- <u>Regulation</u>. The new paradigm requires a new regulatory framework.
- <u>Perverse incentives</u>. Incumbent suppliers may be reluctant to adapt their businesses to the new paradigm. For example, controls companies may have business reasons for making it difficult for building systems to interoperate.

What technological improvements might speed up the paradigm shift? The key technologies are software and sensors. Cost reductions and performance improvements of these technologies will make the paradigm shift easier.

- <u>Software</u>. Low-cost (preferably open-source) controls software is needed to support the interoperation of multiple end uses. Especially important for resilience are algorithms that enable rapid load shedding that supports user preferences on which energy services should be maintained when supplies are constrained, whether for minutes, hours, or possibly days.
- <u>Sensors</u>. Sensors are necessary for good control. They provide information about the state of the system being controlled and feedback on the efficacy of control actions that have been taken. Decreased cost and increased reliability of sensors are priority needs.

What about microgrids? A Google Scholar search conducted on March 1, 2018 of papers published since the beginning of 2017 found more than 900 papers with the word microgrid in the title. Despite this enthusiasm, microgrids have a long way to go before they contribute significantly to resilience. In developed countries most microgrids will be connected to the wide-area grid. (The economies of scale from interconnection, which were the secret of Samuel Insull's success 100 years ago, are still with us.) The institutional and technical problems described above apply to microgrids as well as the utility grid. In addition, there are some microgrid-specific challenges (Ostfeld et al. 2017):

- <u>Institutional</u>. Widespread penetration of microgrids will require a new regulatory framework. Cost allocation for grid services will be a particular problem.
- <u>Technical</u>. When the wide-area grid goes down, a potential advantage of microgrids is the ability to “island," or operate separately from the wide-area grid. Where microgrids depend on variable resources like PVs, demand could exceed supply. Then the technical challenge to islanding will be the need for very rapid balancing of supply and demand, and a likely requirement for some electricity storage.

Is there a role for passive measures? Passive solutions like more insulation and more thermal mass can contribute to resilience. More research on building design can help quantify the potential of passive strategies to contribute to resilience. Also, passive measures complement active measures, such as pre-cooling buildings and sequencing air conditioning across multiple buildings to reduce both grid peak demand and required capacity of a microgrid when operating in islanded mode.

There are no bright lines separating research, development, demonstration and commercialization; the path from beginning to end is highly non-linear. Demonstration and validation are often needed to give potential investors and customers confidence that a technology will be successful. This is particularly important for systems of many interacting components that are owned and operated by different players—building operators, occupants, utilities, independent generators, various grid operators and authorities, and third-party energy service providers.

Government facilities can serve as test beds. The Department of Defense's Environmental Security Technology Certification Program (ESTCP) demonstrates and validates environmental and energy technologies addressing defense mission needs (ESTCP nd). ESTCP's portfolio includes energy efficiency, distributed generation, and storage technologies, some combined as microgrid demonstrations. Similarly, the General Services Administration's Green Proving Ground demonstrates and validates pertinent technologies in civilian federal buildings (GSA nd.). Such test beds can provide real world data to accelerate technology deployment.

Rethinking Deployment Strategies

Beyond RD&D, incorporating building and grid resilience into energy policies and programs will require rethinking traditional approaches to energy management; supplementing energy efficiency and load management with customer-side load flexibility, PV, and storage; and integrating all these systems, both on-site and offsite, with utility grid operations. This approach applies to the full range of policy interventions: utility tariff design, utility and tax incentives, building energy ratings, energy codes and standards, public sector leadership, and local development and permitting processes.

Incentives and voluntary programs. Voluntary, market-driven initiatives, such as LEED, HERS, the DOE Better Buildings Challenge, and ENERGY STAR building and appliance labels, are promising vehicles for introducing criteria for energy resilience and buildings-to-grid integration. For example, the LEED pilot credit for "Passive Survivability and Functionality During Emergencies" (Credit IPpc100) requires implementing two out of three measures applicable to power outages: thermal resilience, back-up power, and access to potable water (Wilson 2015). The USGBC is now re-evaluating this pilot credit for refinement and broader application, including for building renovations. The USGBC also has worked with the Institute for Market Transformation to Sustainability (MTS) on a LEED-compatible, community-scale resilience standard called RELi (Pierce 2017).

Financial and non-financial incentives also can help advance building energy resilience and grid integration. Local jurisdictions can use development and permitting processes such as density bonuses, conditional use permits, and accelerated permit review to encourage owners and developers to include on-site PV systems, CHP, energy storage, and smart EV charging. A growing number of jurisdictions require certain new buildings to either install solar PV systems or design roof slopes and orientation to be solar-ready (CEC 2016). Similarly, tax incentives, utility rebate and design assistance programs, and such mechanisms as performance contracting and commercial property assessed clean energy (PACE) financing that support energy efficiency and PV also could be applied to building resilience and grid-integration measures.

Codes, standards, utility programs, and public procurement. Building energy code provisions for trading off envelope vs. mechanical system efficiencies should consider the resilience value of *reducing* thermal loads. Future code improvements should add grid harmonization strategies (GHS), as California is doing with Title 24. Codes can initially incorporate GHS such as PV, storage, and flexible/dispatchable loads as an option, *supplementing rather than substituting for* energy efficiency requirements. Another first step could be to require all new construction to be PV- and storage-ready. When technology and economic conditions allow, GHS options can then become code requirements.

These changes will require that we look at code cost-effectiveness from a systems and societal point of view, not just from the perspective of the building owner under conventional utility pricing. This means either explicitly accounting for the value of distributed generation, storage, and flexible loads in improving the resilience of the electrical grid or incorporating some form of time-dependent valuation into utility rates and in cost-effectiveness analyses for building energy codes. Similar changes, reflecting TDV pricing, should be applied to cost-effectiveness analyses for appliance efficiency standards, utility efficiency programs, tax incentives, and other policies. Among the many data and analytical challenges, of course, is the difficulty of predicting future time-dependent costs of power from the grid.

Finally, as noted in the RD&D discussion, public buildings can serve as proving grounds to demonstrate and validate technologies that support resilient buildings and controllable, grid-integrated distributed generation and load resources. Once validated, such measures could become requirements for public and institutional buildings, with a special emphasis on facilities critical to health, safety, and security such as hospitals, firehouses, facilities used as emergency shelters, and water supply and treatment plants.

Conclusion

Energy efficiency remains critical to improving the cost, environmental performance, reliability, and resilience of our energy system, but energy efficiency is not enough. Maximizing energy savings—minimizing total kWh or BTU consumption—will not necessarily maximize these benefits, particularly as variable renewable generation grows and linkages among energy efficiency, power generation (both grid and onsite), natural gas, energy storage, and load controllability expand. Improved information and communication technology capabilities will enable a transition from controlling supply to meet demand to a system in which supply and demand are controlled together across multiple types of energy system resources to optimize system performance. However, this transition will not occur spontaneously under current regulatory frameworks. New metrics and policy and program approaches, including supportive price signals, are needed to marry energy efficiency with these other energy system resources. Along with R&D, more demonstration efforts and incentives are needed to refine interactions among technologies and shift institutional culture if we are to meet critical economic, reliability and resilience, and environmental sustainability objectives.

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