Integrating Energy Efficiency, Solar, and Battery Storage in Utility Programs

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Executive Summary

KEY TAKEAWAYS

- Relatively few utilities and independent service providers currently offer programs that integrate distributed energy resources like energy efficiency and solar plus battery storage (solar+).
- Nearly 15 examples from this research demonstrate how program administrators can integrate energy efficiency and solar, or efficiency and solar+. These programs are offered by independent service providers, statewide administrators, and municipal, investor-owned, and cooperative utilities.
- EE/Solar+ programs can combine the benefits of efficiency and solar+, especially energy savings, emissions reductions, grid stability, and resilience.
- EE/Solar+ can also increase program participation for utilities, provide one-stop-shop convenience for customers, and give disadvantaged communities more energy options.
- EE/Solar+ programs that collaborate with existing market providers are likely to see greater participation.
- Because combining efficiency and solar+ may increase customers' initial project costs, robust financing is key to the success of these programs. Energy savings can help offset project and financing costs.
- Program administrators can take steps to address other challenges, including regulatory and administrative siloing and coordinating the work of multiple contractors.

INTRODUCTION

Like energy efficiency (EE) and solar plus battery systems (solar+), distributed energy resources (DERs) are becoming more prevalent as costs decline and customer interest grows. However, due to separate policy drivers, utilities and third-party administrators generally offer these measures in separate siloed programs. Although some market providers (e.g., building technology companies and independent contractors) offer integrated EE/Solar+ programs—largely to commercial customers—utilities rarely do so. This is in spite of the operational and systems benefits that EE/Solar+ can offer utilities, along with the one-stop convenience for customers and the potential for cost savings. This report discusses these benefits in the light of case studies of four market providers and five utility EE/Solar+ programs targeting residential and commercial customers.

EE/SOLAR+ BUILDING BLOCKS

Some EE/Solar+ programs involve a simple combination of measures; others are more complex. In a single-family home, a simple project might pair energy efficiency measures designed to reduce energy loads with a rooftop solar photovoltaic (PV) array to meet the remaining demand. More complex projects integrate battery storage, EV chargers, and connected devices.

BENEFITS OF EE/SOLAR+

Energy efficiency, solar, and energy storage technologies can save money for customers, reduce the need to generate, transmit, and distribute electricity from fossil fuel power plants, and cut down on greenhouse gas emissions (GHGs). Efficiency also saves energy and improves the health, comfort, and productivity of building occupants. Solar+ systems help maximize customer demand-response capability, relieve grid congestion, level demand spikes, and improve building resilience. EE/Solar+ programs have the potential to amplify all these benefits while offering additional advantages to customers and utilities.

EE/Solar+ programs add value for customers and can provide innovative energy solutions to underserved communities. Energy efficiency improvements reduce building energy loads, allowing customers to install a smaller and less costly solar+ system than they would otherwise need. By planning and installing efficiency measures first, customers can use their monthly energy bill savings to help finance the costs of their solar+ system. Solar+ may offer additional bill savings by helping customers shift loads from periods with higher system costs where they may face time-varying rates. EE/Solar+ programs can also offer customers a one-stop-shop for energy-saving technologies and may help them choose the best systems to fit their needs and budget.

EE/Solar+ promises benefits to utilities as well: it has the potential to integrate DERs like solar+ seamlessly into the grid and better manage supply and demand of electricity at specific times in stressed locations. With the right regulatory and incentive structure, combined programs can also help utilities open new value streams by introducing customers to energy solutions they may not have otherwise considered. At the same time, EE/Solar+ gives utilities more control over customer-sited energy generation to ensure it benefits the grid.

CHALLENGES

Despite the above advantages, very few utilities offer EE/Solar+ programs and pilots. Regulators often require utilities to offer energy efficiency and solar in separate siloed programs with different funding sources, cost-effectiveness tests, and reporting requirements. In some states, regulators may not even allow utilities to offer solar or to compete with local solar installers. Even when they can offer EE/Solar+, program administrators may be forced to evaluate and verify performance of the measures independently to determine their combined value. Administrative structures may also be a challenge. Integrated programs may require an extra layer of administration and cost to coordinate management across departments, several incentive applications, and multiple vendors and implementers. Coordinating contractors from separate trades with disparate installation timelines may be particularly challenging.

Other challenges include gaps in technology development and adoption, limited field experience to demonstrate which new products and platforms will be viable over the long term, and high customer costs. Also, a building that is technically unsuitable for a solar installation (e.g., shaded by trees) may disqualify a customer from the entire EE/Solar+ program. These challenges add to other well-documented barriers to customer participation in efficiency programs.

STRATEGIES FOR SUCCESS

Administrators should weigh the costs and benefits of integrated programs, then determine the barriers and devise strategies to overcome them. For example, administrators can engage with third-party solar installers and local contractor networks to coordinate and streamline program delivery and educate prospective customers on their energy offerings. Customer service should be a focus of EE/Solar+. Programs need to clearly define the unique value proposition of integrating these technologies by emphasizing the energy and cost savings as well as the energy independence and flexibility they offer. Marketing and education can help customers understand and justify costly up-front investments, and innovative and robust financing strategies like equipment leasing, power purchase agreements, on-bill financing, and as-a-service pricing structures can help to overcome sticker shock. Administrators can also design offerings with customers' rate options in mind, offering technology bundles designed to deliver bill savings where customers face demand charges or time-varying rates. Effective programs will make participation as simple as possible, offer comprehensive energy assessments, and provide a one-stop shop (perhaps an online marketplace) where customers can navigate both energy efficiency and solar+ measures under the same roof.

RECOMMENDATIONS

Our review of existing projects and programs identified these strategies utilities can take to help EE/Solar+ programs best serve their customers and the grid:

- Evaluate the service territory to identify customers and areas that could benefit most from EE/Solar+ solutions.
- Identify key partners that can bolster customer engagement and participation, including local government officials, local nonprofits, local contractors, and leading market providers in the area.
- Evaluate customers' cost threshold and consider different financing schemes to help reduce overall project costs.
- Engage customers and offer EE/Solar+ solutions through multiple engagement platforms like online marketplaces, personalized communications, and community-based campaigns.
- Target initial EE/Solar+ programs to areas with clear policy needs, such as those looking for non-wires alternatives to meet capacity constraints.
- Identify and reduce internal administrative constraints through such actions as increasing communication between siloed energy efficiency and solar+ teams.
- Implement more pilots to help quantify the benefits of integrated EE/Solar+ and identify key technologies and best practices for program design.

Regulators and policymakers can support EE/Solar+ by:

- Valuing the multiple benefits of EE/Solar+ programs in cost-effectiveness testing to ensure that programs that offer value to the system, participant or society can move forward

- Redesigning rates and valuation to better serve the needs of customers with integrated systems, either through custom rates or improvements to default rate offerings
- Identifying regulatory constraints to integration and working with program administrators to make changes that reduce the complexity and administrative effort needed to provide EE/Solar+ programs

Sharing results with customers, vendors, and technology providers will increase regulatory, customer, and management support for EE/Solar+ programs. With further development, EE/Solar+ can become more common, bringing the combined benefits of energy efficiency and solar+ to many more customers.

Integrating Energy Efficiency with Distributed Energy Resources

Energy-efficient buildings do more than save energy; they also save money by reducing electricity bills. In both new construction and retrofits, measures like insulation and air sealing can make a major difference in a building's energy consumption and the occupants' energy costs. Other measures that can reduce building energy use include efficient appliances, HVAC, and lighting as well as smart technologies like energy management systems. As policymakers and customers are increasingly interested in zero-energy/zero-carbon buildings, the demand for high-efficiency buildings that use clean, distributed energy resources is growing and will continue to do so.

Energy efficiency is one type of distributed energy resource (DER). Baatz, Relf, and Nowak (2018) define DERs as follows:

> Distributed energy resources (DERs) are resources sited close to customers that can provide all or some of their immediate electric and power needs and can also be used by the system to either reduce demand (as with energy efficiency) or provide supply to satisfy the energy, capacity, or ancillary service needs of the distribution grid.

Energy efficiency is a DER insofar as efficiency measures reduce a building's energy use and therefore the overall demand on the system.[1] As shown in figure 1, other DERs include demand response,[2] distributed renewable energy generation (such as customer-sited solar), energy storage, microgrids, combined heat and power (CHP), and electric vehicles.

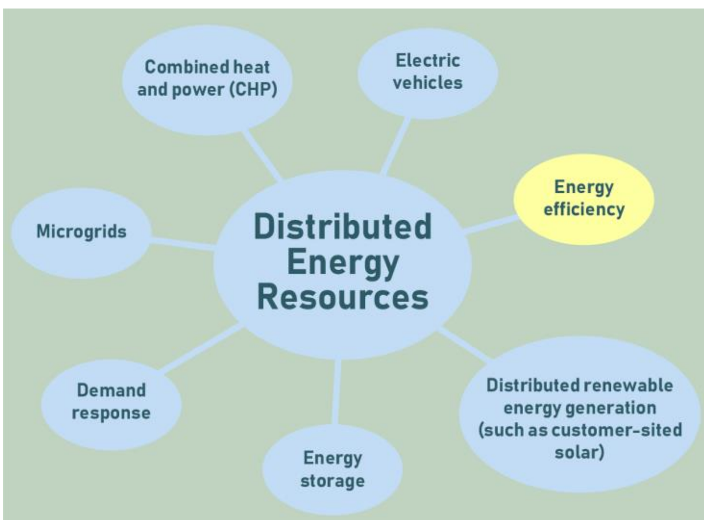

Figure 1. Distributed energy resources

[1] Energy efficiency also provides a range of direct system benefits. See Lazar and Colburn 2013.

[2] Whereas energy efficiency reduces demand over time, demand response (DR) reduces or shifts load from times when demand is at its peak to times of lower demand.

As the use of these and other DERs continues to increase, utilities are increasingly incorporating them into their grid modernization plans (Pollock 2017). For example, in 2018 solar was among the three most deployed resources, with utilities adding a total of 7.3 GW in supply-side solar capacity. This represents a 2.2% increase over 2017, bringing cumulative national solar capacity to 49.7 GW (EIA 2019; SEPA 2019b). Utility-scale solar has become increasingly cost effective, driven in part by the competitive prices of solar PV technology and rising consumer demand. Also in 2018, a total of 760.3 MWh of energy storage was interconnected, an increase of 44.9% over 2017 (SEPA 2019a). Continued growth is expected: in a 2018 survey of utility executives, 45.8% of respondents identified the integration of DERs as a critical priority (Black and Veatch 2018).

Utilities have offered integrated energy efficiency and demand response programs (EE/DR) for a number of years. These programs can yield multiple system and customer benefits, as found in a recent ACEEE report that identified four degrees of integration among current EE/DR programs:

- Dual objectives of saving energy and reducing or shifting peak demand
- Cross promotion of separate efficiency and DR programs
- Administrative coordination of separate programs
- Single programs (York, Relf, and Waters 2019)

In this report, we focus on the integration of efficiency and two other types of DERs: solar and storage. Buildings that use DERs such as solar photovoltaic (PV) arrays and battery storage generate and manage some, if not all, of their own electricity supply, reducing their dependence on the grid.

Such programs are more recent and less prevalent than EE/DR, but they are increasingly timely in light of rapid cost reductions and heightened customer interest. Although our initial research scope included DERs like microgrids and electric vehicles, we found these resources included in so few integrated programs that we decided to focus on offerings combining efficiency with solar plus battery storage systems. We call this combination EE/Solar+.

Utilities and third-party administrators typically offer their customers energy efficiency and solar+ in separate, siloed programs. Although some market providers, such as energy service companies (ESCOs), do provide integrated EE/Solar+ offerings—largely to commercial customers—utilities rarely do so, partly because of separate policy drivers.[3] Most utilities simply direct their energy efficiency program participants to solar programs, and vice versa; for example, a solar program may suggest that customers also explore efficiency offerings and direct them to a web page. In a few cases, utilities require solar program participants to conduct an energy audit in order to qualify for solar incentives.

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[3] See Samarripas and York (2018) for an overview of the policy drivers for solar versus those for energy efficiency.

This report first assesses the landscape of EE/Solar+ programs by presenting case studies of current third-party EE/Solar+ offerings and the few utility programs and pilots that we have identified. It continues with a detailed discussion of the benefits of and challenges to EE/Solar+ and concludes with strategies for maximizing these benefits and overcoming challenges.

Research Objectives and Methodology

The primary audiences for this report include utility program administrators who might be interested in developing and offering EE/Solar+ programs, as well as building service providers, independent installers, and customers interested in implementing EE/Solar+ projects to meet their building's energy efficiency goals. We identify existing examples of EE/Solar+ programs and pilots, trends and opportunities in the market, and strategies for future program design.

We reviewed existing literature and a sample of publicly available program filings from the select set of utilities evaluated for ACEEE's Utility Scorecard. This process revealed how utilities approach the integration of energy efficiency and solar+ in program offerings and enabled us to identify potential case studies. We included a request for information about EE/Solar+ offerings in the call for programs circulated by the ACEEE team researching energy efficiency and demand response programs. In parallel, to gather insights into the benefits and challenges of EE/Solar+, we interviewed 15 industry experts, market providers, and program administrators who offer separate energy efficiency and DER programs. We also interviewed eight program administrators who have integrated energy efficiency and solar+ to understand the value streams of these programs and best practices for making the case to customers and regulators. Finally, we convened an internal focus group of ACEEE researchers to identify strategies to inform future program design and implementation.

EE/Solar+ Building Blocks

While some EE/Solar+ programs involve a simple combination of measures, others are complex. In a single-family home, for example, a simple EE/Solar+ project could reduce energy loads with energy efficiency measures and add a rooftop solar array to meet the remaining demand. By contrast, commercial, institutional, and large multifamily buildings may install complex projects. As shown in figure 2, these projects integrate additional technologies like battery storage, EV chargers, and connected devices. They can also scale to the campus or neighborhood level to form independent microgrids (see *What Are Microgrids?* text box below).

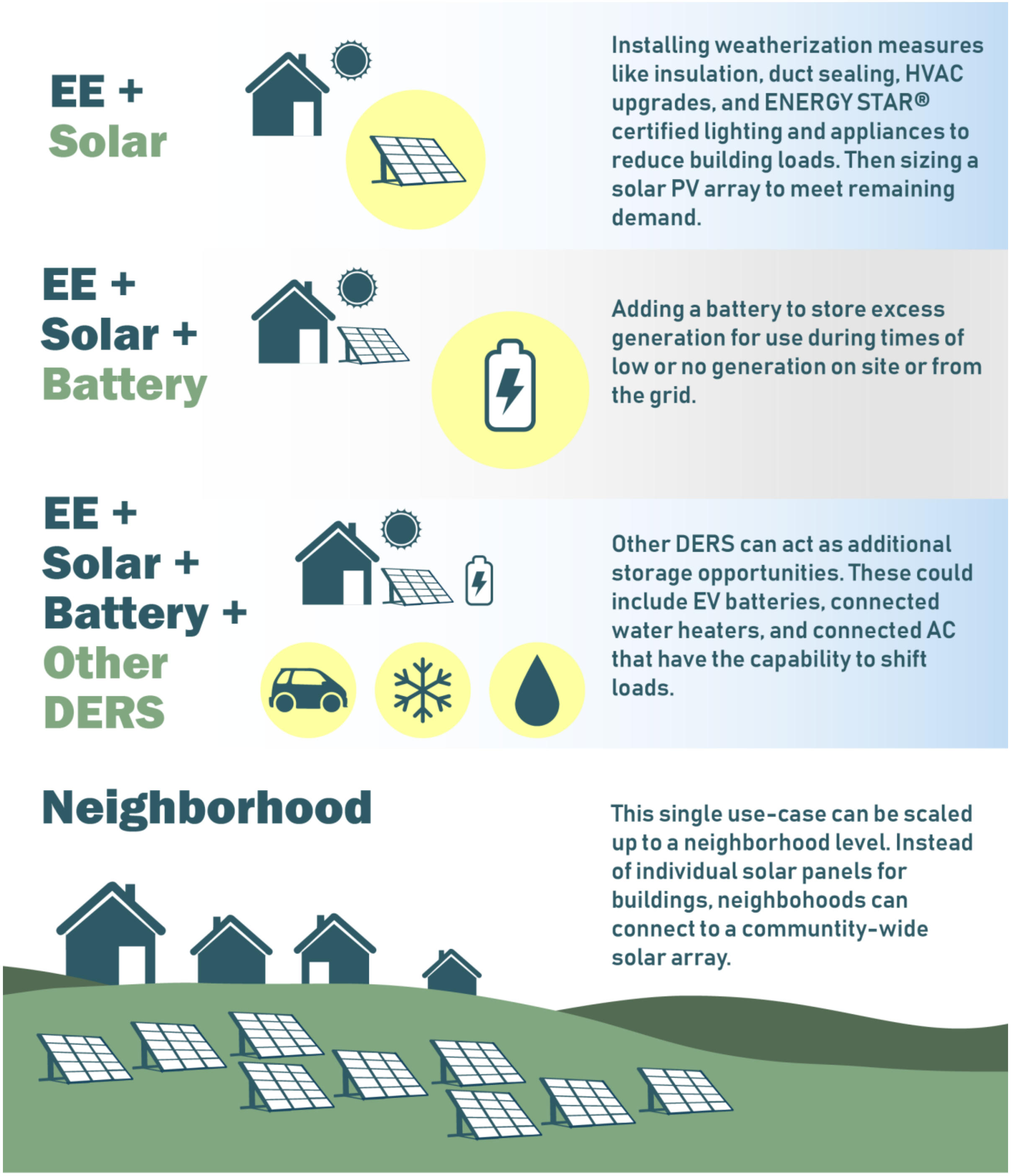

Figure 2. Progressive complexity of integrated energy efficiency and projects

Figure 3 shows a full-featured residential energy efficiency/solar+ system.

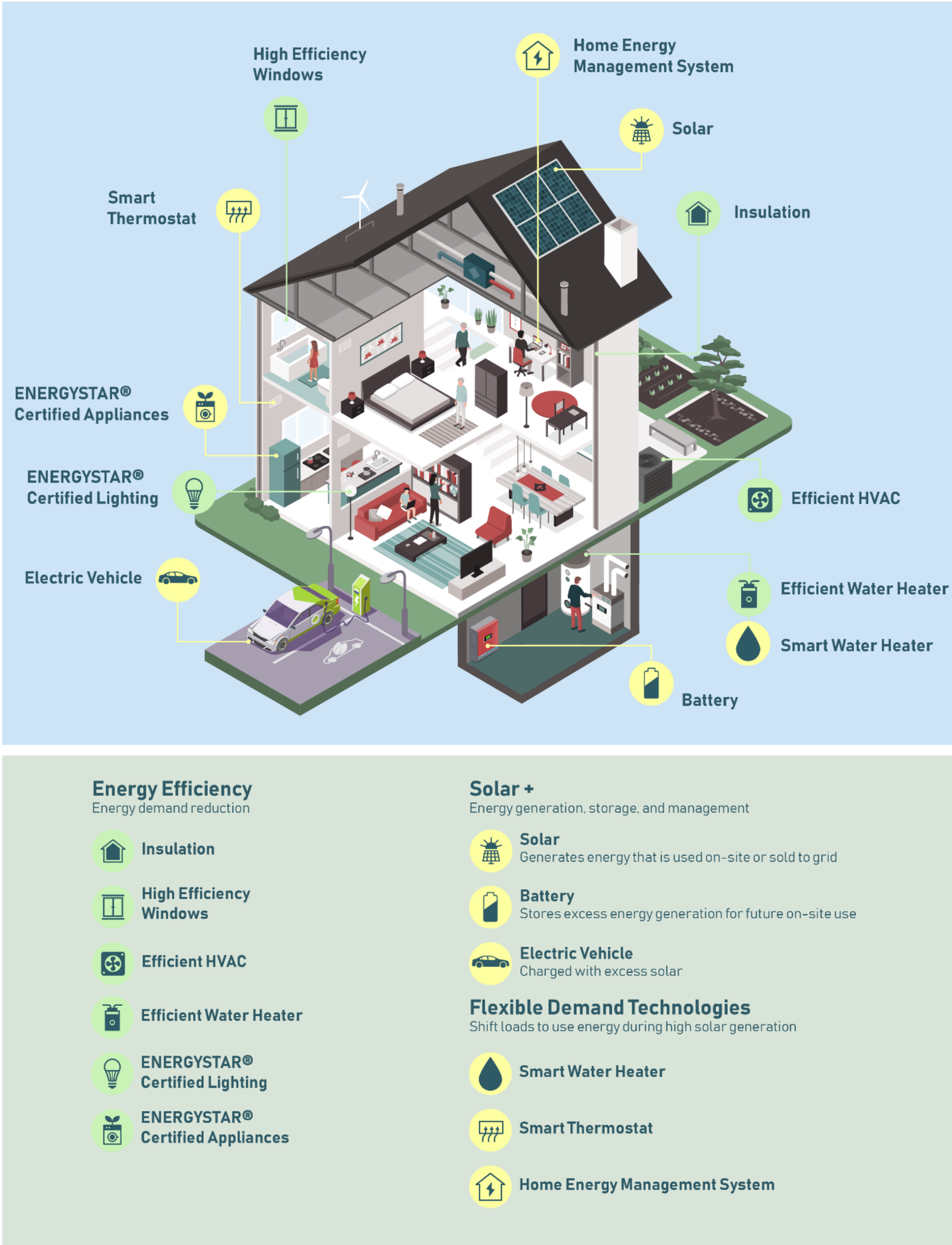

Figure 3. Fully integrated system of residential energy efficiency and solar+ measures

What Are Microgrids?

Microgrids are small-scale power grids that connect certain buildings and facilities to various DERs that can run independently from the centralized grid, such as solar photovoltaic systems and energy storage devices. Microgrids approach EE/Solar+ integration at a neighborhood or district scale rather than at the single-building level. See the University of Hawaii case study below for an example.

Cities and institutions are driving growth in microgrid technology and deployment as they work to improve the resilience of their buildings and communities. In particular, they are exploring how microgrids could provide continuous power for critical facilities like hospitals and water treatment plants during extreme weather events and major grid outages. Maintaining power to these buildings can expedite recovery from disruptive events. For example, maintaining power to a hospital can help avoid mass evacuations and free up emergency response personnel and resources to address emergencies in other parts of the community.

In addition to cities and institutions, utilities and private companies are interested in microgrids and their potential benefits. Microgrids can provide grid benefits like reducing peak demand and improving system reliability, which can reduce their operational costs and decrease the need for new infrastructure. For building and facility owners, microgrids can reduce energy consumption and costs. Commercial building owners—and others—who pay demand charges (fees based on an individual building's highest energy use in a given month) may be particularly interested in microgrid technology because demand charges can account for up to 60% of their utility costs.

Cities, institutions, utilities, and private companies are forming partnerships to develop microgrids that can provide these various benefits simultaneously. For example, Xcel Energy partnered with Panasonic and Younicos to develop the Peña Station NEXT microgrid project in Denver. This ongoing project will provide electricity to 220 recently completed apartment units and to a planned community of homes and businesses. Each building will have a carport solar system, rooftop solar array, battery system (including inverter and controls), and an intelligent energy management system (Hanley 2017).

Independent Service Provider Projects and Programs

EE/Solar+ projects and services are beginning to gain ground in the private marketplace. Independent service providers (e.g., building technology companies, home performance contractors, and ESCOs) combine efficiency measures, solar generation, and energy storage to help customers reduce energy costs and use renewables to meet their sustainability goals. Based on our review of a select set of examples—a few of which are described in detail below—independent service providers have been particularly successful in integrating energy efficiency and solar+ in both the commercial building sector and low-and medium-income housing.

Independent service providers use technical knowledge, innovative financing, and sales experience to optimize EE/Solar+ and identify additional savings opportunities. Furthermore, because these providers are not bound by siloed energy efficiency and DER program approaches like many regulated utilities, they can design projects that include multiple measures.

This section presents case studies of projects and programs offered by these independent service providers. As the following case studies show, many of the projects we identified are in low- and middle-income housing. All the examples take advantage of some combination of federal and state tax credits and state- or utility-sponsored loan or grant programs.

National Housing Trust Enterprise Preservation Corporation and St. Dennis Apartments

St. Dennis Apartments is a 32-unit affordable housing building in the Mount Pleasant neighborhood of Washington, DC. In an effort to persuade tenants to move out, the previous owners had let it fall into a state of disrepair and neglect (while raising rents). However one family refused to leave. In a settlement with the owners in 2008, these residents obtained an option to purchase the building at market price. The family secured financing from the National Housing Trust Enterprise Preservation Corporation (NHT–Enterprise) to acquire and redevelop the property. NHT–Enterprise was an experienced partner, having completed several affordable multifamily renovations with both energy efficiency improvements and solar photovoltaics to reduce operating costs and maintain affordable rents in those buildings.

The project was completed using tax credits, loans, and grants. A total of $9.7 million was raised to complete the redevelopment. The first phase, a $4 million renovation completed in 2011, included several energy efficiency improvements and water conservation measures: efficient lighting and HVAC systems, high-efficiency windows, ENERGY STAR® appliances, a white reflective roof, and low-flow bathroom and kitchen fixtures (NHT 2019).

A 250-kilowatt solar system was installed in 2014. NHT–Enterprise owns the system through its affiliate NHT Renewable. This arrangement reduces the capital cost for the building owner and enabled NHT to take advantage of federal solar tax incentives. NHT is repaid over time through the energy cost savings.

After the renovation, utility costs for each apartment unit decreased by 40%. An additional benefit is that the market value of the property also increased, doubling from $3.2 million to $6.2 million because of the physical improvements and the increase in the owner's operating reserves from higher but still affordable rents (Samarripas and York 2018).

University of Hawaii and Johnson Controls

In 2010 the state of Hawaii required that government agencies contract with energy companies when implementing energy efficiency retrofits. At that time, the University of Hawaii (UH) campuses had a backlog of deferred maintenance projects, including heating and cooling system repairs. Accordingly, the university entered into an energy performance contract with Johnson Controls for a multiyear energy efficiency and renewable energy project (Anzelotti 2018).

In the first phase of the project, Johnson Controls conducted energy audits at UH Maui College and the five Oahu community college campuses. It then implemented energy efficiency measures at UH Maui, including interior LED lighting upgrades, new chillers and related equipment, window film, new interior transformers, and smart controls (Johnson

Controls 2018). These measures lowered the college's electricity consumption enough to allow the solar+ system installed in Phase 2 to meet all its energy needs (Cohn 2018).

In 2015 the Hawaii Legislature and the University of Hawaii system adopted the goal of having all 10 campuses in the university network reach zero net energy by 2035. In response, Johnson Controls embarked on Phase 2 of the project at UH Maui College and the five Oahu campuses, deploying arrays of solar panels in the form of shade canopies and rooftop installations and connecting them to battery storage (Anzilotti 2018).

The Maui array comprises 2.8 MW of solar PV and 13.2 MWh of batteries; the Oahu campuses have 7.7 MW of solar PV and 28.6 MWh of battery storage (Johnson Controls 2018). Linked to smart batteries and smart buildings, the Johnson Controls energy management system (EMS) tracks how much energy is actually used and forecasts dynamic loads for the next three days (Cohn 2018).

Once the Maui system becomes operational, the college will become one of the first campuses in the nation to generate 100% of its own energy. On the Oahu campuses, the combination of solar PV, distributed energy storage, and efficiency measures will reduce fossil fuel use by 70–98% (Anzilotti 2018).

On sunny days, the Maui solar array generates more energy than the college uses. Stored in the batteries, the excess is available for use at night and during cloudy periods. Although the surplus could also be exported to the grid in many other states, Hawaii does not allow this practice (Cohn 2018).

This project is financed through an energy savings performance contract with Pacific Current, an energy services company (ESCO) that bears the up-front cost of the solar+ systems, owns and operates them, and gets repaid over time. The university pays Pacific Current about 19 cents/kWh, compared to Hawaii Electric's cost of about 27 cents (Cohn 2018). Over 20 years, the savings are guaranteed to exceed $79 million in addition to a $20 million reduction in maintenance costs (Johnson Controls 2018).

Johnson Controls and UH have also partnered on an educational program to be rolled out along with the new energy systems. It features coursework on energy efficiency technology, hands-on learning, internships, and workshops for faculty and students (Johnson Controls 2018).

CONNECTICUT GREEN BANK AND POSIGEN

In 2014 Connecticut Green Bank issued a request for proposals to address market barriers to the adoption of clean energy installations among low- to-moderate income (LMI) homeowners.[4] PosiGen, a Louisiana-based solar company, responded and partnered with the bank in 2015 to roll out the Connecticut Solar for All program (Baneman, Dougherty, and Sims 2018). This public–private partnership overcomes several challenges in

[4] Clean energy installations include access to solar and energy efficiency measures.

Connecticut towns and provides services to reduce energy costs for LMI owners of single-family homes, an underserved market.[5]

In the first four years of the program, LMI homeowners were offered a solar lease with a basic energy efficiency package and an optional agreement that covered more advanced efficiency upgrades. With over two-thirds of customers signing up for these upgrades, in 2019 the program combined them with the solar lease into one comprehensive offering.

Combining these services into a single offering has made the enrollment process more efficient and expanded energy efficiency uptake across the state. The program is marketed through promotions at community events, door-to-door canvasing, and television, radio, and web-based advertisements. Community centers and parent–teacher groups also help with outreach (Baneman, Dougherty, and Sims 2018). To facilitate easy participation, there are no requirements for customers to pay a deposit or go through a credit or background check.

The program leverages the Energize Connecticut's Home Energy Solutions (HES) program, which consists of an energy audit and installation of basic weatherization and energy-saving measures (e.g., sealing air leaks, efficient light bulbs, low-flow showerheads, and faucet aerators). On top of these measures, intensive efficiency upgrades like attic-access insulation, advanced air sealing, smart thermostats, and pipe wraps are paired with the rooftop solar installations. The program offers customers four solar array sizes to make the installation more affordable.[6] PosiGen owns the arrays.

In the most basic program offering, customers lease a solar installation for a 20-year period with fixed payments. Their average monthly payment for a system of 3.7–9.6 kW is $50–120. The agreement guarantees that the homeowner will be reimbursed if the system does not produce the estimated electricity (Baneman, Dougherty, and Sims 2018).

PosiGen finances Solar for All through internal funds, equity investors, private-sector lenders, and low-cost capital from the Connecticut Green Bank. It also takes advantage of tax incentives to reduce costs to participants. Since most of PosiGen's customers do not have a large tax burden, they would receive no benefit from federal solar tax credits if they owned their systems. However, as the owner of the systems, PosiGen is able to claim these benefits (as well as depreciation) and can pass them on to its customers in the form of low lease payments (Baneman, Dougherty, and Sims 2018). PosiGen also receives LMI performance-based incentives from Connecticut Green Bank, further reducing program

[5] PosiGen serves 169 towns in Connecticut, all with potentially different policies and marketing challenges, and the company must rely on municipal services when it comes to permits and inspections. To overcome challenges in different towns, PosiGen has partnered with local subcontractors and the Connecticut Green Bank to develop a statewide deployment strategy and co-brand marketing and outreach efforts.

[6] Uniform sizing allows PosiGen to purchase panels in bulk and lowers installation labor costs. It also reduces the amount of time it takes to get a solar project approved, since the same technical drawing can be submitted with multiple permit applications (Pyper 2015).

costs. The incentives are based on the actual kilowatt-hour production and are over 2.5 times higher than market rate (CESA 2018).

Solar for All installations were producing over 280,000 MWh of electricity by 2018. By November 2019, PosiGen had supported 2,661 solar PV projects, many in LMI homes. Participants can expect to save 20–30% on utility costs over a 20-year contract term, which translates to an average annual net savings of $450 (CESA 2018).

ENERGY FUTURES GROUP SOLAR ACCESS PROGRAM

In 2017, in partnership with a group of western Massachusetts organizations and businesses, Energy Futures Group (EFG) developed and launched the Solar Access Program to provide a heat pump and solar PV array package to LMI owners of single-family homes. The implementers set a goal to engage 50 participants and are currently on track to deliver approximately 45 projects (R. Faesy, principal, Energy Futures Group, pers. comm., October 28, 2019).

The Solar Access Program was funded by a grant from the Massachusetts Clean Energy Center and the Department of Energy Resources, with funds pooled from Massachusetts ratepayer dollars. It operates through the nonprofit Center for EcoTechnology (CET).

The program uses several strategies to drive participation, including community-based marketing approaches like booths at local farmers' markets and fairs. A webpage featuring informational videos and participant testimonials outlines the benefits of efficiency and onsite solar, available financing, and the participation requirements. This clear messaging helps interested homeowners understand the program's value proposition.

Interested participants contact CET to learn whether they are good candidates for the program. After they are approved, CET connects them with a contractor to install their system. To streamline the installation process, CET works with just one solar installer (SunBug Solar) and one heat pump installer (Girard Heating and Air Conditioning).

The program partners with UMassFive College Credit Union to provide customers with a 10-year loan for the package, with the guarantee that loan payments will be less than or equal to the energy bill savings from the new systems. Customers are essentially paying off their loans with money they would have spent heating their homes with inefficient HVAC equipment. After the loan is paid off, a customer owns the system for the remainder of its useful life and pockets the savings from reduced energy bills (CET 2019).

The program also coordinates several federal, state, and utility incentives to reduce project costs. It leverages the 30% federal solar tax credit, 10% Massachusetts state solar tax credit, and Mass Solar loan to achieve a 30% principal reduction in solar system costs. It also uses several electric utility incentives including the Solar SMART incentives, the Mass Save heat pump rebate, and a no-interest HEAT® loan. In addition to these external incentives, the program offers its own solar access incentive that pays the participant's first six monthly loan payments, allowing LMI customers to participate with no out-of-pocket costs.

After installing the systems, participants are estimated to save 40–60% on their energy bills by generating their own electricity and, with the heat pump, spending less on fuel for space heating (R. Faesy, pers. comm.).

Utility EE/Solar+ Pilots and Programs

We identified 13 utility customer-funded[7] pilots and programs with EE/Solar+ offerings and developed detailed case studies for five of these programs. As table 1 and the detailed case studies show, energy efficiency and solar+ can be integrated in multiple ways. In the most common approach, customers install both energy efficiency measures and solar+ under a single program and through the same provider. In another approach, customers receive closely coordinated offers that streamline service delivery from different providers.

Based on these integrated examples, we identified five types of EE/Solar+ programs as shown in table 1. Zero-energy building programs, which consistently integrate efficiency and solar+ services, are the most common. Next, we identified a handful of residential solar rebate programs. While these programs do not usually offer or require energy efficiency, we identified two programs that offer streamlined efficiency incentives or require participants to complete energy efficiency upgrades before they install a solar+ technology. Similarly, DER aggregation pilots, though less common, combine both energy-efficient technologies and solar+ systems. Online marketplaces and tariffed-on-bill programs are two further program types. While many utilities offer these program types for energy efficiency products and sometimes services, very few include both efficiency and solar+ offerings.

Table 1. EE/Solar+ programs and pilots

Program type	Description	Examples
Solar rebate program with efficiency assessment	These programs provide solar rebates and require participants to conduct an energy efficiency assessment of their property before receiving solar incentives. While these programs cross-promote efficiency rebates for recommended measures, none require participants to implement efficiency measures.	Fort Collins Utilities Solar Rebate Program* Pacific Gas and Electric Company and Southern California Edison California Solar Initiative programs
Zero energy buildings	These pilots and programs help customers undertaking new construction or deep retrofit projects to make their buildings zero-energy. Administrators often provide both technical and financial assistance throughout the design and construction process.	Consumers Energy Zero Net Energy Pilot Program NYSERDA Retrofit NY pilot PG&E ZNE Builder Demonstration pilot Energy Trust of Oregon Path to Net Zero*

[7] While not all of these programs are administered by utilities, all of the programs described here are ratepayer-funded programs administered by either a utility or statewide administrator.

Program type	Description	Examples
DER aggregation pilot	These are utility pilots and programs that test how grid-interactive technologies can deliver benefits to both customers and the grid. DER aggregation pilots specifically test how to integrate multiple separate DERs into fleets for greater demand flexibility.	SMUD 2500 R Midtown Community Development* Southern Company Smart Neighborhood initiatives
Marketplace	These programs provide an online marketplace for customers to evaluate, compare, and shop for a variety of energy efficient products and solar+ services.	Consolidated Edison Connected Homes Platform* Xcel Energy Store SMUD Energy Store
Tariffed-on-bill program	These programs finance energy efficiency upgrades and solar investments through a tariff on the customer's utility bill. The on-bill charge is tied to the meter location and not to an individual customer. The tariff charges remain in effect until the cost recovery is complete, regardless of a change in ownership/occupancy.	Ouachita Electric Cooperative HELP PAYS*

*** Programs with case studies in this report**

Next we provide five case studies, one for each program type identified. All the case studies integrate energy efficiency and solar and two integrate energy storage as well. The case studies represent a range of program administrator types, including two municipal utilities, a statewide program administrator, a cooperative, and an investor-owned utility.

City of Fort Collins Utilities Residential Solar Rebate Program

The municipally owned Fort Collins (Colorado) Utilities began offering solar rebates in 2008 and residential efficiency incentives in 2010. In 2015 the city of Fort Collins set a goal to achieve an 80% reduction in GHG emissions by 2030 and carbon neutrality by 2050 compared to 2005 emissions. The residential Solar Rebate Program helps the city meet these targets by encouraging customers to consider efficiency upgrades before installing photovoltaics.

Before they commit to the program, customers are advised to assess their roof's solar potential by evaluating its access to sun, possible shading sources, and condition. Once eligibility is established, a home efficiency audit is performed, and customers receive a prioritized list of improvements. Those who live in homes built before 2005 must complete the audit to claim their solar rebates, but it is optional for newer homes. All participants then have the option to implement the recommended efficiency measures and claim rebates available through the utility's Efficiency Works program. Measures include insulation and air sealing; furnace and boiler upgrades; and window, HVAC, and heat pump replacement.

The next step is the sizing and installation of the solar system. Customers first work with a participating solar contractor to design and purchase their systems; the contractor then installs the system and applies for rebates. A Fort Collins city inspector checks the installation for electrical code compliance. The utility also inspects the solar equipment and tests its performance.

The program relies on a number of utility incentives to make it attractive to customers. Participants can sign-up for a subsidized $60 home assessment through the Efficiency Works program, select the retrofit package with the most relevant incentives, and receive solar rebates of up to $1,500. They can also take advantage of Fort Collins Utilities' Epic Loan for energy efficiency upgrades and federal tax incentives for solar installations. In addition, customers are credited for energy returned to the grid, based on the established residential net metering time-of-day energy rates.

Since Fort Collins Utilities began requiring audits, 67% of solar rebate program participants have completed an assessment before installing a solar PV system. Although the number of solar participants who actually undertook an energy retrofit is not available, the utility estimates that 10% of solar rebate participants invest in efficiency upgrades through Efficiency Works before installing a rooftop solar system (Todd Musci, resource conservation specialist, Fort Collins Utility, pers. comm., May 30, 2019).

ENERGY TRUST OF OREGON PATH TO NET ZERO

Energy Trust of Oregon offers Path to Net Zero as part of its New Buildings program. Commercial building owners and businesses constructing or renovating a new building work with program staff to include deep energy efficiency measures and on-site solar generation in their building plans (Energy Trust of Oregon 2019b). To participate, customers set a design goal that is 40% more efficient than required by code. The program supports design teams and building owners throughout the entire project, from early design to post-occupancy, by providing technical assistance and financial incentives at key milestones.

The first step in the process is an early design meeting with building owners and their design teams to set an energy use intensity (EUI) target, identify specific energy efficient strategies, integrate solar, and ensure solar contractors are part of the design team. The EUI target becomes a reference point for staying on track as the detailed design work proceeds. The program uses an energy model to demonstrate that the as-designed building meets the EUI target.

Energy Trust provides financial incentives to support early design, set EUI targets, and propose energy efficiency strategies for building owners to consider throughout the process. Energy Trust then provides funding to offset the cost of purchasing efficient equipment and installing on-site solar. To ensure the building is meeting its as-designed EUI target, the program provides design commissioning and post-occupancy support tailored to the customer's building strategies and goals.

By the end of 2018, 70 customers were actively designing buildings to meet their Path to Net Zero goals (Energy Trust of Oregon 2019a), and another 19 customers had completed and were occupying their buildings. While program-wide savings data are not yet available, individual case studies show overall project success and substantial energy savings. For example, Portland Community College received $236,000 in cash incentives to install deep energy efficiency measures and a 100-kW solar system to achieve zero net energy (Energy Trust of Oregon 2017). Incorporating financial incentives and their commercial retail net metering rate, the school anticipates that it will save $27,000 in energy costs each year.

Sacramento Municipal Utility District 2500 R Midtown Community Development

From 2010 to 2014, the Sacramento Municipal Utility District (SMUD) partnered with a private developer, the 2500 R Group, LLC, to build a zero net energy community with 34 new single-family homes. Each home was designed to be LEED-certified with energy efficiency measures such as demand-responsive smart thermostats and remotely controllable outlets. Each home also received a PV array and a lithium-ion battery. Together, these technologies communicate through an integrated energy management system (IEMS) to optimize energy use, storage, and generation. Homeowners can access their IEMS and review their energy usage information through an online customer portal. SMUD can also send signals to the IEMS about demand-response events (SMUD 2014).

SMUD tested how these technologies could deliver benefits to the grid. The entire IEMS system shifted an average of 2.66 kW of demand on conservation days and 1.35 kW on non-conservation days. The battery and solar system alone shifted 2.47 kW on conservation days and 1.26 kW on non-conservation days. Each customer saved $3.71 per day (SMUD 2014).

SMUD also tested its ability to operate 10 of the houses together as a single flexible demand resource. Compared with homes that had no IEMS, this 10-home fleet reduced demand by 43.8 kW during peak times. The project also tested a simulated grid outage to prove that the homes' IEMS and solar systems could provide continuous power if an actual outage occurred.

During the five-month test period, the 10 participating customers consistently used less energy than did the nonparticipating homes. In two of the months, they used less than half the energy used by nonparticipants.

After this pilot was completed, SMUD launched its All-Electric Smart Home program. The program helps homeowners install smart energy management systems to take advantage of their renewable energy generation. While SMUD runs the program independently of their solar rebate program, they do cross-promote it on the landing pages for their solar and renewable energy programs.

Consolidated Edison Connected Homes Platform

In 2016 Consolidated Edison (Con Edison) partnered with Opower (now part of Oracle) and Enervee to launch the Connected Homes platform to 275,000 customers in Brooklyn and Westchester County. This demonstration project was part of the Reforming the Energy Vision regulatory proceeding issued by the New York Public Service Commission. The program aims to help manage energy costs and comfort, increase customer understanding of which DERs will reduce their energy use, and reduce DER providers' costs of acquiring customers.

The program uses personalized paper and digital communications to connect customers to cost-effective energy efficiency products and services as well as DER offerings. Con Edison sends out offers for energy audits, home energy retrofits, and rooftop solar, as well as high-bill alerts with energy insights and customized recommendations for products (Con Edison 2018). Con Edison uses customer energy data and advanced analytics to generate these unique offers, matching relevant utility-vetted products and services with participant needs.

A key feature of the program is an online marketplace for home energy efficiency and renewable energy products and services. Customers can evaluate energy-efficient products by comparing their ratings, costs, and customer reviews. The site can also direct them to retailers who sell those products. The online marketplace includes a retail site where customers can purchase small and low-cost items like LED light bulbs, smart thermostats, and smart power strips and apply for rebates and incentives (Uchin and Coltro 2016). Other resources include buying guides for light bulbs, thermostats, gas dryers, and water heaters. A concierge-type service is also available for customers interested in solar. A solar expert remotely designs the system, gathers bids, and helps the participant negotiate with potential installers.

Con Edison generates revenue through third-party advertising and retail sales. It also charges efficiency and DER service providers a fee for generating customer leads.

The Connected Homes demonstration project has tracked more than 2.2 million views on the marketplace and 1.3 million unique visits (EEI 2019). By the end of 2018, 220,000 products had been sold through the online platform, including more than 113,000 LED light bulbs. The online sales of smart thermostats and LEDs have generated an estimated 72 GWh of lifetime energy savings (Con Edison 2018). The project has also produced 138 rooftop solar contracts with 53 complete installations as well as 117 community solar contracts with four implementations (Con Edison 2019).

OUACHITA ELECTRIC HELP PAYS

Ouachita Electric cooperative serves low-income residents in rural southwest Arkansas, including people living in mobile homes. Its members are generally unlikely to pursue energy efficiency upgrades on their own (Walton 2017). In 2014, Ouachita partnered with EEtility, a Little-Rock-based B corporation, to offer an on-bill financing program that relied on utility members getting individual loans from the cooperative to pay for energy efficiency upgrades. However the customers who most needed this program were unable to take on additional debt. Therefore in 2016 Ouachita asked EEtility to adopt the Pay As You Save® (PAYS®) tariffed on-bill financing system and dispense with the loan requirement. Called HELP PAYS, the new program allows customers to pay for upgrades through a monthly charge on their utility bill, without the credit score and homeownership requirements that typically accompany a loan.

The HELP PAYS program uses the co-op magazine, local advertising, and word of mouth to educate its members about program benefits. Participants receive a free home energy assessment that identifies recommended measures and estimates the annual energy cost savings from the upgrades. Since the average age of the homes in the program is 40 years or more, they are often very inefficient and have the potential for large energy savings (Walton 2017). Common energy efficiency improvements include LED lighting and HVAC upgrades, air sealing, attic insulation, and duct sealing. After the recommended measures are installed, the EEtility team inspects and verifies the work and authorizes payment to the contractor.

In 2019 Ouachita added rooftop and on-site solar as part of the suite of eligible technologies. Customers have been very interested, but the cost of a solar system can be prohibitive for many. The program is testing solar on one unit and tracking the results.

Leaving aside the cost of solar, the Pay As You Save model removes a number of other barriers to low-income participation in programs of this type. All co-op members can participate regardless of their income, credit score, or renter status; only the condition of the home and the opportunity for efficiency measures to be deployed determines participation.

The PAYS model assures Ouachita Electric a low-risk path to recover its investment costs while benefitting participants. The monthly charge on the customer's bill is always less than the estimated savings from the upgrades. The charges stop after the upgrades have reached 80% of their estimated useful life, leaving the customer with 100% of the savings.

Like property-assessed clean energy financing (PACE), the on-bill tariff is tied to the location and not to the customer. Participants are responsible for paying back the investment only as long as they live in the home. However, unlike with PACE, successor customers do not have to accept the charges once they take possession of the unit.

HELP PAYS had reached over 10% of Ouachita members by the end of 2019. Customers can expect 30% energy savings if they live in a single-family home, or up to 35% in apartment units (Cayce 2016). The upgrades also reduce peak demand by nearly 2 kW per housing unit on average, which results in savings of about $15 per month for the cooperative and thousands of dollars over the life of the upgrades (Walton 2017).

Summary of Project/Program Value Streams

Table 2 highlights the value streams captured by the EE/Solar+ projects and programs we have highlighted, organized by the categories of benefits discussed in the next section.

Table 2. Value streams of featured projects and programs

	Utility benefits				Grid stability		Customer benefits					GHG reductions		
Project or program	Increase energy savings	Defer T&D invest-ments	Add value streams	Introduce new EE solutions	Reduce grid congestion	Integrate DERs	Increase energy savings	Reduce confusion	Serve LMI customers	Increase comfort	Improve health	Support renewable energy goals	Reduce carbon emissions	Support net zero energy goal
NHT and St. Dennis Apartments							•		•	•				
University of Hawaii & Johnson Controls							•					•		•
Connecticut Green Bank & PosiGen							•	•	•	•	•			
Energy Futures Group Solar Access							•	•	•	•				
Fort Collins Utilities Solar Rebate	•			•		•	•	•					•	•
Energy Trust of Oregon Path to Net Zero	•			•		•	•	•						•
SMUD 2500 R Midtown Community	•		•	•	•	•	•	•				•		•
ConEd Connected Homes	•	•	•		•	•	•	•		•		•		
Ouachita HELP PAYS	•			•	•		•	•	•			•		•

Benefits of EE/Solar+

EE/Solar+ programs offer a variety of benefits to the grid, the environment, utilities, and customers. Energy efficiency and solar+ each has its own benefits; integrated programs combine these and add even more through synergistic effects.

ENERGY EFFICIENCY BENEFITS

Efficiency programs help customers reduce their energy consumption and utility bills. In 2017 alone, efficiency programs nationwide saved 29.9 million megawatt-hours of energy consumption (EIA 2019). In addition to saving customers money, energy efficiency is generally the cheapest energy resource for utilities. On average, energy efficiency costs two to five cents per kilowatt-hour, while energy supply sources like coal, community solar, and nuclear energy can cost twice as much (Gilleo 2017).

Reducing energy consumption can lead to significant reductions in GHG emissions. ACEEE estimates that efficiency in buildings could potentially reduce carbon emissions by 33% by the year 2050 (Nadel and Ungar 2019).

Efficiency programs also deliver nonenergy benefits to customers, including a healthier indoor environment and improved comfort, health, and worker productivity. High-performance efficiency measures like air sealing, double-paned windows, and insulation reduce drafts, prevent the growth of mold and mildew, and maintain air heating and cooling for longer periods. These measures improve occupant comfort, security, and health (Denson Jr. and Hayes 2018).

Smart efficiency solutions like connected thermostats and water heaters benefit the grid because they provide greater flexibility and control over when they use power. This helps utilities match energy supply to demand, and also save energy when it is most valuable to the grid. For example, water heaters can preheat water during times of peak energy generation so that they use less energy to heat water at times when demand is peaking.

SOLAR+ BENEFITS

As the cost of solar technology continues to decline rapidly, installing solar-plus-storage systems is becoming much more economical, helping customers to save money on their energy bills. Generating and storing their own electricity reduces the amount of energy that customers need to buy from the utility. Customers' actual savings will vary depending on a number of factors, including how much solar energy they can generate, the price of electricity in their area, and whether they can take advantage of market structures like time-of-use rates or demand-response programs (Roberts 2016).

Solar+ systems mitigate GHG emissions from the grid by lowering energy demand, which reduces the need to generate, transmit, and distribute electricity derived from fossil fuel power plants. Solar+ systems may also be much cleaner sources of energy, which further reduces the GHG footprint of the grid (Relf, York, and Kushler 2018).[8]

Solar+ can play a key role in meeting renewable energy goals. More than 200 US mayors have pledged to work toward 100% renewable energy by 2035 (Sierra Club 2019). In response to states' renewable portfolio standards, many utilities are already using renewables to source some of the energy they generate or sell.

Solar+ systems provide temporal benefits to the grid. The time when energy is saved is becoming increasingly important as demand and supply spikes cause dramatic fluctuations in energy costs. For example, a heat wave in Texas led to more customers using air-conditioning and caused a sudden demand spike. In turn, the cost of electricity more than tripled in a single day because more expensive energy supply sources had to be ramped up to meet the peaking demand (DiSavino 2019). Solar+ can mitigate these spikes and relieve grid congestion by increasing flexibility around when electricity is used. Along with the potential benefits, there can be potential downsides for some customers, notably those facing significant demand charges and misalignment with peak demand periods.

Solar+ can also make buildings more resilient, for example by providing continuous power during grid outages. One study the National Renewable Energy Laboratory (NREL) estimated that the value of resiliency provided by solar+ to a single fire station is $11,824 for a 2-hour power outage and $20,071 for a 22-hour outage (Rickerson, Gillis, and Bulkeley 2019).

EE/SOLAR+ SYNERGY

EE/Solar+ combines the savings of energy efficiency and solar+ and creates synergies that generate additional benefits. Each category of benefits identified is described in greater detail below.

Maximizing Energy Savings

Adding a solar+ system to a building enables it to draw less energy from the grid. If the building is energy efficient, it needs even less energy. Owners of efficient buildings can use their energy bill savings to help pay for solar arrays, saving even more. Incorporating solar+ into energy efficiency program offerings also allows customers (and sometimes utilities) more control over when energy is saved. For example, the SMUD pilot demonstrates how homes that integrate solar generation, battery storage, and demand-responsive smart thermostats and outlets can shift and reduce energy demand during peak times. This combination of measures in an EE/Solar+ program can lead to the ultimate level of energy savings embodied by zero-energy buildings (ZEBs).

[8] Energy storage alone is not in itself inherently clean, but it can enable greater use of clean energy technologies. The carbon emissions reduction potential of energy storage varies based on how it is used; carbon emissions reductions require charging during low-emissions times and discharging during higher emissions times to avoid the need for higher-emitting resources on the grid. Such charging behavior may require better rate designs or carbon pricing.

Zero Energy Buildings

Zero energy buildings (ZEBs) use efficiency measures to minimize energy demand to the point where the remaining load can be met with 100% renewable energy. ZEBs are also resilient. For example, Whole Foods is constructing a zero-energy store in San Francisco in part to reduce economic losses from power outages (Green et al. 2019). The New Buildings Institute (NBI) reports that the number of verified and emerging ZEBs has grown 10-fold since the institute started tracking them in 2012 (Hobart 2019).

Codes and policies promoting ZEBs are one strategy that cities and states are using to make progress toward their climate goals. California, Oregon, and Washington are committed to adopting zero-net-energy residential codes by 2020, 2030, and 2031, respectively. For the most part, ZEB policies and programs target new construction, but retrofitting existing buildings is becoming more technically and economically feasible and will be critical for meeting climate goals (Amann 2017).

ZEBs are becoming a major driver of consumer demand for EE/Solar+ and are the focus of a few utility programs, such as the Energy Trust of Oregon's Path to Net Zero program, described earlier.

Compared with siloed programs, combined EE/Solar+ can better help utilities defer costly investments in traditional generation, transmission, and distribution infrastructure. In the next 15 years, utilities will invest approximately $50–80 billion per year to meet generation, transmission, and distribution needs (Bronski et al. 2015). Clean energy portfolios that integrate efficiency and solar+ solutions not only offer an alternative solution to traditional infrastructure but can also cost less. For example, research by the Rocky Mountain Institute shows that clean energy portfolios that include solar, wind, storage, efficiency, and demand flexibility cost 90% less than proposed natural gas plants (Dyson, Glazer, and Teplin 2019; Teplin et al. 2019). EE/Solar+ can also maximize nonenergy benefits including occupant comfort, health, and productivity.

Grid Stability and Reliability

EE/Solar+ allows utilities to improve system management, integrate DERs more seamlessly into the grid, and better manage electricity supply and demand at specific times in stressed locations. Renewable energy sources, such as building-sited solar systems, tend to introduce variability into energy supply on the grid and cause a mismatch between supply and demand (Golden, Scheer, and Best 2019). For example, grids with a high penetration of solar energy can experience generation peaks in the middle of the day, while energy demand peaks occur later in the evening. To manage this mismatch of generation and demand, utilities may need to use fast-ramping generation sources in the evening not only to meet peak demand but to replace diminishing supply from solar. EE/Solar+ can address this problem by smoothing out energy demand and supply loads throughout the day. Figure 4 shows how flexible demand technologies can shift energy loads to times of peak onsite generation and minimize solar generation peaks on the grid.

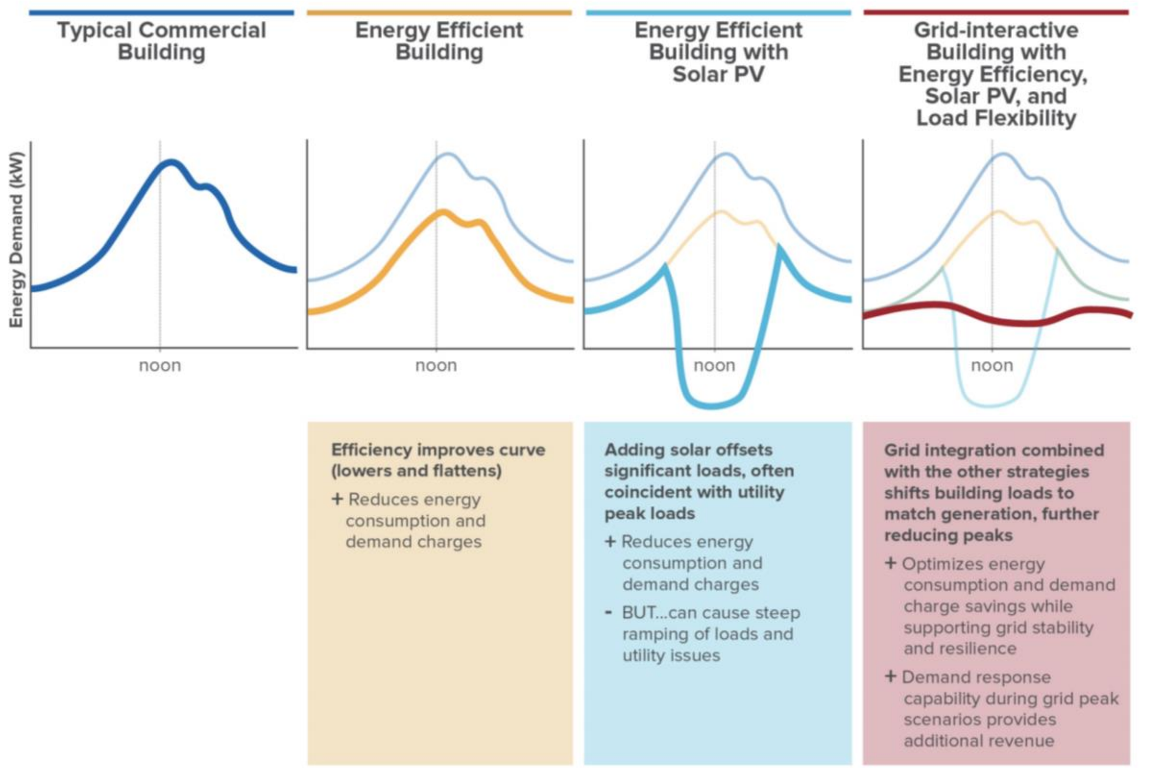

Figure 4. Building load-shape smoothing from efficiency, solar PV, and solar+. *Source:* Carmichael et al. 2019

EE/Solar+ also reduces overall strain on the grid by reducing demand and improves reliability by increasing reserve margins.[9] The increase in reserve margins offsets generation that would otherwise be needed to maintain supply reliability. This can reduce outages during times of high demand, especially if a program delivers projects to congested parts of the grid (Relf, York, and Kushler 2018).

GHG Reductions

By reducing energy consumption, EE/Solar+ allows clean energy sources to meet a greater percentage of the demand, thus reducing GHG emissions.[10] States and cities across the country are setting ambitious sustainability and resiliency goals that call for reliable power with lower carbon emissions. Twenty-nine states now have renewable portfolio standards, a number of which are coordinated with energy efficiency resource standards to reduce

[9] Efficiency measures can provide different levels of peak load reduction depending on their load shape (how much energy they use throughout the day). For example, the load shape of water heaters closely follows the shape of all energy demand on the grid during winter. In other words, the time when water heaters use the most energy is the same time as when energy demand peaks on the grid. Water heaters therefore represent a significant demand-response opportunity for reducing winter peaking because they can specifically reduce or shift their energy use away from peak demand times (Mims, Eckman, and Goldman 2017).

[10] The magnitude of GHG emission reductions depends on the grid composition (energy sources for generation) and time when the EE/Solar+ project offsets power consumption from the grid. For example, a grid with high-penetration solar may have cleaner energy during the day and rely on dirtier generation power plants in the evening to service demand peaks. In this case, EE/Solar+ systems can lead to greater GHG emissions reductions if they shed energy demand in the evening than if they shed daytime demand.

energy demand and help meet climate goals (Barbose 2018). Decarbonization goals in the building sector are another impetus toward adoption of DERs like solar+. Cities have their own carbon reduction goals, and EE/Solar+ can help meet them. For example, the Fort Collins program discussed earlier supports the municipality's goal of carbon neutrality by 2050.

Other Utility Benefits

EE/Solar+ can help utilities open new value streams for their businesses and the grid. The grid will include more and more DERs like solar+ as their price continues to decline and consumer uptake increases. Whether this growth poses challenges or benefits to the grid will depend on how proactively a utility embraces it. In addition to creating an opportunity for utilities to leverage market demand for energy efficiency and DER technologies, EE/Solar+ will also enable more control over customer-sited DERs to ensure they benefit the grid.

EE/Solar+ can also provide an opportunity for administrators to introduce customers to energy solutions they may not have otherwise considered. For example, a customer interested in a solar program may learn that adding energy efficiency measures to their project can shorten the payback period. Similarly, by marketing control technologies like connected thermostats and water heaters, EE/Solar+ programs can help customers save more by shifting their loads to maximize the use of solar generation.

Benefits to Customers

Programs with EE/Solar+ offerings can benefit customers in ways that would not be possible through independent offerings. Combining energy efficiency and solar+ into a single program can reduce customer confusion, yield deeper energy savings, and lead to a better allocation of resources for both customers and providers (Goldman et al. 2010).

EE/Solar+ programs provide customers with a single, streamlined source for various energy-related products, making it easier for them to see their options and choose the ones that best suit their needs. Integrated programs also improve project economics, as customers who first invest in energy efficiency improvements before solar can ultimately reduce the size and cost of the solar+ systems they need. EE/Solar+ can also make projects more financially attractive because efficiency measures often have shorter payback periods. Installing energy efficiency measures with rapid paybacks (e.g., lighting upgrades) can create cash flow to support longer paybacks from a solar+ system.

EE/Solar+ allows customers to maximize the energy and cost savings of their installed measures. For example, projects that use grid-enabled efficiency measures like connected water heating or air-conditioning can shift loads to periods of high solar generation. Through this load shifting, customers reap the greatest benefits from their solar array because they can use their generation rather than selling it back to the grid. This can have even greater economic benefits in areas where customers pay time-of-use rates, demand charges, or solar export rates, or where they participate in demand-response events because they are shifting their usage from periods with high rates to those with lower rates (O'Shaughnessy et al. 2017). Without the flexibility created by storage or consideration of the time value of energy efficiency and solar, integrated solutions in buildings exposed to time-varying or demand rates may not deliver the expected cost savings for customers.

EE/Solar+ also can provide energy solutions to underserved communities. Integrated programs can lessen low-income customers' energy burdens and deliver nonenergy benefits like improved indoor environmental quality and the associated health benefits. These customers often reside in homes that are old, inefficient, and in need of major upgrades or repair (Samarripas and York 2018). When considering efficiency upgrades, disadvantaged communities face barriers such as access financing, credit issues, and education gaps. These challenges can prevent them from participating in efficiency programs and benefiting from public incentives. Integrating energy efficiency, solar+, and financing resources into a single program addresses these barriers by providing LMI customers easy access to capital and increasing their understanding of technologies that can help them reduce their utility bills.

For example, California's Low-Income Weatherization Program for Multifamily Properties requires owners to improve the efficiency of their buildings before adding solar while providing them technical assistance and financial incentives. The integrated incentive structure and application process reduces project costs and customer confusion regarding the different offers, making the program attractive for new customers (Samarripas and York 2018). Similarly, the Ouachita Electric program supports equity initiatives by helping income-qualified property owners and renters (a market that is often underserved by efficiency programs) afford building upgrades and rooftop solar.

Challenges to EE/Solar+ and How to Overcome Them

This report finds that utilities, their customers, and the entire grid could benefit from widespread EE/Solar+ programs. EE/Solar+ can benefit utilities' bottom lines, customer savings, and reliable, affordable, energy supply and demand. Program administrators are increasingly interested in these options. In our interviews, program administrators reported wanting to offer more EE/Solar+ programs but noted they are held back by a lack of precedent and lack of program experience.

Why have so few utilities introduced EE/Solar+ pilots or programs? Our review revealed several challenges that administrators face as they attempt to integrate energy efficiency and solar+ in a single program.

UTILITY BUSINESS MODEL ALIGNMENT

Energy efficiency and customer- or third-party-owned solar and storage conflict with the conventional utility business model by decreasing electricity sales. Utilities typically have an incentive to increase sales in the short term because increased sales will increase short-term profits. Because utilities generally recover some of their fixed costs through volumetric charges, increased sales allow them to collect more than their authorized fixed costs and returns. These windfall profits from customer bills create a bias toward higher sales and against demand reduction resources that decrease sales. Tools like decoupling and other forms of lost-revenue recovery address this throughput challenge.[11]

Further, utilities depend on increasing capital investment and sales to drive shareholder returns (Kihm et al. 2015). This creates bias toward capital expenditures and is a powerful disincentive to meaningfully invest in customer-sited energy efficiency, solar, and storage. By avoiding the need for distribution, transmission, and generation services, these resources undermine the traditional business model. However, in the less-frequent instances where utilities are allowed to own and lease solar or storage systems, they may not face the same "capex" bias, leading them to choose these resources over others (Cross-Call et al. 2018).

These business model challenges can affect several areas of decision making for policymakers: the design of energy efficiency resource standards (EERS) and policy to encourage these resources; business model reforms to address throughput and capex bias; and program design. In each case, policymakers will need to balance the value of integrated programs against the corresponding business challenges.

Regulatory and Administrative Requirements

Regulatory requirements can pose a challenge to establishing an integrated EE/Solar+ program. Note the prevalence of public utility (municipal and co-op) and third-party programs in the profiles above. Regulatory proceedings often require utilities to pursue separate programs for energy efficiency, solar, storage, and electric vehicle offerings. Holding each program separately accountable in terms of funding and operations discourages the combination of technologies (Goldman et al. 2010).

Because energy efficiency and DER programs may be subject to different approaches to valuation and cost effectiveness, EE/Solar+ program administrators may be forced to evaluate and verify performance of the measures independently, according to existing metrics, to determine their combined value (Potter, Stuart, and Cappers 2018). Moreover, many buildings lack advanced energy monitoring systems capable of generating separate savings data for energy efficiency and solar+, which makes it challenging (if not impossible) to evaluate and quantify synergies from EE/Solar+ programs and projects. However this problem might be overcome in the future, as a group of industry stakeholders are working together to develop standard practices for valuing integrated DER investments.[12]

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[11] Decoupling, sometimes known as revenue regulation, fixes the amount of revenue to be collected and allows the rate (price) to float up or down between rate cases to adjust for variations in sales volume. In some cases, this revenue target is allowed to increase based on inflation or the number of customers served (Lazar et al. 2016).

[12] A National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (NSPM for DERs) is being developed to help regulators, utility, and other key industry stakeholders understand the range of benefit–cost impacts and address valuation issues related to integrated DER investments. It includes guidance on a range of DERs, including energy efficiency, demand response, distributed storage, and electric vehicles. See nationalefficiencyscreening.org/the-national-standard-practice-manual-for-ders/

In many states, regulations may not allow utilities to count fossil fuel savings, a practice that prevents them from pursuing an integrated program despite the clear benefits for customers. For example, CET's Solar Access program was able to claim several types of savings from bundling heat pumps and onsite solar systems, including delivered fuel savings and reduced energy consumption from the grid through onsite generation. In Massachusetts, utility program targets include fuel-neutral goals measured in both site and source MMBTU, which enables program administrators to encourage energy efficiency alongside efficient fuel switching (Gold, Gilleo, and Berg 2019).

In addition, since regulatory rules are different in each state, it is difficult to roll out a standardized program nationwide. Standardized programs encourage cross-state stakeholders to participate and provide services through EE/Solar+ programs because they streamline the requirements for participation and reduce the administrative effort needed to participate. For example, owners with a portfolio of buildings in multiple locations can implement a companywide policy for investing in EE/Solar+ projects, and a standardized program can assist that goal. Similarly, nationwide solar installation companies may be more inclined to provide their services through a program if they only have to meet one set of requirements. Engaging cross-state stakeholders can increase program participation and reduce program costs by leveraging economies of scale for products and services. Utilities will likely need to work with regulators and other key stakeholders to ensure that rules facilitate EE/Solar+ programs rather than hinder them.

Many utilities also face program-administration challenges. Assembling combined program offerings requires an extra layer of coordination and cost because it entails coordination within or across departments, separate incentive applications, and multiple vendors and implementers working with customers who wish to pursue program offerings (Martinez and Roehm 2012). Coordinating all these components requires considerable administrative effort.

Additionally, when considering integrated programs, administrators and customers can have trouble reconciling different incentive timetables and sources of funding. This situation can be particularly challenging if the measures fall under separate proceedings. Further, many solar incentives (like the federal solar investment tax credits) are expiring while some states are introducing storage incentives. Administrators will want to take advantage of longstanding incentives (like those for high-efficiency lighting) along with newer incentives (e.g., for battery storage) and federal solar incentives that will soon expire. For example, the project team designing solar systems for the University of Hawaii campuses (discussed above) had to do so in a relatively short time frame, as the state's solar incentives were scheduled to expire. Nevertheless, CET's Solar Access program shows that administrators can overcome this barrier and successfully streamline several incentive sources to improve project economics for participants.

LIMITED CUSTOMER BASE

Technical factors may limit participation in EE/Solar+ programs. Some buildings may not be suitable for efficiency measures like air sealing. Others may not be good candidates for solar installation: they may be shaded by trees or adjoining structures, their roofs may be unable to support a solar array, or their wiring may be inadequate for additional loads. Any of these insufficiencies could disqualify a customer from participating in an integrated EE/Solar+ program. Administrators should be flexible and creative in dealing with these issues. For example, community solar might be an option for individual homes that are unsuitable for stand-alone systems.

CUSTOMER COSTS

In general, ACEEE has found the cost of energy efficiency projects to be one of the greatest hurdles to participation and success (York et al. 2015). This barrier is particularly hard to overcome in integrated EE/Solar+ projects. In nearly all the programs and pilots we reviewed, there was evidence that even with rebates and financing, many customers found comprehensive systems too expensive. While solar and battery storage prices continue to decline, combining these measures may increase project costs and payback periods beyond the point where customers are comfortable. For example, measures like attic insulation and double-pane windows can be first-cost intensive, with payback periods of 7–15 years (Trabish 2019); solar and storage can also have long payback periods depending on financing and ownership options.[13] Pairing this with the cost of installing solar or storage systems can prevent price-sensitive customers from investing in EE/Solar+.

Programs can minimize the cost barrier by strategically choosing which efficiency measures to pair with solar+. Program implementers should consider the impacts of rate design on customer bills and help customers to select efficiency measures whose load profile best supports lower bills. They can also incorporate demand flexibility through storage, energy management, or embedded demand flexibility, as seen in grid-interactive water heaters.

CET's Solar Access program specifically chose to combine heat pump technologies with solar PV arrays to help make renewable energy projects more affordable for LMI customers. The implementers recognized that heat pumps could offset significant energy bill costs from inefficient heating systems and that those savings could help pay for an onsite solar system. While other financial mechanisms like financing and incentives were also necessary to bring down project costs, the Solar Access program shows how administrators can identify key efficiency measures that deliver enough savings to justify integrated EE/solar+ projects.

To overcome the cost barrier, administrators should offer financing options for integrated projects at the lowest cost possible. This approach especially benefits low-income communities, whose members may face more acute first-cost and credit issues. As our EE/Solar+ cases studies show, capital need not come from utility revenues or ratepayer funds. Common financing strategies include leasing, power purchase agreements, on-bill financing, as-a-service pricing structures, and financing from Green Banks.[14] These

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[13] An ACEEE analysis compares payback and return on investment for energy efficiency and solar PV projects based on various levels of retrofit and different net metering rates. See aceee.org/blog/2019/05/existing-homes-energy-efficiency

[14] A power purchase agreement is a long-term financial arrangement wherein a provider plans and manages the permitting, financing, and installation of an energy system on the customer's property. The customer buys the generated power from the project developer at a fixed rate that is lower than the utility's retail rate. As-a-service pricing is a financial solution that helps organizations implement energy and water efficiency projects with no

mechanisms make it possible to finance larger projects that pair capital-intensive upgrades like HVAC or window replacements with solar+ investments.

Regardless of who owns the solar or battery system, customer cost can be reduced through incentives and federal tax credits. If the customer owns the system, he or she can apply for and receive solar and storage rebates. But not all customers have the capital to pay for these systems or a tax burden large enough to make tax credits worthwhile. In these cases, programs or providers can own the asset, receive the benefits of the rebates, and share the savings with customers. This is PosiGen's approach in the Solar for All program.

Government investment in early EE/Solar+ pilots and projects can also help make these efforts economically viable. For example, the SMUD pilot was made possible by a federal grant.

CONTRACTOR COORDINATION

Various tradespeople with specific skills must collaborate on EE/Solar+ programs (Cohen, Bone, and Jones 2019). To illustrate, suppose a project combines energy efficiency improvements with solar panels and a storage system. A general contractor who specializes in efficiency supervises a team of electricians, plumbers, and others, all of whom provide a mix of services related to permitting, material procurement, and upgrades to structural, electrical, and mechanical systems. However this contractor may not have the design or technical skills needed to install a solar panel or storage battery. The reverse may be true for a solar installer who is not adept at retrofits.

One way that programs can overcome this issue and coordinate expertise is by tapping into local contractor networks. Through this approach, administrators can leverage existing resource streams rather than try to compete in the market. Contractors can educate customers on program offerings and help them understand the benefits of EE/Solar+. Conversely, innovative EE/Solar+ can familiarize the local construction workforce with new practices, such as zero-net-energy design, that promote the integration of energy efficiency and DERs.

Programs should also consider engaging local third-party battery and solar installers in order to provide faster service and make it easier for customers to participate. For example, a partnership with local solar installers allowed the Fort Collins Utilities to expand the reach of its program and become a trusted adviser to its customers.

When designing their programs, administrators should set requirements for contractors to ensure that they promote integrated efficiency and solar+ offerings. Contractors must either provide both efficiency and solar+ technologies and services or coordinate with other contractors to deliver both. When collaboration is not possible, EE/Solar+ program design should ensure that a home retrofit contractor without solar+ system expertise is able to connect the customer with a qualified solar installer. Administrators can create mechanisms

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up-front capital expenditure. The provider designs the project scope, finances the material and construction costs, maintains project equipment, and monitors performance to validate energy savings (ACEEE 2019).

to help facilitate this type of contractor coordination by providing a list of vetted and certified efficiency and solar installers.

INSTALLATION TIMELINES

EE/Solar+ programs require multiple contractors and coordinated timelines for efficiency and DER installation. Projects will require especially careful planning if they are to proceed smoothly. Should the efficiency contractors complete their work before the solar installation begins, or can both jobs proceed simultaneously? This may depend on technical considerations as well as contractor schedules, and the administrator will have to coordinate the two processes. Inspection timelines may also be an issue if they do not coincide. To encourage customer participation, program operators should also minimize the number of site visits necessary to inspect and verify efficiency measures and solar installations.

Other Strategies for EE/Solar+ Success

FOCUS ON CUSTOMERS

Why does combining efficiency and solar+ offer superior value? Energy and potential cost savings are obvious benefits; customers also want buildings that are independent of the grid and resilient during outages.[15] Emphasizing both savings and energy independence can help utilities increase program participation and retain customers who might otherwise defect from the grid entirely.

EE/Solar+ offers another advantage: Combined programs can be a one-stop shop to help customers navigate energy efficiency offerings and solar+ in the same effort. Programs should make participation as simple as possible. For example, the ETO Path to Net Zero program provides a single point of contact where owners can receive numerous incentives for both energy efficiency and solar generation throughout the construction process.

Marketing and education can help customers understand and justify costly up-front investments (York et al. 2015). Con Edison's Connected Homes platform shows how combined online marketing for energy efficiency and solar+ can result in customer-led pairings of EE/Solar+ technologies. Another effective way to educate customers about EE/Solar+ opportunities is to implement community-based outreach. PosiGen has used door-to-door community campaigns and word-of-mouth referrals to increase participation. In 2017, customer referrals were responsible for 40% of solar sales in the Connecticut region (Baneman, Dougherty, and Sims 2018).

LEVERAGE DATA TO TARGET GEOGRAPHICAL AREAS AND CUSTOMER DEMOGRAPHICS

Programs should identify areas on the grid that stand to reap the greatest rewards from EE/Solar+ deployment, such as communities that are congested, hard to reach, or subject to frequent power outages. Designing EE/Solar+ programs and financing specifically for

[15] Buildings that can operate completely independent from the grid, sometimes also referred to as islandable, require additional technologies and expenses.

customers in these areas could improve the reliability of service and increase customer satisfaction.

Utilities can also leverage customer data to improve their offerings and increase participation. Customer demographics can inform the types of technologies included in programs as well as best marketing and customer education strategies. As we have seen, Con Edison's Connected Home platform uses customer data and analytics to provide individualized product recommendations.

Utilities with advanced metering infrastructure (AMI) that measure and record interval energy use data can use customer load-shape data to determine which customers could benefit most from EE/Solar+ offerings. They can also use non-intrusive load monitoring and data analytics to segment each individual customer's end-uses and identify the customers most likely to benefit from particular offerings (Scheer et al. 2018). This type of granular data can enable EE/Solar+ program administrators to target customers whose usage coincides with peak and net peak times to balance out energy demand and available supply.

REQUIRE COMPREHENSIVE ASSESSMENTS

Programs should begin by presenting customers with an integrated energy assessment, solar evaluation, and storage assessment. This information will reduce customer confusion, enable them to see the benefits of combining efficiency with solar+, and help them make better decisions to meet their needs and budget. It will also allow a scope of work that achieves the most cost-effective results.

The assessments should include recommendations for multiple EE/Solar+ technology packages that customers can choose from. These options must be customized based on the participant's concerns and requirements, and they should highlight benefits such as health, comfort, and cost savings (Sussman, Chikumbo, and Miller 2019). For example, Fort Collins Utilities customers who schedule home assessments through the Efficiency Works program receive three performance package options (good, better, and best) that are based on a standardized pricing model. Such assessments provide customers with the relevant but simplified information they need to act on the recommendations that meet their individual needs and budgets.

FORM PARTNERSHIPS

Utilities should identify key partnerships that can bolster program participation and success. Partnering with local community groups and advocates like a city council member can increase trust and customer buy-in. Programs may also gain support from local governments insofar as they help them reach their energy and climate goals.

Utilities should also evaluate whether it makes sense for them to partner with a third-party implementer or an energy service provider to deliver a program. This type of partnership enables utilities to offer turnkey services for energy efficiency and solar+ installations. Ouachita Electric Cooperative has successfully partnered with service provider EEtility to operate the HELP PAYS program to bring EE/Solar+ opportunities to the underserved market of low-income households. Similarly, MassCEC partnered with CET to provide the

Solar Access program because they could leverage the nonprofit's brand recognition and good standing in the community to engage potential participants.

CONSIDER ONLINE MARKETPLACES

Online marketplaces are an emerging EE/Solar+ program approach that engages and educates customers and helps them integrate various technologies to maximize energy savings. Utilities can use these platforms to guide customers toward products that will reduce their energy consumption, to provide them with a list of qualified installers and contractors, and to enroll them in the appropriate efficiency program. Utility marketplaces may also offer online audits and digital energy reports. Con Edison's Connected Home platform goes one step further and offers customized technology options and incentives based on customer data analytics. It also generates revenue through product advertising and referral fees paid by third-party providers.

POSITION THE UTILITY AS AN ADVISER

EE/Solar+ programs provide a unique opportunity for utilities to act as trusted advisers to their customers and to play an active role in their decision making. Such programs expand the utility's role from a power source to a service provider that can educate customers on the most relevant energy-efficient products and DER technologies, available incentives, and qualified installers. This in turn gives utilities more potential influence over the performance of customer-sited DERs and ensures that they integrate well into the grid.

Recommendations

The private and utility-led EE/Solar+ projects and programs highlighted in this report demonstrate the many benefits of an integrated approach. EE/Solar+ programs can help customers save energy and money by educating them on all available technologies and helping them choose the ones that can best meet their needs in the most cost-effective way. EE/Solar+ also provides benefits to utilities, including better control over customer-sited DERs, improved grid management, and increased customer engagement. Together, these benefits represent an opportunity for utilities and highlight the need for more EE/Solar+ programs.

However tapping into these benefits for customers and utilities requires that program administrators design integrated programs with customer value in mind, making sure to select bundles of technologies that deliver savings based on that customer's rates. Absent flexibility from storage and other demand flexibility technologies, zero-energy commercial buildings that use EE and solar may not align with demand charges, creating unexpectedly high bills for building owners. Still, by incorporating demand flexibility and selecting energy efficiency resources with load shapes that minimize peak usage, program designers can align deep savings with customer bill savings. Program administrators can also ensure that customers know what their best rate design option is and help them sign up for it, or bundle new rates with EE/solar+ offerings. Further, they can find opportunities to help customers enroll in demand response or other market or program-based opportunities for further bill reductions or credits.

Our review of existing projects and programs identified the following strategies that utilities can use to help EE/Solar+ programs best serve their customers and the grid:

- Evaluate the service territory to identify customers and areas that could benefit most from EE/Solar+ solutions.
- Identify key partners that can bolster customer engagement and participation, including local government officials, local nonprofits, local contractors, and leading market providers in the area.
- Evaluate customers' cost thresholds and consider different financing schemes to help reduce overall project costs.
- Engage customers and offer EE/Solar+ solutions through multiple engagement platforms like online marketplaces, personalized communications, and community-based campaigns.
- Target initial EE/Solar+ programs to areas with clear policy needs, such as those looking for non-wires alternatives to meet capacity constraints.
- Identify and reduce internal administrative constraints through actions such as increasing communication between siloed energy efficiency and solar+ teams.
- Implement more pilots to help quantify the benefits of integrated EE/Solar+ and identify key technologies and best practices for program design.

Regulators and policymakers can support EE/Solar+ by:

- Valuing the multiple benefits of EE/Solar+ programs in cost-effectiveness testing to ensure that programs that offer value to the system, participant or society can move forward
- As needed, redesigning rates and valuation to better serve the needs of customers with integrated systems, either through custom rates or improvements to default rate offerings
- Identifying regulatory constraints on integration and working with program administrators to make changes that reduce the complexity and administrative effort needed to provide EE/Solar+ programs

Sharing results with customers, vendors, and technology providers will increase regulatory, customer, and management support for EE/Solar+ programs. With further development, EE/Solar+ can become more common, bringing the combined benefits of energy efficiency and solar+ to many more customers.

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